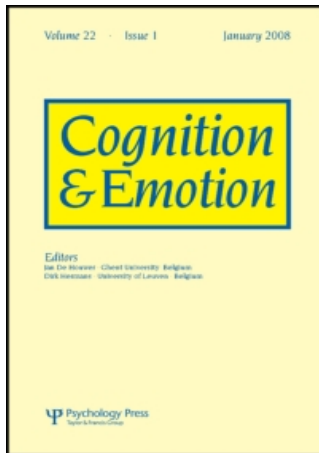


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The discrimination of angry and fearful facial expressions in 7-month-old infants: An event-related potential study

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The discrimination of angry and fearful facial expressions in 7-month-old infants: An event-related potential study

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The important ability to discriminate facial expressions of emotion develops early in human ontogeny. In the present study, 7-month-old infants' event-related potentials (ERPs) in response to angry and fearful emotional expressions were measured. The angry face evoked a larger negative component (Nc) at fronto-central leads between 300 and 600 ms after stimulus onset when compared to the amplitude of the Nc to the fearful face. Furthermore, over posterior channels, the angry expression elicited a N290 that was larger in amplitude and a P400 that was smaller in amplitude than for the fearful expression. This is the first study that shows that the ability of infants to discriminate angry and fearful facial expressions can be measured at the electrophysiological level. These data suggest that 7-month-olds allocated more attentional resources to the angry face as indexed by the Nc.

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Implications of this result may be that the social signal values were perceived differentially, not merely as “negative”. Furthermore, it is possible that the angry expression might have been more arousing and discomforting for the infant compared with the fearful expression.

INTRODUCTION

Facial expressions convey emotional information during social interactions that help people to interpret the internal states and the intentions of others (Schupp et al., 2004). The human face plays a fundamental role in social communication for infants. The important ability to recognise emotions expressed by other people develops early in human ontogeny. Numerous studies have shown differences in the perception and processing of positive versus negative facial expressions at either the behavioural or neural level (Grossmann, Striano, & Friederici, in press; Kotsoni, de Haan, & Johnson, 2001; LaBarbera, Izard, Vietze, & Parisi, 1976; Nelson & de Haan, 1996; Nelson & Dolgin, 1985; de Haan, Belsky, Reid, Volein, & Johnson, 2004). Previous studies investigating the perception of negative facial expressions have indicated that infants discriminate fearful and angry expressions by the age of five months (Schwartz, Izard, & Ansul, 1985), reflected in different looking behaviour, however, this discrimination has not been detected at the neural level (Nelson & de Haan, 1996). In contrast to positive expressions, fear and anger are less often experienced by infants growing up in normal environments (Malatesta & Haviland, 1982). Both emotions are similar in valence and arousal (unpleasant and highly arousing), however, their social-signal values differ. Angry faces indicate imminent aggression on the part of the expressor, whereas fearful faces signal potential environmental threat perceived by the expressor (Adams, Gordon, Baird, Ambady, & Kleck, 2003). The aim of the present study was to investigate the perception of negative facial expressions, of anger and fear, by 7-month-old human infants and to assess infants' event-related potentials in response to the perception of these emotional expressions.

A common paradigm in infant behavioural studies is the habituation paradigm where an infant is repeatedly presented with the same object or the same category of stimuli until his looking time decreases. The recovery of the infants' attention following the presentation of a new object indicates that the infant recognises it as new and different. For example, Serrano, Iglesias, and Loeches (1992) showed in a habituation procedure that 4- to 6-month-old infants discriminated and recognised the expressions of anger, fear, and surprise. They also found that infants spend more time overall looking at angry expressions than at fearful expressions. In contrast, Schwartz et al. (1985) found that 5-month-old infants visually discriminated the expressions anger, fear, and sadness, but that this was not the case when in their visual

paired-comparison paradigm the novel stimulus was an angry emotional expression, suggesting that angry expressions were less novel than the fearful or sad expressions. Alternatively, angry expressions might have been more aversive than fearful or sad expressions. There are no studies that assess visual preference for angry and fearful expressions in direct comparison. However, when fearful and angry expressions are compared with happy expressions, visual preference studies suggest that 4- to 6-month-old infants avoid looking at angry expressions (LaBarbera et al., 1976). Yet, they are more interested in fearful than happy expressions, reflected in longer looking times for fearful expressions in paired-preference paradigms (Nelson & Dolgin, 1985; Kotsoni et al., 2001). Looking-time paradigms do not explain why infants look longer at certain expressions than at others. It has been argued, however, that the social signal value might be a factor that contributes to the infants' responses toward different expressions (Nelson & de Haan, 1996; Serrano et al., 1992). For example, fearful expressions might induce a defensive response in infants leading to enhanced attention (Nelson, Morse, & Leavitt, 1979), whereas angry expressions might induce gaze aversion (Schwartz et al., 1985).

