Deactivating attachment strategies associate with early processing of facial emotion and familiarity in middle childhood: An ERP study

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At the time the research was undertaken participants did not provide permission for their individual data to be made publicly available, that is an informed consent did not specify this option. So full data is not able to be shared. If readers would like further information, they can contact Melanie Kungl (melanie.kungl@fau.de). Upon receipt of a reasonable request and given the researcher's confidentiality, restricted access may be given to data excluding potentially identifiable information.

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Neurophysiological evidence suggests associations between attachment and the neural processing of emotional cues (i.e., facial emotion). The current study asks whether this relationship is also evident in middle childhood, and whether there is an additional influence of social relevance (i.e., facial familiarity). Attachment strategies (deactivation, hyperactivation) were assessed in 51 children aged 9 to 11 years using a story stem completion task. Electroencephalography (EEG) was recorded while children passively viewed pictures of their mother and a female stranger displaying angry and happy emotional facial expressions. At the stage of early facial information encoding (N250), we observed attachment deactivation to be associated with a pattern pointing to an increased vigilance towards angry faces. Finally, we found the attention-driven LPP to be increased to happy mother faces as motivationally highly relevant stimuli overall, but not in children scoring high on attachment deactivation. These children did not seem to discriminate between mothers' facial emotions, besides showing a general attentional withdrawal from social-emotional stimuli. While our results on attachment deactivation support a two-stage processing approach, there was no effect of attachment hyperactivation on any of the assessed EEG components.

Keywords: ERP, face processing, attachment, middle childhood, deactivation, facial emotion

1. Introduction

A key component of the internal working model of attachment (IWM) is the perception and evaluation of social situations including the caregiver's and other persons' emotional signals (see Bretherton & Munholland, 2016). While securely attached individuals are assumed to freely evaluate emotional information, insecurely attached individuals, - presumably having experienced caregivers to be unavailable or inconsistent in attachment relevant situations – adapt to their social environment by applying secondary strategies (Kobak, Cole and Ferenz-Gillies, 1993). These strategies involve a tendency to either deactivate (i.e., suppress and withdraw from emotional information) or hyperactivate (i.e., enhance processing of negative- information) the attachment system, and are characteristic of avoidant and preoccupied/ambivalent attachment, respectively (Bowlby, 1982). Theoretical assumptions linking the processing of relevant social-affective cues and individual attachment orientations (Bowlby, 1982) are supported by numerous empirical studies in children as well as adults (for reviews see Dykas & Cassidy, 2011; Zimmermann & Iwanski, 2015).

Interestingly, evidence in this field points to the relevance of a two-factor model approach proposing attachment-related variations regarding early automated and later, more deliberate processing stages (e.g., Zimmermann & Iwanski, 2015). Here, the use of deactivation as a defensive strategy to minimize potentially hurtful experiences has been studied in more detail suggesting an automatic vigilance towards relevant (negative) emotional cues followed by an effortful withdrawal from these cues. While the idea of an early perceptual vigilance in avoidant individual is supported by studies focusing on perceptual thresholds (Maier et al., 2005) and startle responses (Spangler, Maier, Geserick, von Wahlert, 2010), others particularly tested the dual stage process model (Derakshan et al., 2007). Here, attachment avoidance was found to be associated with an initial bias to attend to and later disengage from threatening facial cues on a millisecond basis (Chun et al., 2015). Also, Zheng and colleagues identified similar patterns of neural responses to emotional faces to be associated with attachment-related deactivation (Zheng et al, 2015). Regarding hyperactivating strategies, research on anxious attachment in adults (assessed via self-reports) suggests a rather generally heightened vigilance towards stimuli of social and emotional significance and increased attention specifically to unpleasant stimuli in this group (e.g., Fraley et al., 2006). In other words, differences between deactivation and hyperactivation may emerge only at a later processing stage whereas early perceptual vigilance is expected to be inherent to both strategies (see Niedenthal et al., 2002). Taken together, it is suggested that in line with a dual stage process model the use of attachment strategies may reflect as differences in the temporal processing domain. Still, to our knowledge research particularly testing this assumption is limited to studies using self-reports of attachment in adult samples.

Here, applying the event-related potential (ERP) technique is a well-suited approach. Following a standardized procedure (Luck, 2014), relevant ERP components are extracted from the ongoing electroencephalogram (EEG), each of which is indicative of specific underlying mental processes. The method’s great advantage lies in the possibility to detangle different processes at very early stages of information processing (i.e., perception, attention, evaluation, etc.) that may remain obscured when using more traditional behavioral methods alone (Woodman, 2010). Regarding its high temporal resolution, it is also superior to other neuroscientific methods (e.g., functional magnetic resonance imaging, fMRI).

Within the field of social neuroscience, interest in the impact of early caregiving on brain mechanisms of social and emotional processing is growing steadily (see Taylor-Colls and Fearon, 2015, Long et al., 2020). Previous ERP studies in the field have especially focussed on facial emotion and familiarity processing. Variations in this domain have shown to be associated with experiences of maltreatment (e.g., Curtis and Chicchetti, 2013), institutionalisation and foster care (e.g., Moulson et al., 2009; Kungl et al., 2017) and the development of attachment disorders (Mesquita et al., 2015). Facial emotion processing has also repeatedly been used as a neural marker of socio-emotional outcomes related to parenting behaviour (e.g., Taylor-Colls & Fearon, 2015, Swingler et al., 2007) and parental affective symptoms (e.g., Kujawa et al., 2012). Relevant ERP studies usually include well-studied components representing both very early perceptual processing of facial information and later sustained attention to salient stimuli.

