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Attention to Faces Expressing Negative Emotion at 7 Months Predicts Attachment Security at 14 Months

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To investigate potential infant-related antecedents characterizing later attachment security, this study tested whether attention to facial expressions, assessed with an eye-tracking paradigm at 7 months of age (N = 73), predicted infant–mother attachment in the Strange Situation Procedure at 14 months. Attention to fearful faces at 7 months predicted attachment security, with a smaller attentional bias to fearful expressions associated with insecure attachment. Attachment disorganization in particular was linked to an absence of the age-typical attentional bias to fear. These data provide the first evidence linking infants' attentional bias to negative facial expressions with attachment formation and suggest reduced sensitivity to facial expressions of negative emotion as a testable trait that could link attachment disorganization with later behavioral outcomes.

Developing during the 1st year, the attachment behavioral system facilitates different response patterns upon threatening situations and separation from caregivers (Bowlby, 1969). Compared to securely attached infants who readily seek and manage to get comfort from the caregiver when feeling frightened, insecurely attached infants are characterized by an inhibition of outward signs of distress and apparent indifference toward the caregiver (avoidance), clinginess and anger toward the caregiver (resistance), or a lack of a coherent behavioral strategy and potential signs of fear of the caregiver (disorganization; Ainsworth, Blehar, Waters, & Wall, 1978; Main & Solomon, 1990). An extensive amount of research has established the importance of sensitive and supportive caregiving on the emergence of secure attachment (Ainsworth et al., 1978; Bernier, Matte-Gagné, Bélanger, & Whipple, 2014; De Wolff & van IJzendoorn, 1997), and provided evidence for an enduring impact of attachment security on a range of measures of social adaptation such as externalizing and internalizing problems, social competence, and emotion regulation (Fearon, Bakermans-Kranenburg, van IJzendoorn, Lapsley, & Roisman, 2010; Groh, Roisman, van IJzendoorn, Bakermans-Kranenburg, & Fearon, 2012; Groh et al., 2014; Sroufe, 2005).

Although the 1st year of life is critical for attachment formation and the role of the caregiving environment in this process has been investigated in detail, there are considerably fewer prospective studies investigating how developmental trajectories during this period differ in infants later classified as securely or insecurely attached. Studies addressing this question have shown that child characteristics such as temperament (Van IJzendoorn & Bakermans-Kranenburg, 2012) and candidate genetic variants (e.g., Luijk et al., 2011) may not consistently predict attachment, but there is some evidence for responses more closely related to interactive contexts, such as infants' positive affect

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expressions and behavioral responses during the Still Face procedure, to predict later attachment (e.g., Braungart-Rieker et al., 2014; Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009, for a review). In the present study, we continued this line of research by testing a hypothesis that infants' attention to facial emotion expressions, particularly to emotions of negative valence, is associated with later attachment security.

There are good reasons to assume that attachment formation in infants is marked by changes in attention to facial expressions. Models of attachment and socioemotional information processing suggest that recurrent attachment-related experiences shape representational, physiological, and behavioral responses to emotional information, and to cues signaling threat in particular (Bowlby, 1969; Cassidy, Jones, & Shaver, 2013; Dykas & Cassidy, 2011; Vrtička & Vuilleumier, 2012). Cues signaling threat can range from direct and attachment-specific threat signals (such as the separation from or displays of anger by the caregiver) to more ambiguous cues of potential danger (such as fearful faces). It is argued that attachment-related information processing biases toward potential threat cues in the environment are constantly operating (cf. Bowlby, 1969; Dykas & Cassidy, 2011), although experiencing threat oneself may amplify the preexisting response patterns. Although there is evidence from adults showing that attachment security is associated with patterns of attending toward or away from threat-related stimuli such as angry faces (e.g., Dewitte & De Houwer, 2008), no studies have investigated the early origins of attachment-related information processing biases in infancy. The possibility that variations in attention to facial expressions of negative emotion are associated with the evolving attachment relationship in early development is further suggested by findings showing that individual variations in attention to fearful facial expressions in 7-month-old infants are related to maternal stress and depressive symptoms (Forssman et al., 2014) and that attention to angry faces is enhanced in school-age children with histories of parental maltreatment (e.g., Pollak & Kistler, 2002).