Measuring event-related potentials (ERPs) while infants are watching emotional expressions provides information about the ongoing neurocognitive processes that occur during the perception of these emotions. Previous research with infants into neural correlates associated with the perception of emotional expressions has consistently shown that infants differentially process negative and positive emotional expressions, i.e., that negative emotions elicit a larger response than positive emotions in the middle latency negative component (Nc; see de Haan, Johnson, & Halit, 2003, for a review), which is prominent at fronto-central channels (de Haan et al., 2004; Nelson & de Haan, 1996; see de Haan, 2001, for a detailed review of other electrophysiological measures of emotion processing in the infant brain).

In one study, 7-month-old infants watched happy and fearful faces during the recording of ERPs (Nelson & de Haan, 1996). Fearful faces elicited a larger Nc, peaking around 500 ms, than happy faces, indicating a greater allocation of attentional resources to the fearful face. In a second experiment, infants were presented with fearful and angry faces. However, the ERP components elicited by these negative emotions did not differ. The authors concluded that possibly the infants did not discriminate angry and fearful expressions because both expressions were equally novel to them. Alternatively, they may have perceived the social-signal value of the expressions to be the same (i.e., both emotions are negative in value). However, these ERP findings contradict those behavioural findings previously reviewed, indicating that infants can discriminate between fearful and angry expressions by 5 months (Schwartz et al., 1985).

Previous infant ERP studies investigating face perception have identified two face-sensitive components, the N290 and the P400, as possible developmental precursors of the adult N170, a face-responsive ERP component (de Haan, Pascalis, & Johnson, 2002; de Haan et al., 2003; Halit, de Haan, & Johnson, 2003). The N290 is a negative-going deflection over posterior electrodes (de Haan et al., 2003), the latency of which decreases from approximately 350 to 290 ms between the age of 3 and 12 months (Halit et al., 2003). The P400 is a positive-going deflection most prominent over posterior lateral electrodes, with peak latencies from approximately 450 to 390 ms between 3 and 12 months of age (de Haan et al., 2003). Like the adult N170, both infant components show larger amplitudes for inverted than upright faces. To our knowledge, there is no study that has investigated these two components in the context of emotion perception. However, given the functional nature of these components in face processing, there is cause to believe that they may be modulated by emotional information in the context of face processing.

In the current research, we attempted to better understand the contradictory behavioural and ERP findings by comparing 7-month-old infants' ERP responses to a fearful and an angry face. In contrast to the previous ERP study by Nelson and de Haan (1996), we used a new set of fearful and angry faces and presented the pictures for 1000 ms (as compared to 500 ms in their study) in order to allow infants a more thorough exploration of the expressions. Based on previous findings from behavioural studies, we predicted that infants' ERP elicited by an angry and a fearful face would differ from one another. Behavioural studies suggest that the fearful expression overall elicits more attention in infants than the angry expression, reflected in the duration of looking time when compared to happy expressions (Kotsoni et al., 2001; LaBarbera et al., 1976; Nelson & Dolgin, 1985). Therefore it was hypothesised that the fearful expression would elicit a larger amplitude of the negative component of the infant ERP when compared with the angry expression. In order to test whether emotional expressions interact with face-specific processes, we assessed infant face-sensitive components (N290 and P400).

METHOD

Participants

A total number of 38 infants were tested. All infants were born full-term (37–42 weeks gestation) and had a normal birth weight (> 2500 g). They came from a White and middle-class population. The final group of participants consisted of seventeen 7-month-old infants ($M = 204.5$ days, range 195–217 days; 5 males). Twenty-one infants were not included in the

final sample because of eye or body movements that resulted in excessive ERP artefacts ($n = 12$), not enough data because of fussiness or inattentiveness ($n = 6$), because of equipment failure ($n = 1$), or because of procedural error ($n = 2$). The minimum criterion for inclusion was 10 trials per condition, however, each infant contributed 10 to 29 (mean of 14.1) trials in the angry condition and 10 to 25 (mean of 14.2) trials in the fearful condition. After the elimination of artefacts resulting from eye and body movements, 30.6% of the number of trials in which the infant attended to the screen could be used for analysis in the angry condition and 31.3% could be used in the fearful condition.