Typically, face stimuli (as compared to non-face stimuli) elicit an early negative activity over occipital-parietal regions, that appears to discriminate between caregiver and stranger faces in children (e.g., Dai et al., 2014) and is also suggested to be modulated by attachment in younger age groups (Kungl et al., 2017, Peltola et al., 2020). In contrast to its neural precursor, the P100 (see supplement S1), this negativity is related to robust facial representations and the detection of facial information beyond low-level visual properties (Rossion & Caharel, 2011). In adults, it has a typical topography and is referred to as the N170, representing the most widely used marker for face perception (see Eimer, 2011). However, there is some debate about its topographical distribution in children (see Kuefner et al., 2010), which only becomes more adult-like by the teenage years (Taylor, Batty, & Itier, 2004). Testing early ERP patterns of face sensitivity developmentally, Kuefner et al. (2010) suggest that the repeatedly observed second negative going peak directly following children's N170 is actually the N250, and that both components tend to merge, leading to a wider negative going waveform evident in children. The N250 itself is sensitive to the recognition of known or learned faces (e.g., Schweinberger et al., 2004) as it relates to the neural recruitment of long-term (facial) representation. More precisely, it is enlarged in response to personally familiar as compared to unfamiliar faces (e.g., Pierce et al., 2011).

Subsequent to the early encoding of facial information, salient stimuli elicit an ongoing positive slow wave in parietal regions. The so-called late positive potential (LPP) is thought to reflect sustained attentional engagement when processing emotionally and/or motivationally relevant stimuli (e.g., Schupp et al., 2000) and can reliably be identified throughout development. In both children and adults, the LPP is elevated in response to emotional as compared to neutral stimuli (Hajcak, Weinberg, MacNamara, & Foti, 2012 for review), including emotional facial expressions (Smith et al., 2013). Moreover, the LPP was found to be enlarged to angry as compared to happy faces (e.g., Schupp et al., 2004). However, when stimuli were socially relevant (i.e., anticipated future interaction partners), LPP enhancements have also been identified for happy as compared to angry faces (Bublatzky et al., 2014). Interestingly, in children, the LPP's sensitivity to emotion has been linked to emotion regulatory processes (Babkirk, Rios, & Dennis, 2014) and is discussed as a neural marker for internalizing disorders (e.g., Chronaki et al., 2018).

Notably, ERP studies linking attachment strategies to social emotional processing are highly heterogeneous regarding the method used to assess attachment, the employed experimental paradigms and the included age groups, limiting comparability and generalization of findings. To our knowledge, the only two ERP studies that have specifically looked at attachment-related differences in children's facial information processing using ERPs are restricted to preschool (Kungl et al., 2017) and infant samples (Peltola et al., 2020). Importantly, these studies did not differentiate between the two insecure groups making it impossible to draw conclusions about specific attachment-related strategies (i.e., deactivation and hyperactivation). Finally, the phase of middle childhood when children become more self-reliant in the regulation of their emotions (Zimmer-Gembeck & Skinner, 2011), remains neglected, albeit children's perceptions and regulatory efforts within social interactions are especially critical to socio-emotional adjustment during this time (Ziv, Oppenheim, & Sagi-Schwartz, 2004).

Current study

Addressing a void in the literature, the current study aimed to identify emotion regulatory patterns associated with the use of individual attachment strategies (deactivating/hyperactivating) in middle childhood. We therefore looked at two well-studied ERP components representing different stages of facial emotion processing (N250, LPP), which were extracted from the ongoing EEG signal during a passive viewing task using happy/angry faces of children's mothers and female strangers. Guided by the proposed two-factor model of attachment related socio-emotional processing in middle childhood (Zimmermann & Iwanski, 2015), we expected that children's deactivating strategies would lead to increased vigilance to (angry) faces at an early perceptual processing stage (N250), followed by an attentional withdrawal from social-emotional information reflected in dampened LPP amplitudes. Conversely, we expected hyperactivating strategies to result in overall heightened neural responses to emotional faces at both stages. We further asked whether by middle childhood, these patterns would generalize to a broader social context (Ziv, Oppenheim, & Sagi-Schwartz, 2004) and thus would be comparable for mother and stranger faces.

2. Methods

Participants

The final sample consisted of 51 children (29 female) aged 9 to 11 years (M = 9.91, SD = .51). Six more children were tested but excluded due to an insufficient number of EEG signal artefact-free trials. Children were right-handed and of Caucasian origin. All children were living with their biological mother. The sample of children was comparable to a normative German sample regarding mental health as indexed by the Strength and Difficulties Questionnaire (SDQ, Woerner et al., 2002). Participants were part of a sub-sample of a larger longitudinal study (Goecke et al., 2008; Hein et al., 2014; Eichler et al., 2017).

Procedure

The current study used data from two laboratory assessments, one behavioural and one neurophysiological. Both times, mother and child came to the laboratory together and mothers gave written consent for themselves and their children. After completion of each assessment, the dyads received a small present and monetary compensation (20 Euro). The study was conducted in line with the guidelines for neurophysiological research provided by the German Psychological Society and in accordance with the Declaration of Helsinki. It was approved by the University’s ethics committee.