Research documenting the early ontogeny of the perception of emotional stimuli has shown that during the second half of the 1st year, infants begin to reliably discriminate between a range of emotional expressions presented in different channels such as the face (Leppänen & Nelson, 2009; Nelson & Dolgin, 1985), voice (Flom & Bahrick, 2007), and body movements (Zieber, Kangas, Hock, & Bhatt, 2014). A notable developmental feature of emotion perception at around 5–7 months of age is a robust attentional bias toward facial expressions of fear. This bias is typically observed in prolonged engagement of attention to fearful facial expressions in comparison to happy or neutral stimuli (Nakagawa & Sukigara, 2012; Nelson & Dolgin, 1985; Peltola, Hietanen, Forssman, & Leppänen, 2013; Peltola, Leppänen, Palokangas, & Hietanen, 2008), augmented heart rate deceleration (Leppänen et al., 2010; Peltola, Leppänen, & Hietanen, 2011), and attention-related electrocortical brain responses to fearful faces (Leppänen, Moulson, Vogel-Farley, & Nelson, 2007; Nelson & de Haan, 1996; Peltola, Leppänen, Mäki, & Hietanen, 2009). Importantly, the attention bias appears to be relatively specific to fearful expressions as similar biases have not been observed to sad or angry expressions (e.g., Grossmann, Striano, & Friederici, 2007; Soken & Pick, 1999) or to faces displaying novel, nonfearful expressions (Peltola, Leppänen, Vogel-Farley, Hietanen, & Nelson, 2009; Peltola et al., 2008), although the extent to which infants assign specific emotional meaning (e.g., fear) to pictures of facial expressions remains debatable (Kagan & Herschkowitz, 2005). The robustness and relative specificity of infants' attentional bias to fearful facial expressions are reasons to assume that this phenomenon reflects an important aspect of early emotional information processing, and variability in this bias may therefore present a particularly suitable starting point for investigating the early antecedents of later attachment. However, as yet, there have been no studies examining the potential of interindividual variation in attentional biases to negative facial expressions as a marker of subsequent social and emotional development, or as a precursor of more refined functional behavioral responding to emotional events (cf. Walle & Campos, 2012).

In the present longitudinal study we examined whether infants' attentional biases to facial expressions at 7 months of age predict mother–infant attachment quality after 1 year of age. Infants were tested with an eye-tracking measure of attention to facial expressions (i.e., the Overlap paradigm) at 7 months of age and mother–infant attachment was assessed at 14 months of age with the Strange Situation Procedure (SSP; Ainsworth et al., 1978). The Overlap paradigm (modified from the original paradigm by Aslin & Salapatek, 1975), examines infants' gaze shifts from a central stimulus (i.e., a neutral, happy, or fearful expression, or a face-shaped control stimulus) to a high-contrast stimulus in the left or right periphery. Due to the temporally overlapping presentation of the two stimuli, a gaze shift to the peripheral stimulus requires active disengagement of attention from the central face stimulus (Colombo, Brez, & Curtindale, 2012), which makes this task suitable for probing differences in attention allocation between distinct centrally presented stimuli. Attentional biases can be assessed most reliably by calculating the probability of attention shifts from the centrally presented stimuli toward the peripheral stimuli, and a robust bias to fearful expressions has been observed as a higher probability of missing attention shifts from fearful versus happy/neutral faces in independent infant samples (Forssman et al., 2014; Leppänen et al., 2011; Nakagawa & Sukigara, 2012; Peltola et al., 2008, 2011).