Stimuli

The stimuli were taken from the MacBrain Face Stimulus Set, a battery of 646 facial-expression stimuli (<http://www.macbrain.org/faces/index.htm>). Two colour portrait photographs of the same Caucasian woman (model No. 9) posing either an angry or a fearful facial expression were used in the present study. The pictures were obtained by photographing a female actress posing various facial expressions. They were originally taken using a Nixon 35 mm camera and then scanned and transformed into computer images (8-bit colour, 800×600 pixel resolution). Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development.

Procedure

All the infants sat on their parent's lap in a dimly lit sound-attenuated and electrically shielded cabin, at a viewing distance of 60 cm away from a 70 Hz 17-inch stimulus monitor. The experiment consisted of one block with 200 trials (100 angry, 100 fearful). The two conditions were presented to the infant in a random order. Each picture was presented for 1000 ms on a black background. Each trial was preceded by a black-and-white dotted attention attractor on a white background presented for 200 ms. This high-contrast picture was the same size as the facial stimuli, namely 17.5×22 cm. The resulting visual angle was 16.6 degrees. The inter-stimulus interval varied randomly between 1300 and 1700 ms. The parent was instructed not to talk to the infant, and to look down on the infant rather than at the computer screen. If the infant became fussy or uninterested in the stimuli, the experimenter gave the infant a short break. The session ended when the infant's attention could no longer be attracted to the screen. On average the experiment lasted 7 minutes and 55 seconds. EEG was recorded continuously, and the behaviour of the infants was also video-recorded throughout the session.

EEG recording and analysis

EEG electrodes were attached to a cap. EEG was recorded continuously with Ag–AgCl electrodes from 19 scalp locations of the 10–20 system, referenced to the vertex (Cz). Data were amplified via a Twente Medical Systems 32-channel REFA amplifier. Horizontal and vertical electro-oculograms (EOGs) were recorded. Horizontal EOG electrodes were integrated into the cap, as well as the upper vertical EOG electrode on the forehead above the right eye. The lower vertical EOG electrode was placed on the infant's right cheek with a small plaster. Sampling rate was set at 250 Hz. EEG data were re-referenced offline to the linked mastoids utilising in-house EEG analysis software. Offline filters from 0.3–20 Hz were applied. The EEG recordings were segmented into epochs of waveform that comprised a 200 ms baseline featuring a black-and-white dotted attention attractor and 1000 ms of angry or fearful faces. For the elimination of electrical artefacts caused by eye and body movements, EEG data was rejected off-line whenever the standard deviation within a 200 ms gliding window exceeded 80 μV at the eye electrodes and 50 μV at any other electrode. Data were also visually edited offline for artefacts. Additionally, the video recordings of infants were examined, and all trials in which the infants did not look at the screen were rejected from further analysis.

For statistical analysis, a time window was chosen around the negative component with maximum amplitude from 300–600 ms after stimulus onset. ERPs were evaluated statistically by computing the following region of interest (ROI): left fronto-central (F3, FC3, C3), fronto-central (FZ, CZ) and right fronto-central (F4, FC4, C4), as the Nc is most prominent over fronto-central electrodes (de Haan et al., 2003). A time window from 180 to 320 ms was chosen to capture the N290 for the posterior electrodes P4, PZ, and P8. The literature suggests that the infant N290 is prominent over midline and paramidline, posterior electrodes (de Haan et al., 2003). For analysis of the P400, a time window from 300 to 420 ms was chosen for lateral posterior electrodes (P4 and P8), as it is here that previous studies have identified the P400 (de Haan et al., 2003), and this was also seen in our data.

ERP mean amplitudes of the Nc were analysed with a 3×2 repeated measures ANOVA with the factors (1) Localisation (left fronto-central, right fronto-central, fronto-central) and (2) Condition (angry, fearful). ERP peak amplitudes of the N290 were analysed with a 3×2 repeated measures ANOVA with the factors (1) Electrode Position (P3, PZ, P4) and (2) Condition (angry, fearful). ERP peak amplitudes of the P400 were analysed with a 2×2 repeated measures ANOVA with the factors (1) Electrode Position (P3, P4) and (2) Condition (angry, fearful). For ERP latencies of the

N290 and the P400, repeated measures ANOVAs were performed with the same factors as for the amplitudes of the components.