Children's Attachment Strategies

Children's attachment strategies were assessed with the Attachment Story Completion Task (ASCT, Bretherton et al., 1990), which consists of five story stems designed to activate children's attachment representations (e.g., separation from and reunion with the parents, fear, injury, etc.) and a warm-up story. The task was initially designed for younger children but has successfully been used in older children up to 11 years of age (Bovenschen et al., 2016; Richartz et al., 2013). Children's stories were videotaped and coded by two experienced and trained raters using a German version of the Q-sort procedure developed by Miljkovitch, Pierrehumbert, Bretherton, and Halfon (2004). The rating was correlated with three ASCT criterion sorts describing different representational attachment strategies (e.g., attachment security, deactivation, and hyperactivation of the attachment system), yielding scores between -1.0 and +1.0 for each scale. For reliability testing, 15 videos were double-coded. Pearson's r was .79 for attachment security, .84 for deactivation, and .69 for hyperactivation, which can be interpreted as moderate to strong pairwise correlations.

Z-standardized scores for security ranged from -.49 to .94 (M=.25, SD=.38), while deactivation and hyperactivation scores ranged from -.80 to .51 (M=-.18, SD=.39) and from -.21 to .24 (M=-.03, SD =.10), respectively. Correlational analyses showed no statistically significant association for hyperactivation neither with attachment security, r = -.14, p = ns, nor with deactivation, r = .08, p = ns. However, attachment security and deactivation were highly correlated, r = -.99, p <.001. Notably, similar associations between the two security and deactivation dimensions have also been reported in other studies (Charest et al., 2019), and similarly resulted when correlating the expert scores provided by Miljkovitch and colleagues (2004). Given the focus on attachment strategies rather than attachment per se, in our analyses, the two dimensions *hyperactivation* and *deactivation* were used as predictor variables, while keeping in mind that lower scores in the latter relate to increases in attachment security.

ERP data collection

Children were seated in front of a computer screen and the experimenter sat behind a curtain monitoring the EEG signal and observing children via a webcam. Short breaks were made between blocks when necessary to keep up children's attention.

Stimuli

Stimuli included two types of facial emotion expressions (happy, angry) each presented by either the children's mother or a female stranger, all Caucasian. Stranger faces were taken from a standardized picture set (Tottenham et al., 2009) each expressing both emotions with mouth closed. For each mother, one out of six actors was chosen individually to match face stimuli with regard to visual features (i.e., hair colour, shape). Right before the ERP assessment, mothers' pictures were taken against a blue screen. They were instructed to pose both emotional expressions by imitating images of the corresponding stranger. Afterwards, two experimenters rated mothers' pictures regarding emotion intensity and, for each expression, the best match to the corresponding stranger stimuli was chosen. Colour information was removed and images were adjusted in figure-ground ratio, position, contrast, and lightning if necessary. Images were placed on a grey background layer and were presented on a 19-inch screen at a size of 14 cm x 10 cm at a distance of 65 cm.

Task Design

The passive viewing paradigm consisted of 160 trials and followed a 2 (emotional condition: happy, angry) by 2 (familiarity: mother, stranger) design with 40 trials per condition. It was divided into four blocks each presenting 40 trials in randomized order.

Each trial started with a 200ms pre-stimulus recording interval (black screen) followed by the stimulus appearing at the center of the screen for 500ms, a blank post-stimulus recording interval of 1300ms as well as a blank intertrial interval varying between 600 and 1200ms. The total duration of the experiment was about 10 minutes. Stimuli were presented using Inquisit (Version 3, Millisecond Software)

EEG recording and Data Reduction

EEG was recorded using a 32-channel system with active electrodes (ActiCap, Brain Products, Munich) placed in standard positions Fp1, Fp2, Fz, F3, F4, F7, F8, FC1, FC2, FC5, FC6, Cz, C3, C4, T7, T8, CPz, CP3, CP4, Pz, P3, P4, P7, P8, O2, O1, O2, TP9, TP10, PO9, and PO10, with FCz serving as the online reference. The signal was amplified and digitized with a 500 Hz sampling rate using Brain Amp (Brain Products, Munich). Electrooculogramm (EOG) was recorded from one electrode placed underneath the childs' right eye.

Offline analyses were carried out using Brain Vision Analyzer (Brain Products, Munich). After a visual raw data inspection, an average of 1.86 channels affected by excessive artefacts were interpolated using spherical splines with a maximum of six interpolated channels per subject. Blinks were detected and corrected following the procedure by Gratton et al. (1983). An offline filter with a bandwidth ranging from 0.1 to 30 Hz (24 dB/oct) was applied and the signal was re-referenced to an average reference. Data was segmented from 150ms before to 1000ms after stimulus onset and the signal was corrected using brain activity from -150ms to 0ms as the baseline. Artifact correction on segmented data was run automatically and restricted to an interval length of 800ms. The whole segment was removed when there were voltage steps of 75 mV/ms. The maximum/minimum allowed amplitude was +- 100 mV. A minimum of 20 artefact-free trials per condition was critical for inclusion in the final sample.

