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Face processing in adolescents with and without epilepsy

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Abstract

Children with temporal lobe epilepsy frequently suffer memory deficits, often marked in face processing. To determine the neural correlates of this dysfunction, we investigated face processing in adolescents with intractable epilepsy compared to typically developing controls. The M170 and M220 MEG event-related fields (ERFs) were recorded while the adolescents completed an n-back task on blocks of upright and inverted faces. Source analyses of the ERF data were performed using an event-related beamforming technique that allowed the detection of multiple sources. The control adolescents showed the expected waveforms and inversion effects, although there were differences in source localization, compared to the adult literature. The participants with epilepsy had poor performance on the tasks. The adolescents with extra-temporal lobe epilepsy showed both the M170 and M220 but the source localizations were highly atypical. The patients with right temporal lobe epilepsy had an absent or highly atypical M220, a component related to face recognition processes. We hypothesize that the children with extra-temporal lobe epilepsy have difficulty with face encoding processes while the patients with right temporal lobe epilepsy have specific difficulty with face recognition.

Keywords: Face processing; Adolescents; Epilepsy; M170; M220; Memory

1. Introduction

Faces comprise the most important and salient visual stimuli in human social interaction. Behavioural studies confirm that healthy adults enjoy an impressive aptitude for facial processing (Bruce and Young, 1998), which contrasts sharply with the poorer face recognition skills in children. Despite the interest and importance of faces to children, and despite a prolonged and steep learning curve for face recognition, our understanding of the development of the ability to readily recognise faces remains limited.

1.1. Electrophysiological measures of face processing

Precise measures of neuronal timing of early face processing can be obtained with electromagnetic recordings: EEG event-related potentials (ERPs) or MEG event-related fields (ERFs). A large literature now exists on a face-sensitive ERP component, the N170, which has been intensively studied since it was first reported (Bentin et al., 1996). N170 is recorded over posterior temporal leads, generally larger over right than left hemisphere, and is much larger to faces than objects. Many ERP studies have investigated the N170 and demonstrated its sensitivity for various aspects of face processing (e.g., Sagiv and Bentin, 2001; Latinus and Taylor, 2006), and to faces compared to a wide range of non-face stimuli (e.g., Itier and Taylor, 2004a).

N170 is the middle of a triphasic response and additional information can be obtained from the other peaks. The positive component preceding N170, P1, reflects early, rapid processing of both simple and complex stimuli, and is responsive to task

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demands (Taylor, 2002). P1 has been investigated in some face ERP studies, and can show sensitivity to configural changes (Halit et al., 2000; Batty and Taylor, 2003), particularly with inversion (Linkenkaer-Hansen et al., 1998; Taylor et al., 2001a; Itier and Taylor, 2002, 2004b). The P2 following N170 has been associated with in-depth or further processing of faces (Latinus and Taylor, 2005; Schweinberger et al., 2002) related to identity recognition; it is more sensitive to task demands than is the N170 (Halit et al., 2000). The P2 source is in similar brain areas as the N170 (Itier and Taylor, 2004c; Itier et al., 2004; Boutsen et al., 2006), suggesting reactivation of the visual ventral stream for this stage of processing.

1.2. Neuromagnetic measures of face processing

There are fewer face processing studies in MEG, but they have focused on similar issues as in ERPs. The ERF component, M170, has also been shown to be selective for faces (Swithenby et al., 1998; Liu et al., 1999; Streit et al., 1999; Liu et al., 2002; Taylor et al., 2001b), and indexes face detection or face identification (Liu et al., 2002), including the processing of gaze direction (Taylor et al., 2001b). However, the M170 does not always have the same pattern of sensitivities as the N170 and whether it is the magnetic equivalent of the N170 or reflects at least partially different brain activities is debated (Halgren et al., 2000; Taylor et al., 2001b). Recent studies have shown that the M170 amplitude correlated with the successful identification of faces (Liu et al., 2002; Tanskanen et al., 2005; Xu et al., 2005). The preceding component, the M100, which occurs between 90–140 ms over occipital sites, also shows some face sensitivity (Linkenkaer-Hansen et al., 1998; Halgren et al., 2000; Liu et al., 2002). The ERF and ERP studies suggest that face detection starts at the M100/P1 while the M170/N170 reflects refined stages where identity encoding could begin (Linkenkaer-Hansen et al., 1998; Itier and Taylor, 2002, 2004b; Liu et al., 2002; Jemel et al., 2003). As with the P2 in ERP studies, the peak following the M170, the M220, is less studied than the P1/M100 and its role in face processing is still being determined. In a face memory task, the M220 sources for upright and inverted faces showed right-lateralised activation in the posterior cingulate and inferior parietal cortex (area BA40) (Bayle et al., 2007), which has been shown to be linked with visual memory (Ding et al., 2000); the left hemisphere homologues of which are suggested to have a role in verbal memory (Ravizza et al., 2004; Romero et al., 2006).