RESULTS

The 3×2 repeated measures ANOVA with the factors (1) Localisation (left fronto-central, right fronto-central, fronto-central) and (2) Condition (angry, fearful) analysing the Nc revealed a significant effect for condition, $F(1, 16) = 11.37$, $MSE = 19.51$, $p = .004$, indicating that the mean amplitudes elicited by the angry expression were significantly larger than the mean amplitudes elicited by the fearful expression (see Figure 1 and Table 1a).

For analysis of the N290, a 3×2 repeated measures ANOVA with the factors (1) Electrode Position (P3, PZ, P4) and (2) Condition (angry, fearful) revealed a significant effect for condition, $F(1, 12) = 5.80$, $MSE = 171.53$, $p = .033$, indicating that there was a significant difference between the minimum amplitudes of the two conditions, with the angry condition larger than the fearful condition (see Table 1b). For analysis of the P400, a 2×2 repeated

TABLE 1
Angry/fearful expression: Means (standard deviations) of ERPs in microvolts

| <i>(a) Nc: 300–500 ms</i> | | <i>Lead</i> | | |
|-----------------------------|--|------------------------------------|---|--|
| <i>Expression</i> | <i>Left fronto-central (F3, FC3, C3)</i> | <i>Fronto-central (FZ, CZ)</i> | <i>Right fronto-central (F4, FC4, C4)</i> | |
| Angry | | | | |
| Mean (SD) | –16.63 (11.51) | –19.11 (14.36) | –14.67 (14.12) | |
| Fearful | | | | |
| Mean (SD) | –11.60 (13.06) | –12.05 (16.69) | –11.43 (15.75) | |
| <i>(b) N290: 180–320 ms</i> | | <i>Lead</i> | | |
| <i>Expression</i> | <i>P3</i> | <i>PZ</i> | <i>P4</i> | |
| Angry | | | | |
| Mean (SD) | –9.17 (14.44) | –10.00 (17.61) | –8.38 (15.25) | |
| Fearful | | | | |
| Mean (SD) | –0.71 (13.25) | –1.79 (18.76) | –3.78 (17.01) | |
| <i>(c) P400: 300–420 ms</i> | | <i>Lead</i> | | |
| <i>Expression</i> | <i>P3</i> | <i>P4</i> | | |
| Angry | | | | |
| Mean (SD) | 2.03 (13.63) | 1.02 (13.23) | | |
| Fearful | | | | |
| Mean (SD) | 7.92 (13.03) | 7.32 (13.47) | | |

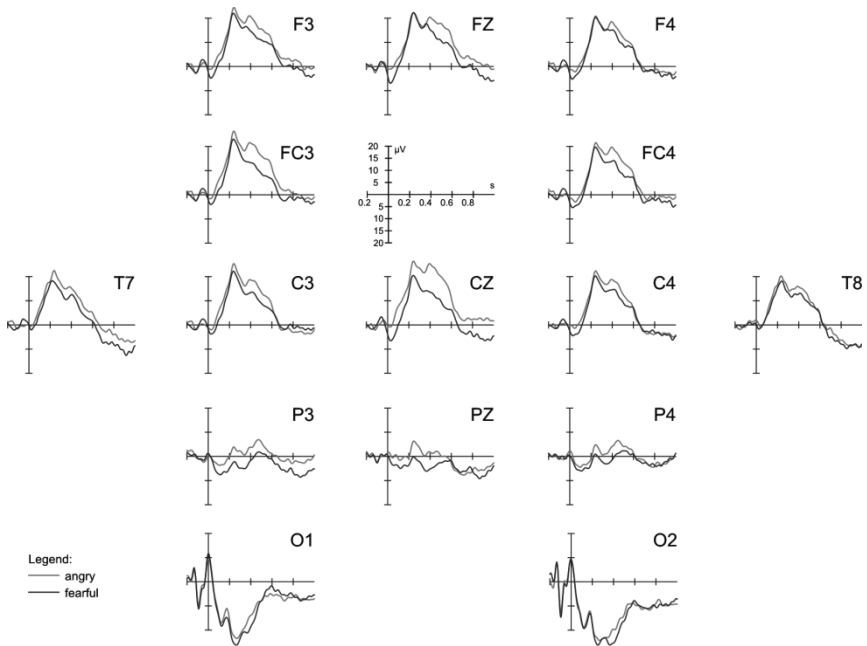


Figure 1. Grand average comprised of the single averages of 17 infants. Note that negative is plotted upward in this figure. The effect of larger Nc amplitude for angry relative to fearful emotional expression is clear in frontal and central electrodes from 300 to 600 ms. The effect of larger N290 amplitude for angry relative to fearful expression can be observed in midline and paramidline posterior electrodes (P4, PZ and P8) from 180 to 320 ms. The effect of larger P400 amplitude for fearful relative to angry expressions is clear in paramidline electrodes P4 and P8 from 300 to 420 ms.