Insert Figure 1 here

Electrode sites (**Figure 1**) and time intervals were chosen based on the literature and a visual inspection of the grand average waveform. At parieto-occipital electrode sites, we identified a waveform that resembled the age-typical topography of an extended face-sensitive negativity described by Kuefner et al. (2010), which might coincide with the N250. Following a positive peak (P100), the N250 was most prominent between 200 and 320 ms and was defined as the maximum peak during this time window (*M*=246ms, *SD*=19) averaged over parietal electrodes PO9 and PO10 (e.g., Kuefner et al., 2010). At parietal electrodes, we found a positive-going modulation of the ERP amplitude peaking at around 300ms (similar to the P300 component) followed by an ongoing positive waveform starting at about 400 ms and a subsequent decrease. Informed by the average waveform as well as other studies (e.g., MacNamara and Hajcak, 2010) mean activity between 400 and 800 ms averaged over electrode sites P3,Pz,P4 (e.g., Kujawa et al., 2012) was extracted to measure the LPP. Notably, we also explored the LPP at occipital electrodes but found no effect of emotion, familiarity, attachment or their interaction.

Statistical Considerations and Analysis Plan

Before analysing, all measures (averaged amplitudes for each condition for each ERP component, attachment and demographic variables) were checked for outliers and distribution. Outliers were defined as values deviating more than 3 standard deviations from the mean and winsorized up or down to the respective 3 standard deviation boundaries. No distribution issues were detected. All dimensional variables were centered.

Analyses were computed separately for the N250 and the LPP. For each ERP component, one main repeated measures analysis of variance (RM-ANOVA) was computed with emotion (happy, angry) and familiarity (mother, stranger) as repeated factors. Biological child sex and age were entered as control variables but not further explored. Subsequently, one more RM-ANOVA per component including the attachment dimensions deactivation and hyperactivation as covariates of interest (i.e. RM-ANCOVAs) was computed. In the case of significant effects, Bonferroni-corrected post-hoc t-tests were performed and interactions with deactivation and hyperactivation scores were visualized by plotting mean scores at -1 and +1 standard deviations from the mean. Alpha values <.05 defined a significant effect. Effect sizes are reported as partial eta squared (η_p^2), where .01 represents a small effect size, .06 represents a medium effect size, and .14 represents a large effect size (Cohen, 1988). Detailed results of each analysis are shown in **Supplementary Tables S2.3** to **S2.6** (supplement).

3. Results

Behavioral Data

We checked for associations between child age and biological sex and attachment deactivation and hyperactivation scores. Child age did not correlate with attachment scores (Pearson correlations, *ps*> .35). There was, however, a significant sex-difference for deactivation scores (independent samples t-test; *t*= 3.13, *p*= .003, mean difference = .32, 95% CI .12 to .52) because deactivation scores were higher for boys as compared to girls. No such sex-difference was present for hyperactivation scores (*p*= .81).

N250

The RM-ANOVA with familiarity (mother, stranger) and emotion (angry, happy) as within subject variables (controlling for child age and biological sex) revealed significant main effects for familiarity (mother > stranger), *F*=14.701, *p*<.001, η_p^2=.234, and emotion (angry > happy), *F*=7.252, *p*=.010, η_p^2=.131 (see **Figure 2**), but no significant interaction. When adding the two attachment dimensions, there furthermore was a significant interaction between emotion and deactivation, *F*=5.423, *p*=.024, η_p^2=.105. For visualizing and interpreting this interaction, we plotted mean amplitudes for emotion (happy, angry) at deactivation values of -1 and +1 standard deviations from the mean (see **Figure 2**, right panel) and derived post-hoc t-tests. The t-tests revealed that while for children with lower deactivation scores, there was no significant amplitude difference between happy and angry faces, *mean difference*= .041, *p*=.948, *95%CI* -1.216 to 1.297, this amplitude difference was significant for children with higher deactivation scores, *mean difference*= 2.130, *p*=.001, *95%CI* .947 to 3.313. In other words, with increasing deactivation scores, the difference in N250 amplitude between happy and angry faces (in the direction angry > happy) also increased.

-Insert Figure 2 here-

LPP

The RM-ANOVA with familiarity (mother, stranger) and emotion (angry, happy) as within subject variables (controlling for child age and biological sex) did not reveal any main effects neither for emotion nor for familiarity. However, we observed a significant interaction between familiarity and emotion, F=4.581, p=.037, η_p^2=.087. Post-hoc t-tests showed that the familiarity by emotion interaction emerged because the LPP amplitude (i) only significantly differed between happy and angry faces in the mother condition, *mean difference*= .795, p=.017, *95%CI* .150 to 1.44, and (ii) only significantly differed between mother and stranger faces for happy emotion, *mean difference*= .622, p=.047, *95%CI* .008 to 1.236 (see Figure 4). In other words, the LPP effect showed a differentiation between happy and angry emotional expressions (in the direction happy > angry), but only for the mother and not the stranger faces.