1.3. Developmental studies of face processing

Few studies have examined the neurophysiological correlates of the development of face processing over childhood. The N170 is found consistently in children over four years of age, but at long latencies (Taylor et al., 1999, 2001a). It is largest over parieto-temporal locations in children as in adults. The latency decreases of the N170 from 4 years until adulthood suggest a quantitative improvement with age, that is, face processing becoming faster and more efficient with development.

There are few developmental MEG studies on face processing. Kylliäinen et al. (2006a) recorded ERFs to face and object stimuli in 8–11 year olds and reported components at 135 ms and at 245 ms. These would be equivalent to the P1 and N170 in children at that age (Taylor et al., 1999, 2001a, 2004). In a second study on eye gaze with children 7–12 years old, the same group (Kylliäinen et al., 2006b) proposed that the M140 in young children was equivalent to the M170 in adults. This could not be the case, as latencies are not shorter in children than adults. This component at this latency would be the M100 in this age range. Gaze-sensitivity was seen on the later component at 240 ms, probably the M170 equivalent in the young children. In contrast, Kimura et al. (2004) reported gaze sensitivities only at the M100 component at 140 ms in children, with no effects seen at the M170.

1.4. Importance of configural processing

Behavioural investigations of face processing across childhood (Ellis, 1992) show that there is a gradual increase in facial recognition performance with age, due largely to improvements in configural processing. Configural processing shows a protracted development and demonstrates neurophysiological correlates; hence, understanding the development of configural processing may be a key to understanding the development of face recognition. A means of assessing configural processing is the use of inverted faces, as inversion disrupts the configural information necessary for accurate face recognition (Bartlett and Searcy, 1993; Rhodes et al., 1993; Freire et al., 2000; Leder et al., 2001). Inverted faces are recognised more slowly and with higher error rates than are upright faces (Valentine, 1988; Rhodes et al., 1993), and this decrement in performance is more marked for faces than other objects (Yin, 1969).

ERP studies have consistently shown that the N170 is delayed and larger for inverted than upright faces (Rossion et al., 1999; Eimer, 2000; Rossion et al., 2000; Sagiv and Bentin, 2001; Taylor et al., 2001a; Itier and Taylor, 2002, 2004a,b; Itier et al., 2006b) and a few studies reported similar effects for the P1 (Taylor et al., 2001a; Itier and Taylor, 2002, 2004b). In contrast, ERF studies found that the M170 was delayed but not larger in amplitude for inverted faces (Linkenkaer-Hansen et al., 1998; Taylor et al., 2001b; Watanabe et al., 2003); one report found inversion effects on the M100 (Linkenkaer-Hansen et al., 1998).

Studies that examined development of the inversion effect have reported inconsistent results: some show increasing inversion effects with age (Carey and Diamond, 1994; Mondloch et al., 2002) and others report no improvements with age (Pedelty et al., 1985; Tanaka et al., 1998). Itier and Taylor (2004d) found inversion effects from eight years of age until adulthood that did not increase with age; i.e., performances increased steadily and in parallel for upright and inverted faces until adulthood, with a constant lag in the inverted faces. Thus, performance on both canonically typical and atypical faces improved with age. In children, inversion produces age-dependent changes in N170 with the adult pattern of longer latencies appearing between 8 and 11 years, depending on the task (Taylor et al., 2001a; Itier and Taylor, 2004e,f), and the