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Multimodal processing of emotional information in 9-month-old infants II: Prenatal exposure to maternal anxiety

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ABSTRACT

The ability to read emotional expressions from human face and voice is an important skill in our day-to-day interactions with others. How this ability develops may be influenced by atypical experiences early in life. Here, we investigated multimodal processing of fearful and happy face/voice pairs in 9-month-olds prenatally exposed to maternal anxiety, using event-related potentials (ERPs). Infants were presented with emotional vocalisations (happy/fearful) preceded by emotional facial expressions (happy/fearful). The results revealed larger P350 amplitudes in response to fearful vocalisations when infants had been exposed to higher levels of anxiety, regardless of the type of visual prime, which may indicate increased attention to fearful vocalisations. A trend for a positive association between P150 amplitudes and maternal anxiety scores during pregnancy may suggest these infants are more easily aroused by and extract features more thoroughly from fearful vocalisations as well. These findings are compatible with the hypothesis that prenatal exposure to maternal anxiety is related to more extensive processing of fear-related stimuli.

1. Introduction

The ability to read each other's emotional expression is an important skill in our day-to-day interactions with others. In most social situations, emotional information can be inferred from more than one modality simultaneously, such as from both the face and the voice of the other person. Previous research has found that emotional information from one modality, such as a face, may influence how emotional information from another modality, such as a voice, is processed and perceived. For example, de Gelder and Vroomen (2000) and de Gelder, Pourtois, and Weiskrantz (2002) found that in adults, both recognition and judgement of emotions from voice can be modulated by consciously as well as unconsciously recognised emotion in the corresponding face. Developmental studies have shown that in infants, too, emotional faces may affect processing of emotional voices and the other way around (e.g. Flom & Bahrick, 2007; Grossmann, Striano, & Friederici, 2006; Walker-Andrews & Lennon, 1991; for a review, see Grossmann, 2010). What has not been studied, however, is the potential effect of early life influences on the ability to detect and process emotional audiovisual information. If the development of the auditory or the visual system is altered or even disrupted, for instance by atypical maternal psychological mood during pregnancy, this may change how information is processed for both modalities. The goal of the current study, therefore, was to examine whether early life experiences, in the form of prenatal exposure to maternal anxiety, influence the ability to process emotional information from face and voice.

Over the last decades, evidence has become available that exposure to atypical or adverse environmental factors during gestation may modulate the programming of genetically based neural architecture of the brain, thereby changing the developmental pathway of neurocognitive processes (part of the field 'developmental origins of behaviour, health and disease (DOBHaD)'; see

Abbreviations: GA, gestational age; PELS, prenatal early life stress study; STAI, Spielberger State-Trait Anxiety Inventory; SCL, symptom checklist-90; Nc, negative component; Pc, positive component.

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e.g. Gluckman, Hanson, & Buklijas, 2010; Räikkönen, Seckl, Pesonen, Simons, & Van den Bergh, 2011, and Van den Bergh, 2011 for reviews). The DOBHAD hypothesis encompasses the short- and long-term consequences of the conditions of the developmental environment for health and disease risk (Gluckman et al., 2010). For instance, iron deficiency during life in the womb, as inferred from serum ferritin concentrations at birth, has been associated with impaired auditory recognition memory in newborns and infants, possibly due to disruptions of the myelination process (Beard, 2008; Georgieff, 2008; Georgieff, Wewerka, Nelson, & deRegnier, 2002; Nelson et al., 2000; Siddappa et al., 2004). In the same vein, the psychological status of the mother during pregnancy may influence offspring neurocognitive development. In evidence of this, associations have been found between prenatal exposure to maternal stress, depression, and anxiety, and alterations in infant, child, and adolescent neurocognition. As an example, in a previous study, we found that maternal anxiety during pregnancy influences processing of rapidly presented sound sequences in both 2-month-old (Otte, Braeken, Winkler, & Van den Bergh, 2011) and 9-month-old infants (van den Heuvel, Donkers, Winkler, Otte, & Van den Bergh, 2014). Also, Weikum, Oberlander, Hensch, & Werker (2012) described that prenatal exposure to maternal depressed mood shifted developmental milestones in infant speech perception. (For other examples, see e.g. Charil, LaPlante, Vaillancourt, & King, 2010; Entringer, Buss, & Wadhwa, 2010; Mennes, Stiers, Lagae, & Van den Bergh, 2006; Sandman, Davis, Buss, & Glynn, 2011; Van den Bergh, 2011; Van den Bergh, Mulder, Mennes, & Glover, 2005). There is as yet no full understanding of the exact mechanisms underlying these findings, although a body of literature suggests that the hormone cortisol and the placental enzyme 11β-HSD2 may play a role (e.g. Harris & Seckl, 2011; Monk, Fitelson, & Werner, 2011; Wyrwoll, Holmes, & Seckl, 2011). Also, recent findings indicate that epigenetic dysregulation is an important underlying mechanism (Gillies, Virdee, McArthur, & Dalley, 2014; Graignic-Philippe, Dayan, Chokron, Jacquet, & Tordjman, 2014; Hompes et al., 2013; O'Donnell et al., 2012; Van den Bergh, 2011). Here, we pose the question whether altered multimodal processing of emotional stimuli can also be related to in utero exposure to maternal anxiety.