When adding the two attachment dimensions, we observed a significant effect of deactivation on the mean LPP amplitude across all conditions, F=9.546, p=.003, η_p^2=.172. For interpretation of this effect, we derived the mean LPP amplitude for deactivation values at -1 and +1 standard deviations from the mean. This analysis revealed overall higher mean LPP amplitudes for children with lower deactivation values, *mean*=4.223, *95%CI*=3.284 to 5.161, as compared to children with higher deactivation values, *mean*=2.152, *95%CI*=1.269 to 3.036. There furthermore was a significant association between familiarity and deactivation, F=5.356, p=.025, η_p^2=.104, and between familiarity and emotion, F=5.328,

p=.026, η_p^2=.104, which was qualified by the interaction between familiarity, emotion, and deactivation, F=4.177, p=.047, η_p^2=.083. For visualizing and interpreting the three-way interaction, we plotted LPP amplitudes for familiarity (mother, stranger) and emotion (happy, angry) at deactivation values of -1 and +1 standard deviations from the mean (see **Figure 3**), and we calculated the familiarity and emotion effects at deactivation values -1 and +1 standard deviations from the mean as separate post-hoc t-tests. These post-hoc t-tests revealed only a significant difference in mean LPP amplitudes between (i) happy and angry emotional faces in the mother condition for lower deactivation values, *mean difference*= .1.779, p<.001, *95%CI* .834 to 2.725, and (ii) mother and stranger faces in the angry emotion condition for lower deactivation values, *mean difference*=-1.514, p=.006, *95%CI*= -2.575 to -.453. Overall, these findings revealed that the emotion by familiarity interaction observed across the entire participant sample decreased the higher the children's deactivation scores were.

-Insert Figure 3 here-

4. Discussion

Being the first study to investigate whether hyperactivating and deactivating attachment strategies were associated with certain patterns of neural sensitivity to mother and stranger emotional (angry/happy) faces in middle childhood, we found familiarity and attachment to affect perceptual stages of facial encoding as early as the N250. Here, attachment interacted with emotion pointing to an increased vigilance towards angry faces (as compared to happy faces) in children scoring high on deactivation. This was followed by a general increase in attentional engagement to happy mother faces as motivationally highly relevant stimuli (LPP) in all children, which, however, was not evident in children scoring high on deactivation. These children showed a pattern of less discrimination of mother’s facial emotion expressions and a general disengagement from socio-emotional stimuli. In sum, our results partly confirm a two-stage model of socio-emotional processing related to deactivating attachment strategies. Still, there was no effect of hyperactivation at any stage of face processing.

Confirming previous evidence (e.g., Kungl et al., 2017), facial familiarity processing did not modulate the P100 (see supplement S1), but an early subsequent parietal negativity that may reflect the stage of perceptual memory retrieval as indexed by the N250 (Schweinberger et al.,2004). In line with previous data, the N250 in our study was increased for mother as compared to stranger faces (e.g., Pierce et al.-, 2011; Waller et al., 2015). Interestingly, we also found this early negativity to be increased in response to angry versus happy faces, although we are not aware of any other reports on the parietal N250’s sensitivity to emotion expression. Since in children, the early face-specific component is subject to developmental changes and may in fact be generated by several sources (Batty and Taylor, 2006), studies on the preceding N170 may also be informative here. For example, comparable to our findings, O’Toole et al. (2013) have identified an early negativity to angry versus happy faces probably indexing an early staged threat-related attentional bias, which was found to moderate increases in symptom severity in child anxiety.

When adding attachment dimensions, the N250 angry face effect was qualified by an interaction between emotion and deactivation. Children scoring higher on deactivation more strongly discriminated between angry and happy faces, with N250 amplitudes to angry faces becoming more pronounced with increasing deactivation scores. In contrast, previous research on attachment and affective cue processing is rather unspecific with regard to emotional valence. For example, in a behavioral study, lower perceptual thresholds to emotional - but not neutral - social stimuli in avoidantly attached adults were found (Maier et al., 2007). Regarding previous ERP evidence, early face-sensitive components were repeatedly observed to be increased in response to emotional face stimuli in avoidantly (Zheng et al., 2015) or insecurely attached individuals in general (Fraedrich et al., 2010, Irak et al., 2020). While these latter studies did not find specific effects of emotional valence, increased early face sensitive negativities to angry versus happy faces were only recently reported in both avoidantly and anxiously attached (or deactivating and hyperactivating) adults, with avoidantly attached individuals additionally showing shorter latencies to angry faces (Irak et al., 2020).

Our findings extend the current literature in important ways. For the first time we report neural evidence that children using deactivating (but not hyperactivating) attachment strategies show an early perceptual negativity bias as indexed by increased N250 amplitudes to angry versus happy faces. As theorized by Bretherton (1991), avoidantly attached children may be more vigilant towards their social environment in order to instantly apply a deactivating strategy when needed (also see Zimmermann & Iwanski, 2015). Within this context, the detection of negative (as opposed to positive) social cues may be especially relevant, as negative cues (here angry faces) are likely to trigger early experiences of rejection and thereby activate defensive mechanisms to protect the child from painful feelings. Interestingly, the above effect was found across both mother and stranger faces, suggesting a more generalized perceptual bias towards angry emotional faces in this age group.

Converging with our findings on the N250 ERP amplitude, the LPP was also modulated by facial familiarity, emotion, and deactivation (but not hyperactivation).

Specifically, over all time windows, the LPP indicating sustained attentional engagement to motivationally highly relevant stimuli (e.g., Schupp et al., 2000) only discriminated between emotions in mother but not stranger faces, with increased amplitudes to mothers' happy (as compared to angry) facial expressions in all children. This finding contrasts with previous studies that have repeatedly found increased LPP amplitudes to angry as compared to other facial emotion expressions (e.g., Schupp et al., 2004). Such inconsistency may be explained by the salience of mother face stimuli in our mid-childhood sample. Accordingly, Bublatzky et al. (2014) found increased LPP amplitudes in response to happy versus angry faces of people that were anticipated to be future interaction partners. Suggesting a moderating effect of social relevance on LPP amplitudes to varying emotional valence, the authors point out that especially in low-arousing experimental conditions, socially relevant happy faces may efficiently activate the motivational approach system leading to LPP amplitude increases (Bublatzky et al., 2014). Along these lines, our finding is also indicative of a sustained facilitation effect for the processing of happy familiar faces proposed by Wild-Wall et al. (2008).

