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Original article

Electrophysiological study of face inversion effects in Williams syndrome

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Abstract

Objective: In order to evaluate whether face perception is intact or not in Williams syndrome (WS), the face inversion effects (FIE) in the event-related potential (ERP) or magnetoencephalography (MEG) were investigated in three teenaged patients with WS. *Methods:* Responses to the inverted faces and upright faces were compared using MEG for one 13 year old girl with WS (subject A) and ERP for boys with WS at 16 and 14 years of age (subjects B and C, respectively). *Results:* Although age-matched control children showed FIE in both MEG and ERP studies, two subjects (A and B) with WS showed no FIE at all. The neurophysiological data of ERP in subject B was significantly different from those of the age-matched controls. On the other hand, a boy with WS (subject C) showed typical FIE in the same manner as the age-matched controls. *Conclusions:* The difference between those with or without FIE was not explained merely by the chronological age, a simple delay in mental age or in the ability to discriminate among upright faces. The absence of FIE may be related to the severity of a deficit in the dorsal pathway function that is characteristic to the syndrome.

Keywords: Williams syndrome; Face inversion effects (FIE); Magnetoencephalography (MEG); Event-related potential (ERP); The ventral pathway; The dorsal pathway

1. Introduction

It is well known that Williams syndrome (WS) demonstrates uneven cognitive functions [1,2]. Even within the visual domain, the function in the dorsal pathway, which is related to motion perception, recognition of the position or 3D perception, is more disturbed than that in the ventral pathway [3–6]. Facial recognition, for which the ventral pathway of the human visual system is responsible, was considered to be relatively preserved in WS patients [1], while some studies have suggested that people with WS process faces using strategies different from typically developing (TD) subjects [7–9] by investigating the responses to upright or inverted faces.

Concerning the processing of upright and inverted faces, healthy adults generally can recognize upright faces more quickly and efficiently than inverted faces

Abbreviations: MEG, magnetoencephalography; ERP, event-related potential; WISC, Wechsler intelligence scale for children; K-ABC, Kaufmann assessment battery for children; IQ, Intelligence quotient; pIQ, performance intelligence quotient; vIQ, verbal intelligence quotient; FIE, face inversion effects

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[10–14] as they use configural processing in recognizing upright faces [11,12]. In the configural processing of a face, it is essential to recognize the spatial relationships between facial components. On the other hand, in the local processing of a face, which is used when recognizing inverted faces, the components are processed one by one and the process appears to take more time than configural processing. The increased difficulties in identifying inverted faces in psychological investigations or the delays in response time or increased activities of the responses in neurophysiological tests are referred to as "face inversion effects" (FIE).

Our previous study using magnetoencephalography (MEG) revealed that FIE were absent in a 13-year-old boy with WS whose neurophysiological responses to upright faces were not different from those of healthy adults [15]. While some reports also showed similar findings for FIE in patients with WS [7,8,16], others didn't [17,18].

Therefore, in the present studies we aimed to evaluate the following questions:

1. Whether participants with WS lack FIE.
2. What is the reason for the differences in FIE among WS patients? In other words, can it be explained by a simple developmental delay or mental retardation, or, is it related to a syndrome-specific dysfunction?

2. Study 1 (MEG study)

2.1. Subjects

A thirteen-year-old girl with WS (subject A) diagnosed by the fluorescent in situ hybridization (FISH) test of elastin gene and two age-matched TD girls participated in the study. All of the participants and their parents provided informed consent. The study was approved by the Ethics Committee of the National Institute for Physiological Sciences and the Institute for Developmental Research. It was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Subject A had the characteristic clinical features and her deficits in visuospatial cognition were similar to those previously reported for WS. Some examples of copied line drawings are shown in Fig. 1. Her score in the Benton facial recognition test (43) was within normative standards for adults. The Intelligence quotient (IQ) scores by Wechsler intelligence scale for children (WISC) test revealed that she had mild mental retardation (Table 1).

2.2. Methods

2.2.1. Visual stimulation and MEG recording

Visual stimuli of upright faces (*upright*) and inverted faces (*inverted*) with a neutral expression, used in our previous study [19], were presented as two stimulus conditions together with target images. The participants were asked to count the numbers of target images. All images were gray-scaled and the faces were unfamiliar to the subjects. Each stimulus was 11 degrees by 11 degrees in size and presented in the left visual field at a 1 degree offset from a central fixation point, as in our previous report [13], to investigate the function of the right hemisphere, since the right hemisphere is considered to be dominant for face perception. Each stimulus was presented for 250 ms with a random inter-stimulus interval ranging from 1750 to 2250 ms in pseudo-random order until the number of trials became more than 60 for each condition. Eye position was monitored with an apparatus (ISCAN, Pupil/Corneal reflection Tracking System, Burlington, MA, USA). Epochs with eye movements of more than one degree were rejected from the recording. The window of averaging was 500 ms post-stimulus onset, and a pre-stimulus baseline of 100 ms was adopted.

A helmet-shaped 306-channel MEG system, (VectorView™, Elekta Neuromag Oy, Helsinki, Finland) was used for the MEG recording. The results were obtained with 204 gradiometers (102 pairs) out of the 306 sensors. A band-pass filter (0.1–50 Hz) and a sampling rate of 1042 Hz were used.

2.2.2. Analyses

The magnetic responses to *upright* and *inverted* were analyzed focusing on the temporal changes of the responses of the components around 170 ms, which are known as face sensitive components (M170) [13,20].

In order to estimate the dipole locations of the cortical activities, we used a single equivalent current dipole (ECD) model [21]. The sensor pairs that showed the largest M170 in amplitude and ten additional sensors (five paired sensors in descending order of amplitude from M170) around them were chosen for estimating the dipole location. We checked the dipole moments (strength), which is called the Q value, in nAm at each estimated dipole location. The peak latencies when the Q values were estimated to be largest were compared between *upright* and *inverted* in each participant. The dipole locations at the peaks of the Q value were overlaid onto the MR images of each participant. The goodness of fit (GOF) at each point was confirmed to be more than 90%.

We considered that the FIE were present if there was a delay in the peak latencies of the Q value for *inverted* compared to those for *upright*.

2.3. Results

The M170 component was found in the right postero-temporal area in each participant. The sensor pair with the clearest and largest responses of M170 to *upright* happened to be the same as those to *inverted* in each