measures ANOVA with the factors (1) Electrode Position (P3, P4) and (2) Condition (angry, fearful) revealed a significant effect for condition, $F(1, 11) = 5.89$, $MSE = 73.54$, $p = .034$, indicating that there was a significant difference between the maximum amplitudes of the two conditions, with the fearful condition larger than the angry condition (see Table 1c). The peak latencies did not differ between conditions for any component.

DISCUSSION

In the present study, we investigated the neural processing of angry and fearful emotional expressions in 7-month-old infants. The current data revealed that infants' electric brain responses (Nc, N290, and P400) differ between the two negative emotions. This suggests that infants discriminated between the two facial expressions. This result is in congruence with previous behavioural studies (Schwartz et al., 1985; Serrano et al., 1992) and resolves

questions raised by an earlier ERP study in which no difference was found between anger and fear in electrophysiological measures obtained from 7-month-old infants (Nelson & de Haan, 1996).

We found that a fronto-centrally distributed Nc was larger in amplitude to angry than to fearful facial expressions. The frequently observed Nc in infant ERPs is believed to reflect a general orienting response associated with attention (Richards, 2003a). The amount of attentional resources allocated is thought to be reflected in the size of the Nc amplitude, with a larger Nc indicating a relatively greater allocation of attention. The data suggest that infants discriminate the two expressions. This is indexed by the larger Nc amplitude for the angry facial expression, implying that infants at this age devoted more attentional resources to the angry than to the fearful facial expression. Although we expected to find a difference in the size of the Nc amplitude elicited by the two emotion expressions, this result is contrary to our prediction, that the amplitude of the Nc would be larger for the fearful expression. This prediction was based on infant-looking data, which overall show that infants look longer to fearful emotional expressions than to angry emotional expressions. Possible explanations for this finding could be that (1) the signal values of the two expressions are not perceived to be the same, and/or that (2) the infant is more affected by the angry expression than by the fearful expression. Furthermore, it could be that (3) the infant has a better understanding of the angry expression than the fearful expression.

As mothers tend to avoid negative affect around their young infants (Malatesta & Haviland, 1982), it is not until an infant starts to locomote that it is more likely to be exposed to potentially dangerous situations and thus provoke fearful or frightened expressions in the parent (Serrano et al., 1992) as well as an increased amount of angry expressions (Campos et al., 2000). However, it has been suggested that the recognition of expressions could be crucial for an infant. For example, the recognition of an angry expression facilitates a crying response, which may bring the caretaker to defend the child (Nelson & de Haan, 1996; Serrano et al., 1992). The useful function of recognising expressions might therefore have led to the creation of specialised neural systems that may require relatively little experience to develop (Nelson, 1987; Nelson & de Haan, 1996). In favour of the first explanation that the signal values of the two expressions are not perceived to be the same, it is possible that angry and fearful faces were not merely recognised as “negative”, but that the infants in our study differentiated between these two negative expressions. Both human and animal literature suggests that angry expressions may function as a discrete social signal from a very early age (Sackett, 1966; Stenberg & Campos, 1990).

In research with adults using functional magnetic resonance imaging (fMRI), it has been shown that fearful faces evoke response habituation in the amygdala and the prefrontal cortex (Breiter et al., 1996; Fischer et al.,

2003), whereas angry faces evoke sensitisation in neural structures such as the insula, gyrus cinguli, thalamus, basal ganglia, and hippocampus (Strauss et al., 2005). These neural response patterns toward anger might reflect the emotional response of the individual confronted with anger, namely a sustained level of attention while awaiting the negative consequences. Furthermore, adult subjects rated angry faces, in contrast to fearful faces, as significantly more likely to inflict harm (Strauss et al., 2005). In our study, it is possible that the infants were affected by the observation of a dyadically oriented angry expression, resulting in a high level of arousal evoked by discomfort or even elicited fear. In congruence with this, it has been proposed that the Nc response is also larger when the general arousal system is energised (Richards, 2003b). Our ERP data are in line with the view that shorter looking times for angry expressions, compared to other emotion expressions, might reflect that angry faces are truly aversive rather than less interesting to look at than other expressions. The infant brain, however, might be “working” on this expression even more.