Adding attachment to our analyses revealed that the above-described discrimination between happy versus angry familiar (mother) faces was only evident in children scoring lower on deactivation. In children scoring higher on deactivation, the LPP amplitude did not differentiate between mothers' facial emotions. This finding partly corresponds to results of a previous eye-tracking study, which also showed atypical processing of mother faces in avoidantly attached children, however, independent of emotional valence (Vandevivere et al., 2014).

Regarding the emotional valence of mothers' face processing it came somewhat as a surprise that we found deactivation to affect the extent to which the LPP discriminated between happy and angry faces in the direction of happy > angry. In fact, attachment is more readily associated with socio-emotional processing in association with threat that conveys a higher intrinsic salience in terms of survival. Notably, given the study design we cannot draw conclusion on attachment and happy face processing per se. Still there are several explanations, why happy (as compared to angry) mother faces may still be particularly relevant in the attachment context. For example, happy mother faces are naturally very likely to trigger attachment-relevant experiences. In particular, through successful co-regulation (i.e., social allostasis), positive interactions with the caregiver become encoded as rewarding (Long et al., 2020). Children scoring low on deactivation may be more open to evaluate both negative and positive information and clearly distinguish between mothers' emotional signals with happy mother faces being especially salient. In our study, decreased discrimination between happy and angry mother faces (as indexed by the LPP) may be indicative of a rather ambiguous emotional climate within the family. This may mean that for children scoring high on deactivation mothers' happy as well as angry faces both associate with withdrawal tendencies (here indexed by overall dampened LPP amplitudes). In that sense, our results also support previous neurophysiological evidence suggesting that an insensitivity to reward (such as in the processing of a happy familiar face) may be one of the most characteristic features of attachment avoidance (see Long et al., 2020).

Notably, beside the above-described pattern of mother face processing in more avoidantly attached participants, we found an overall effect of deactivation on the LPP. Higher deactivation was additionally associated with overall dampened LPP amplitudes, pointing to a more general disengagement from social-emotional stimuli. Previous ERP studies identified similar patterns of attentional disengagement to both positive and negative emotional pictures (MacNamara, Kotov, & Hajcak, 2016) and faces in different age groups showing depressive symptoms (e.g., Proudfit et al., 2015). In addition, this pattern of electrocortical reactivity to emotional faces was also found in children exposed to rather negative family environments (James et al., 2018; Goldstein et al., 2021). Importantly, such application of defensive exclusion (Bowlby, 1982) has its costs, as the inhibition of attachment-related information requires cognitive effort potentially impacting emotional functioning and well-being (Chun et al., 2015; Leyh et al., 2016).

In our study, higher deactivation was associated with less differentiation regarding the valence of mothers' facial expressions. Future studies should include neutral faces to test whether there is also less LPP differentiation between emotional and neutral faces in this group, a pattern that has been linked to backgrounds of maternal depression and is discussed as a possible marker for children’s own risk of depression (Kujawa et al., 2012). In fact, although deactivating attachment strategies presumably result from withdrawing parenting behaviours that are also evident in maternal depression (Martins & Gaffan, 2000), evidence for the mediating role of deactivating strategies between avoidant attachment and children’s own depressive symptoms remains inconsistent (Malik et al., 2015). However, it is possible that, in line with previous findings (Kungl et al., 2016; Monti & Rudolph, 2014), specific components of emotional processing may indeed make avoidantly attached individuals particularly vulnerable to the development of affective symptoms.

One major study aim was to test a two-stage model with regard to emotional processing related to insecure attachment. While hyperactivating attachment strategies were not related to emotional face processing in our study, there was some evidence for the model with regard to deactivating strategies. In particular, deactivating strategies were associated with enhanced perceptual processing (N250) of angry faces followed by a later application of attentional disengagement (LPP) to emotional face stimuli, which was particularly evident in response to a differentiation between happy and angry mother faces. A similar processing pattern of attentional vigilance followed by attentional avoidance (here: of rejection stimuli), has also been identified in children with reactive attachment disorder using a dot-probe paradigm (Zimmermann & Meier, 2011) as well as in adult ERP studies on facial emotion processing (e.g., Zheng et al., 2015). In sum, our study not only further support the idea of two distinguishable processing stages, but it also extents previous evidence of a defensive exclusion of attachment-related information in avoidantly attached individuals (e.g., Kirsh & Cassidy, 1997, Dykas & Cassidy, 2011). Further studies are needed to confirm our findings regarding a possible neural signature of a two-stage processing underlying deactivating attachment strategies in children.

Limitations and Directions for future research

Regarding the LPP effect, it should be mentioned that the increased ERP difference between angry and happy mother faces in children scoring low on deactivation may, at least partially, be explained by decreased LPP amplitudes to mother angry faces (especially relative to stranger angry faces). Thus, the positivity bias in association with mother face for low deactivation may not only have been driven by the happy mother face condition alone, but in combination with the angry mother face condition.