To answer this question, we studied multimodal processing of emotional information in 9-month-old infants by means of event-related potentials (ERPs). Until now, behavioural measures have most often been used to study both multimodal processing of emotional information in infants, and infant neurocognitive outcome following prenatal exposure to maternal anxiety. ERPs, however, have a number of advantages over behavioural measures. First, ERPs provide a continuous measure of information processing from stimulus exposure to until after elaboration of the response, which allows for assessment of which stage(s) of processing are affected by a specific experimental manipulation (Luck, 2005). Second, ERPs have a very high temporal resolution, and therefore the timing of neurocognitive processes can be studied with millisecond precision (Luck, 2005). Third, ERPs can be recorded in the absence of a behavioural response (Nelson & Bloom, 1997), even for unattended stimuli (Sussman, 2007). This makes them quite suitable for studying actual brain functioning in neonates and infants, instead of making inferences about neurocognitive functioning based on behavioural measures.

The paradigm for the current study was based on an ERP study by Grossmann et al. (2006), who investigated in 7-month-old infants the processing of angry and happy vocalisations following the presentation of an emotionally congruent or incongruent facial expression (prime). The authors found that the emotionally incongruent condition elicited a larger auditory Negative component (Nc) around 500 ms post-stimulus. In contrast, the emotionally congruent condition elicited a larger auditory Positive component (Pc) approximately 800 ms after stimulus onset. Grossmann et al. (2006) concluded that the attenuation of the Nc and enhancement of the later Pc for the congruent condition reflected recognition of the familiar/expected face/voice pairs, and that the infants had thus recognised and processed emotions from both modalities.

To our knowledge the study by Grossmann et al. (2006) is the only ERP study with infants in which the processing of emotional auditory stimuli following an emotional visual prime is investigated, instead of the other way around. However, since the auditory system develops earlier than the visual system (Anderson & Thomason, 2013; Anderson et al., 2001), from a developmental perspective, emotional vocalisations may be just as relevant as facial expressions in the first months of life. Thus, to supplement the existing literature with data on the processing of emotional vocalisations in infancy, in the current study (and in our twin-paper Otte et al., 2015) we focused on effects of emotional facial expressions on the processing of emotional auditory stimuli (in the context of prenatal exposure to maternal anxiety).

Following Grossmann et al. (2006) we used both a positive and a negative emotion (happiness and fear), and investigated the processing of auditory vocalisations following an emotional (happy/fearful) visual prime. In contrast to Grossmann et al. (2006), fear instead of anger was used as the negative emotion. We had several reasons for this. First, research has found that (1) exposure to maternal anxiety is associated with more anxiety in the offspring (Lupien, McEwen, Gunnar, & Heim, 2009; O'Connor et al., 2002; Van den Bergh & Marcoen, 2004); (2) individuals with high state anxiety respond stronger to fearful stimuli (Bishop, Duncan, & Lawrence, 2004); and (3) high trait anxiety has been related to altered processing of emotional information from face and voice (Koizumi et al., 2011). Studying responses to fearful stimuli may yield insights into how these findings relate to each other. Second, infants display increased attention to fearful stimuli, at least from 7 months old onwards (Kotsoni, de Haan, & Johnson, 2001; Montague & Walker-Andrews, 2001; Peltola, Leppänen, Mäki, & Hietanen, 2009).

As this study represented the first effort to relate prenatal exposure to maternal anxiety to processing of multimodal emotional information, our hypotheses were of an exploratory nature. We hypothesised that higher levels of maternal anxiety during pregnancy (1) would be associated with larger responses to fearful auditory stimuli; and (2) would most strongly affect responses to auditory stimuli which had been preceded by visual stimuli conveying the same (versus a different) emotion, reflecting a relationship between prenatal exposure to maternal anxiety and multimodal processing of emotional information. Leaving from the paper by Grossmann et al. (2006), we were interested in potential modulations of the auditory Nc and Pc by prenatal exposure to maternal anxiety. Because of the exploratory nature of the study and the fact that infants in our study were about 2 months older than the infants in the study by Grossmann et al. (2006), we also examined the earlier occurring auditory ERP components P150, N250 and P350.

2. Methods

2.1. Subjects

Subjects were 82 infants (one pair of twins) and their mothers from a normal (i.e. non-clinical) population who have been taking part in a longitudinal study on prenatal early life stress (PELS project). The study was approved by the Medical Ethical Committee of St. Elizabeth Hospital in Tilburg, The Netherlands. Informed consent was obtained from all mothers and fathers in accordance with the Declaration of Helsinki. Detailed information on the cohort and its recruitment has been described previously in Otte et al. (2013).