Our primary aim was to test for differences in attention to facial expressions between infants grouped as securely or insecurely attached (i.e., avoidant, resistant, and disorganized), with additional exploratory analyses aiming at a further characterization of the data across the attachment subgroups and with a continuous measure of attachment disorganization. As described above, we were particularly interested in whether early attentional responses to negative facial expressions predict the activation of attachment behaviors in later development. Because previous studies have shown infants within this age range to display robust attentional biases to fearful faces, we selected fearful faces as the negative emotion category in this study. There are no prior studies examining the association between processing of facial expressions and attachment security in infants, which led us to adopt an exploratory approach and refrain from strong directional hypotheses. Theoretical and empirical work with adults (Dewitte & De Houwer, 2008; Dykas & Cassidy, 2011) suggest that, possibly serving a regulatory function to suppress emotional overarousal, a relatively automatic tendency to divert attention away from threat-related cues is associated with insecure attachment. In the present paradigm such tendency would be observed as a relatively smaller attention bias to fearful expressions. Alternatively, the reverse could also be expected; that is, secure attachment could be associated with a relatively smaller attention bias to fearful expressions, possibly due to a decreased need to monitor the environment for potential signs of threat in infants with a more established expectation of caregiver availability.

Besides infants' attention to facial expressions, maternal sensitivity was assessed when the infants were 7 months old. Maternal sensitivity was assessed to examine whether attentional biases to facial expressions, and their potential associations with later attachment, are associated with differences in the mothers' ability to detect and respond to infant signals. Apart from studies with maternal personality (de Haan, Belsky, Reid, Volein, & Johnson, 2004) or depressive symptoms (Forssman et al., 2014) as a proxy of the caregiving environment, there is a lack of research on the associations between parental caregiving sensitivity and the processing of emotional stimuli in infancy. Also, as parental sensitivity has an established role in the development of attachment security, it is important to determine whether other potential predictive factors (such as attentional biases to facial expressions) are independent from or interact with parental sensitivity in predicting later attachment security. We expected secure attachment to be associated with higher maternal sensitivity, but did not advance a specific directional hypothesis with respect to the influence of maternal sensitivity on attention to facial expressions.

Method

Participants

The infants were recruited from an ongoing longitudinal cohort study ($N = 126$; 44% females; Forssman et al., 2014; Peltola et al., 2013) in which eye-tracking assessments of attention to facial expressions with the Overlap paradigm have been conducted at 5 months ($M = 152.43$ days, $SD = 3.64$) and 7 months of age ($M = 213.85$ days, $SD = 4.39$). All infants were healthy, full-term ($\geq$ 37 weeks), and from urban, middle-class families of Caucasian ethnicity. A total of 73 infants from the original cohort participated in the attachment assessment at 14 months of age ($M = 414.85$ days, $SD = 20.24$; 44% females). The notable loss of infants for the follow-up attachment assessments is partly explained by the fact that the attachment assessment was introduced as a supplemental visit after the onset of the longitudinal study. Importantly, no statistical differences were found between those who did and did not participate in the attachment assessment in maternal sensitivity, attention to facial expressions, or temperament (as measured with the Infant Behavior Questionnaire; Rothbart, 1981), ps = .28–.96, indicating that the participants included in the current analyses are representative of the complete longitudinal study cohort. All infants with $\geq$ 3 scorable trials in each of the four stimulus conditions in the Overlap paradigm and attachment data were included in the present analyses. Given that a relatively greater number of infants had insufficient eye-tracking data in the 5-month assessment (n = 26) as compared to the 7-month assessments (n = 11), the final analyses reported here are based on infants who had valid eye-tracking data from the 7-month-assessment and had participated in the attachment assessments at 14 months of age (n = 62; 39% females; see Data S1 in the Online Supporting Information for the 5-month data analyses). Approval for the project was obtained from the Ethical Committee of Tampere University Hospital, and informed written consent was obtained from the parent of each child.