Furthermore, our results need replication in a larger sample of children using comparable measures. In general, studies on attachment and neural correlates of emotional face processing are highly heterogeneous regarding the employed attachment assessment measure, the ERP paradigms used, and the age groups included. As ours was the first ERP study to focus on attachment strategies and their associations with emotion and familiarity processing in mid childhood, more studies are needed to confirm our findings. Also, as discussed above, future studies may need to include sad, fearful as well as neutral faces to gain a broader understanding of attachment and social-emotional information processing in children (e.g., Kammermeier, 2020; Peltola et al., 2020).

Notably, we did not find any effects of hyperactivating strategies. This may partly be due to the fact that hyperactivation was not pronounced in our sample leading to low statistical variance (M=-.03, SD =.10). Indeed, meta-analytic results suggest that regardless of gender, only 14% of children aged between 6 and 14 years old can be classified as insecure-ambivalent (Bakermans-Kranenburg & van Ijzendoorn, 2009). While many studies do not differentiate between insecure groups (also see Zimmermann & Iwanski, 2015), the few that assessed socio-emotional processing regarding attachment, for example, found clear effects of vigilance for the avoidant but only mild (Maier et al., 2005) or no effects for the preoccupied/anxious group (Chun et al., 2015). Also, in an eye-tracking task disengagement from angry and happy faces were related to avoidance but there was no significant effect of an anxious attachment style (Byrow et al., 2016).

Still, we cannot rule out the possibility that hyperactivation could be associated with specific neural patterns of emotional face processing. Future studies may be more successful using certain strategies to activate hyperactivation by experimentally inducing stress prior to the assessment or implementing stimuli associated with rejection (e.g., DeWall et al., 2012).

Finally, methodological limitations regarding the ASCT criterion sort (Miljkovitch et al., 2004) need to be mentioned. One refers to the high negative correlation between attachment security and deactivation ASCT criterion sort (Miljkovitch et al., 2004), which may but cannot certainly be ascribed to sample characteristics alone. In addition, there was only a moderate interrater reliability on the hyperactivation scale (.69). Finally, there was only limited availability of a second reliable coder due to discontinuities in the study progress in the course of the pandemic. Eventhough the percentage is comparable to other studies, the rather small absolute number of the ASCT reliability codings points to another possible methodological weakness.

Concluding remarks

Due to the novelty of our findings, they should be viewed as preliminary. Future studies including larger sample sizes are necessary for confirmation and extension. In general, studies especially focussing on attachment and socio-emotional information processing in mid-childhood samples are highly relevant due to an increasing demand for emotional self-regulation during this important developmental stage (e.g., Zimmer-Gembeck & Skinner, 2011). In fact, when children spend more time away from home, the IWM plays a central role in their socio-emotional adjustment (Boldt et al., 2016). This may be especially true as our results show that in this age group the IWM is likely to shape not only perceptions of cues presented within the family context but generalize to a broader social context (here: stranger faces). Biased processing of social-emotional cues and related emotion regulation strategies discussed above may then guide behavior in novel situations, possibly hindering positive experiences in new social relationships (Feeney et al., 2008). Finally, future studies in mid-childhood samples should also include more deliberated processing steps like attributional biases or the interpretation of social situations (e.g., “attributions of others’ intentions, theory of mind ability etc., Zimmermann & Iwanski, 2015, p.54). Linking these different components of emotion regulation may then have the possibility to lead to a more comprehensive social-information processing theory related to deactivation, like it has been done for children showing certain maladaptive interaction styles (i.e., aggression, see Dodge & Crick, 1990).

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Figures

Figure 1:

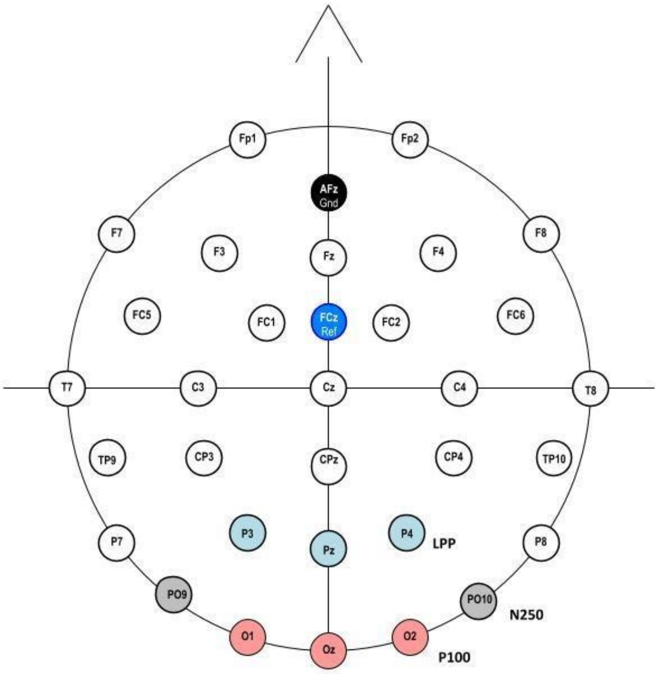

Figure 2:

