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論文内容の要旨

Face perception is considered to be one of the most important factors of daily life in humans. An object with a distinctive top and bottom is difficult to recognize upside down. This change caused by inversion, is particularly remarkable for human faces, a phenomenon called the "face inversion effect" (Yin, 1969). In electrophysiological study, using event-related potential (ERP), face-dominant component (N170) recorded from the scalp surface. The N170 is a large posterior negative deflection that follows the visual presentation of a picture of a face, peaking at occipitotemporal sites at around 170 ms. Many reports have shown that the N170 is larger and longer for inverted faces than for upright faces (e.g. Rossion et al., 1999).

About the interhemispheric difference, recently several studies for human face perception have reported that the right hemisphere is more dominant for upright face processing (e.g. Yovel et al, 2003). But these are the results of laterality to upright faces, and laterality to inverted faces is not clear. And it is not clear the function of left hemisphere.

In order to investigate the interhemispheric difference in face inversion effect, it is necessary to provide a stimulus in a visual hemifield, but most previous studies provided a stimulus in the central field. Therefore, she recorded ERP by presenting images in the left or right visual hemifield, and she tried to clarify the interhemispheric difference in ERP in the perception of upright and inverted faces in more detail by placing many electrodes to investigate scalp topography.

Fifteen normal healthy subjects (7 females, 31.5y.o.) participated in this study. The gray-scaled images of upright and inverted faces presented in the left or right visual hemifield to know the differences in activities between each hemisphere. The stimuli were delivered in a pseudorandom order across subjects, with each stimulus being presented for 250 ms with a random inter-stimulus interval ranging from 800 to 1200 ms. Every stimulus was projected at 7.0 degrees * 7.0 degrees and were projected in the left or right hemifield offset at an angle of 3.0 degrees from the central point of fixation (a red light 0.2 degrees in diameter) to the edge of each face. She recorded the EEG for 1000 ms, during passive viewing. EEG electrodes were placed at Fz, Cz, T3, T4, C3, C4, Pz, P3, P4, T5, T5' (left temporal area, 2 cm below T5), T6, T6' (right temporal area, 2 cm below T6), O1, and O2 based on the International 10-20 System.

All subjects had positive components in occipital areas between 70 and 130 ms after stimulus onset (P100) and negative components in occipitotemporal areas between 150 and 250 ms after stimulus onset (N170). The P100 latency showed no significant difference between each condition (face orientation, hemispheres, and visual field). This finding indicates that the latency difference of N170 in each condition is not due to a delay in previous information processing.

In contralateral hemisphere, the face inversion effect of N170, the prolonged latency and enhanced amplitude for inverted face, were found in both hemispheres. She considered that N170 reflects identical cortical activity for upright and inverted faces, but it require more neural activity for inverted face, therefore prolonged latency and enhanced amplitude are observed.

N170 amplitude was significantly larger in the right hemisphere than the left. The same as previous study, this finding confirms that the right hemisphere is dominant for face processing in humans.

By presenting stimuli in the hemifield, the following new findings related to interhemispheric differences, which previous ERP studies presenting stimuli in the central field could not find, were obtained. The N170 latency was significantly longer and larger in the ipsilateral hemisphere than contralateral hemisphere. The N170 recorded from the left and right hemisphere showed different behavior to face inversion.

In the latency difference of N170 between contralateral and ipsilateral condition, probably through the corpus callosum, for the left hemisphere, it took only 18.9 ms in average following the presentation of an inverted face, which was much shorter than the response to the upright face (28.8 ms). The other side, for the right hemisphere, it took 28.8 ms following the presentation of an inverted face, which was almost the same as that elicited by an upright face (29.5 ms). That is, when the inverted face was presented in the left hemifield, the latency difference was remarkably shorter than that in other conditions. Simply put, this finding indicates that the conduction through the corpus callosum from the right hemisphere to the left was significantly faster when subjects viewed the inverted face presented in the left hemifield. However, it seems difficult to believe that the conduction from the right to left hemisphere is specifically faster when an inverted face is presented.

So she hypothesized that at least two temporally overlapped for N170 activities were generated in the right hemisphere when an inverted face was presented in the left hemifield. The latency delay is explained if the peak latency of the second component was longer than that of the first. A larger amplitude and wider spread of topography are explained by a summation of two activities. In fact, in seven of 15 subjects, N170 had two peaks or a small notch on an ascending slope following the presentation of an inverted face in the left hemifield, but not in the left hemisphere following stimulation of the right hemifield. By contrast, such double peaks were not identified following the viewing of an upright face. But double peaks were not found in about half of subjects, so she considered that two activities temporally overlapped very close together and fused, appearing as one peak in such subjects.

Watanabe et al. (2003) and Itier and Taylor (2004) reported that the two component for face perception was generated in the inferior temporal region, around the fusiform gyrus, and lateral temporal region, probably around the superior temporal sulcus. But it is difficult to identify the generator mechanisms for two components generating N170 in the right hemisphere on the viewing of the inverted face in the present study. One possibility is that one component is related to a holistic recognition of the face and the other, a parts-based recognition. It is known that she recognized an upright face holistically, relying on the spatial relations between isolated face parts.

Another possibility is that the inverted face is mainly processed in the left hemisphere, such information being processed more rapidly in the left hemisphere after signals are received from the right hemisphere. However, these hypotheses have no supporting evidence and need to be tested in future studies.

論文の審査結果の要旨

一般に正立顔の情報処理は右半球が優位であるとされている。倒立顔に関しての活動は左半球優位であるとする報告があるものの、その理由などについては未解明な点が多い。申請者は、顔の情報処理の左右半球間の連関を調べる目的で、事象関連電位(ERP)を用いて、顔画像の刺激(正立顔、倒立顔)を左右半視野に呈示した際の脳の電気的活動を記録した。

視野の対側半球からの記録では、すべての被験者において、刺激呈示後150-250msに、側頭部から後頭部で顔認知と関連のあるとされる陰性成分(N170)が記録された。振幅は正立顔、倒立顔共に右半球で左半球よりも大きく、広範囲な活動を示した。この事は、右半球でより多くの情報処理が行なわれている事を示唆する。潜時は正立顔では両半球において倒立顔よりも速く、左右半球間の差はなかった。倒立顔は右半球より左半球で反応が短縮する傾向を示した。これは硬膜下記録や脳磁図でなされた先行研究の結果と同様であった。

一方、視野の同側半球からの記録は、対側半球での処理を受けた信号を、脳梁を介して受けた結果生じた活動と考えられる。倒立顔が左半視野に呈示されてから同側(左)半球の活動までの潜時は、右視野に提示された場合の同側(右)半球での潜時にくらべて著明に短かった。正立顔ではこのような現象は見られなかった。これは、倒立顔の信号が右半球に到達した後左半球にて処理されるまでの時間が、その逆、左半球に入力された信号がその後右半球にて処理されるまでの時間より短いことを示している。このような順序効果はこれまで報告がなく、大脳皮質視覚野での顔の情報処理における両半球間の連関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。