Measures

Attention to Facial Expressions

Eye-tracking data were collected during the Overlap paradigm for measuring attention to facial expressions and face-shaped control stimuli (Figure 1). The facial expression stimuli were neutral, happy, and fearful expressions posed by two female models, and the face-shaped control stimuli were phase-scrambled images of both of the models' faces, preserving the outer contour of the face. The face and control stimuli measured 15° and 11° vertically and horizontally, respectively. The session started with the placement of an electrode net for recording electroencephalography (for these data, see Yrttiaho, Forssman, Kaatiala, & Leppänen, 2014). During the experiment, the infants sat on their parent's lap at a 60-cm viewing distance from a corneal-reflection eye-tracker monitor with a 58-cm diameter (Tobii TX300; Tobii Technology, Stockholm, Sweden), which recorded data on infants' eye positions on the screen with a 300-Hz sampling rate. Data collection started with the calibration of the eye-tracker cameras during which an audiovisual animation was presented sequentially at every corner and the center of the screen. If the first calibration was not successful (i.e., one or more calibration points were missing or were not properly calibrated), the calibration was repeated at least two times to attain satisfactory calibration for all five locations. If one or more calibration points were missing after more than 2 recalibration attempts, the final calibration outcome was accepted and the experiment was started. If none of the locations were successfully calibrated after several recalibration attempts, the experiment was then run without collecting eye-tracking data. In the Overlap paradigm, a fixation stimulus (a red circle repeatedly expanding from 0.4° to 4.3°) preceded

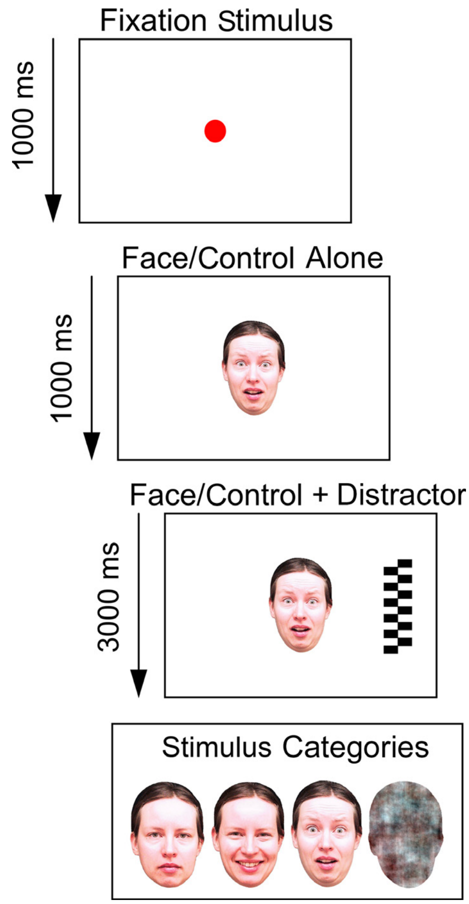

Figure 1. The sequence of events in the Overlap paradigm and examples of the stimuli.

each trial. Once the infant looked at the fixation stimulus, the experimenter pressed a key to present a face or a face-shaped control stimulus on the center of the screen. The central stimulus was flanked after 1,000 ms by a peripheral stimulus presented 14° equiprobably on the left or right for 3,000 ms. The peripheral stimuli were black-and-white vertically arranged circles or a checkerboard pattern, measuring 15° × 4° visual angle. Each stimulus condition (i.e., control, neutral, happy, fearful) was repeated six times for both models in a random order (i.e., a total of 48 trials), with the constraint that the same stimulus condition was presented no more than four times in a row and the peripheral stimulus on the same side no more than three times in a row. Stimulus presentation was controlled by E-Prime 2 software (Psychology Software Tools Inc., www.pstnet.com).

All data processing from the raw x–y gaze position coordinates to the parameters reflecting attention disengagement were completed automatically by using *gazeAnalysisLib*, a library of MATLAB