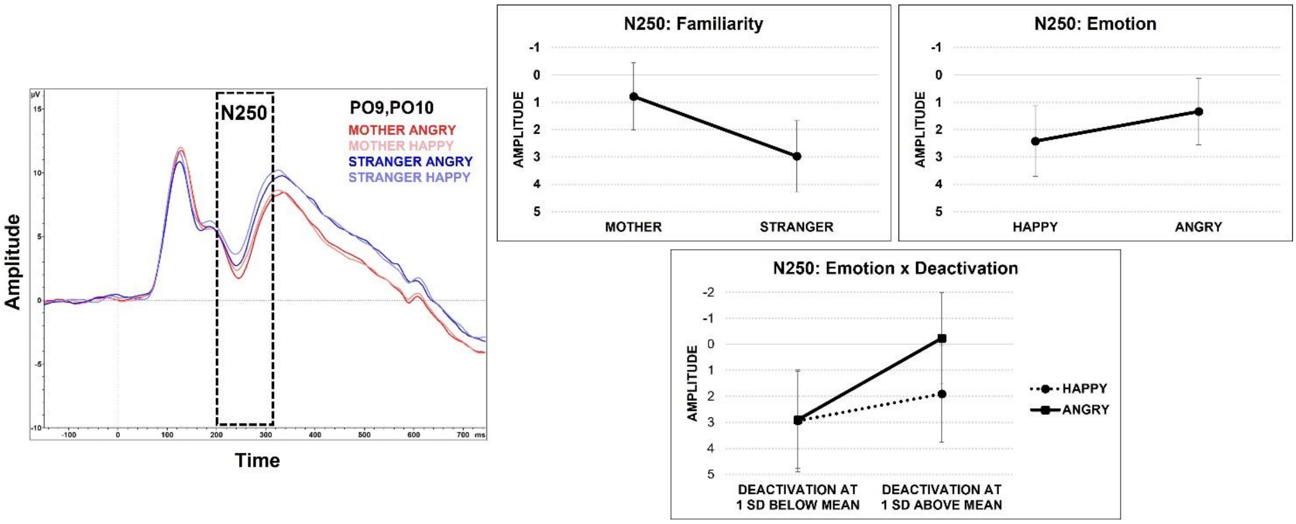

Figure 3:

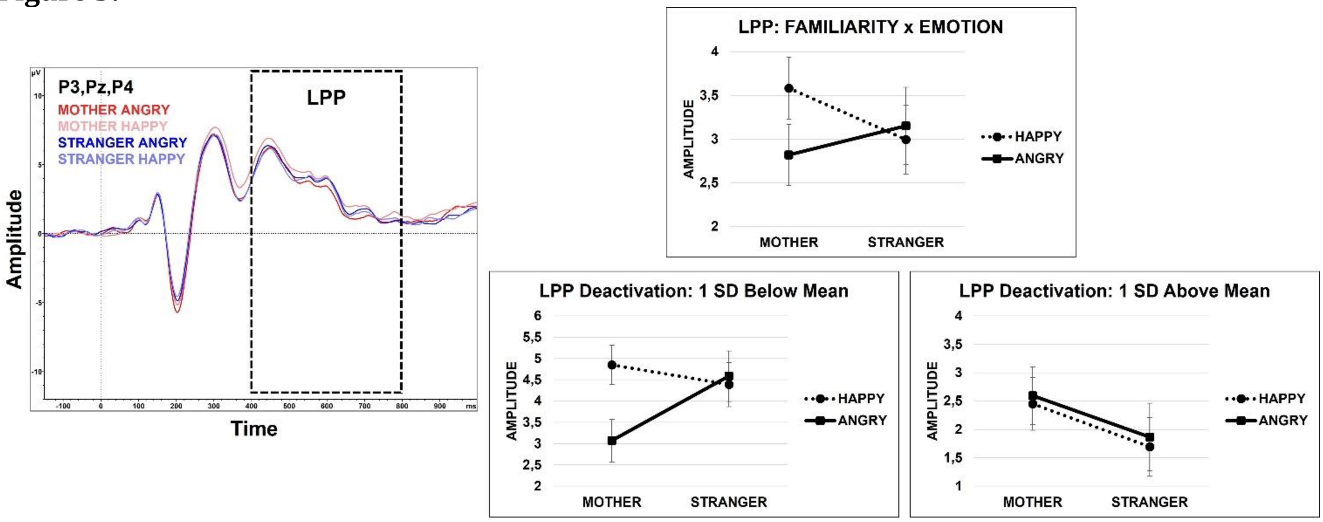
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Figure 1: Electrode layout and electrode sites chosen for the P100 (O1,Oz,O2), N250 (PO9,PO10), and LPP (P3,Pz,P4).

Figure 2: N250 Results. Left panel: Stimulus-locked waveforms showing the N250 elicited by mothers' and strangers' angry and happy facial expressions averaged over parietal-occipital electrode sites PO9 and PO10. Right panel: Line plots of the main effect of familiarity (top left), main effect of emotion (top right) as well as emotion x deactivation interaction for deactivation at -1 and +1 standard deviation (SD) from the mean. Error bars are +/-1 SEM. *Please note that for the line plots, N250 ERP amplitude is depicted inversely (i.e., more negative deflection on top).*

Figure 3: LPP Results. Left panel: Stimulus-locked waveforms showing the LPP elicited by mothers' and strangers' angry and happy facial expressions averaged over parietal electrode sites P3, Pz, and P4. Right panel: Line plots of the interaction between familiarity and emotion (top), and the interaction between familiarity and emotion with deactivation plotted at deactivation values -1 standard deviation (SD; bottom left) and +1 SD (bottom right) from the mean. Error bars are +/- 1 SEM.