An alternative explanation is that it might be easier for an infant to comprehend an angry expression relative to a fearful expression. Understanding the implications of an angry face involves the ability to anticipate a negative consequence, such as the interruption of interpersonal contact. This may be relatively less complex than those processes required determining the function of a fearful expression. A fearful face signals potential environmental threat perceived by the expressor (Adams et al., 2003). However, it is unlikely that a normally developing infant will induce a fearful expression in the observed individual. Hence, it might be easier for an infant to anticipate the consequence of someone expressing anger toward him than to anticipate the consequence of someone expressing fear toward him. In line with this, most infants do not begin to express fear before the age of 7 to 8 months, in contrast to the emotion of anger, which emerges between 4 and 6 months (Lewis, 2000). This can be explained by the higher cognitive complexities that are required for the expression of fear. When infants express fear, they need to be able to compare a situation that causes fearfulness with some previously experienced situation they remember, involving memory processes. For example, in stranger fear, an infant has to compare the face of a stranger to its internal representation or memory of faces (Lewis, 2000).

We also found a differential effect of emotion on the N290 and P400. The amplitude of the N290 elicited by the angry expression was larger, whereas the amplitude of the P400 elicited by the angry expression was smaller. In the adult work, no effect of expressions on the N170 was found (e.g., Eimer & Holmes, 2002). However, the intensities of negative expressions have an impact on the size of the amplitude of this adult face-sensitive component with the more intense expression eliciting a larger amplitude (Sprenkelmeyer & Jentsch, 2006). It is thus possible that infants in the current study

perceived the angry expression as more intense than the fearful expression, perhaps because of the previously discussed impact of the angry expression that might also explain the difference of the Nc amplitude. Alternatively, from a developmental perspective, these data suggest that the neural processes associated with face and emotion processing might interact in infancy but with development these processes become more functionally specialised and distinct (Grossmann & Johnson, 2007). This in line with theoretical accounts of functional brain development (Johnson, 2001), and could explain why an interaction of emotion and face processing on the level of the N290/P400 is observed in infants but not on the N170 in adults.

The results of our study are not consistent with Nelson and de Haan (1996), who showed no difference in 7-month-olds Nc elicited by angry and fearful expressions. The difference between the results of Nelson and de Haan (1996) and the present study is mainly constituted in a larger Nc amplitude for the angry expression in the present study when compared to Nelson and de Haan's results. The fearful faces elicited similar Nc amplitudes across the two studies. Various explanations exist to explain the difference. For example, it is possible that the angry expression that we used is more typical of the emotion than the expression used in Nelson and de Haan (1996). Furthermore, Nelson and de Haan presented the stimuli for 500 ms, whereas we presented our stimuli for 1000 ms. As the peak of the Nc is elicited beyond 500 ms in some individuals (see de Haan et al., 2004), we concluded that 500 ms duration may be too brief for an adequate processing of the face, including its configural and holistic information. Another technical possibility for the difference between studies may be the size of the images. As the image size in Nelson and de Haan (1996) was not reported, the visual angle of the stimuli may have differed between the studies. This may subsequently have had implications for the processing of the face. For example, a difference in the size of the eyes could have an additional impact on how an infant visually explores a presented face.

In order to further understand the neural mechanisms evoked by negative facial expressions, a series of behavioural and ERP studies are necessary, using different pairs of stimuli at a time and separately investigating the different parts of the face that constitute an angry and a fearful expression, such as the eyes and the mouth. It would, moreover, substantially add to our understanding of infants' emotion discrimination and perception to investigate both infants' behavioural and ERP responses toward negative emotions expressed in a more natural way, e.g., moving, rather than static facial expressions.

In summary, the results of the present study demonstrate that fearful and angry emotional expressions are dissociated by the Nc, N290, and P400

component of the infant ERP. We found a relatively larger Nc for the angry expression than for the fearful expression. This result suggests that the infant's attention is evoked more strongly by the angry expression, possibly because the infant is directly addressed and threatened by the angry expression, whereas this might not be the case for the fearful expression. This result represents an important step in understanding the neural mechanisms associated with emotion processing in the infant brain. The results furthermore show that the infant event-related potential is a more sensitive index of infant facial expression processing than previously thought.

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