(Mathworks, Natick, MA) routines for offline analysis of raw gaze data (Leppänen, Forssman, Kaatiala, Yrttiaho, & Wass, 2014). First, a 37-sample median filter was applied for removing abrupt spikes in the gaze data (attributable to technical artifacts). Second, data segments with a maximum of 200 ms of missing eye position data were interpolated by continuing the last recorded *x*- and *y*-coordinates until the tracking came back online. Third, bad trials were excluded from further analyses. These included trials with infant movement, inattentiveness, or technical problems in eye tracking (fragmented tracking), resulting in more than 200 ms of missing eye position data during the trial or the infant looking at the central stimulus for less than 70% of the time preceding gaze disengagement or the end of the analysis period (on average 21.9% of all trials). Additionally, a small number of trials were excluded due to anticipatory eye movements (i.e., a saccade commenced less than 150 ms after the peripheral stimulus onset; 0.5% of all trials) or computer timing errors (i.e., the stimuli not presented for the correct duration; 0.15% of all trials). No significant difference was observed in the number of excluded trials between securely and insecurely attached infants, $t(68) = 1.11$, $p = .27$. Of the remaining scorable trials, the proportion of *missing attention shifts* (i.e., no eye movement toward the peripheral stimulus during a 150- to 1,000-ms time window after the peripheral stimulus onset) was calculated for each stimulus condition (cf. Leppänen et al., 2011). In addition, *attentional bias scores* were calculated for each stimulus type for post hoc comparisons. The bias scores are deviation contrasts, which reflect the relative weighting of attention to particular face stimuli in the context of other stimuli (e.g., missing attention shifts for fear minus the mean of missing attention shifts for all other face stimuli). To be included in the statistical analyses a minimum of three scorable trials was required for each stimulus condition. On average, the infants included in the analyses had 9.2, 9.4, 9.0, and 9.4 scorable trials in the control, neutral, happy, and fearful stimulus conditions, respectively, with no differences in the number of scorable trials between securely and insecurely attached infants, $F(1, 60) = .48$, $p = .49$.

Maternal Sensitivity

Mother–infant dyads were videotaped at their homes during a free-play interaction for 15 min within 2 weeks after the 7-month laboratory session. Maternal sensitivity was assessed from videotapes using the Emotional Availability Scales (EAS), 4th ed. (Biringen, 2008) by a certified coder (author 3), unaware of infants' attachment classifications and performance in the eye-tracking task. Maternal sensitivity was coded on a scale of 1–7, consisting of parental affect expression, the ability to detect and appropriately react to child signals and behaviors, and communicating in respectful ways. The EAS data were available for 69 (of 73) mother–infant dyads. The average sensitivity score within this sample was 5.14 ($SD = 1.14$, skewness = .20), which is similar to nationally representative maternal sensitivity data (e.g., Merras-Salmio et al., 2013). Intercoder agreement (intraclass correlation [ICC]) between the main coder and an independent certified coder on a set of 20 cases was ICC = .95.

Infant–Mother Attachment

Infants and mothers were observed in the SSP (Ainsworth et al., 1978). In accordance with standard procedures, the SSP consisted of seven 3-min episodes, including two separations from and two reunions with the mother, and interaction with a female stranger. Infants' attachment behaviors were coded from videotapes according to the organized attachment scales by Ainsworth et al. (1978) and the Main and Solomon (1990) coding system for assessing attachment disorganization. On the basis of ratings on 7-point scales assessing infants' proximity seeking, contact maintenance, resistance, and avoidance during the two reunion episodes, infants were first classified as secure (B), insecure-avoidant (A), or insecure-resistant (C). Next, signs of attachment disorganization (D) during each episode when the mother was present were rated using a scale from 1 (*no signs of disorganization*) to 9 (*strong signs of disorganization*), with scores higher than 5 receiving a disorganized classification. Infant behaviors contributing to attachment disorganization scoring include contradictory behaviors (e.g., rapid avoidance following a cry for the mother), stereotypical or anomalous behaviors, stilling or freezing, direct signs of apprehension regarding the mother, and misdirected or disoriented behaviors. Intercoder agreement was calculated from 18% of the sample by two coders (authors 1 and 4, both unaware of the maternal sensitivity scores or infants' performance in the eye-tracking task). For the four-way ABCD classifications, presence versus absence of secure attachment (i.e., B vs. non-B), and the presence versus absence of attachment disorganization (i.e., D vs. non-D), intercoder agreement was 92%

(κs = .88, .85, and .81, respectively). Agreement on the continuous D scores was ICC = .91. For the remaining sample, the ABCD classifications were based on a consensus between the first author and expert coders from Leiden University. In the full sample of 73 infants, 46 infants (63%) were classified as securely attached (B), 10 (14%) as insecure-avoidant (A), 6 (8%) as insecure-resistant (C), and 11 (15%) as disorganized (D). Within the sample of 62 infants having sufficient eye-tracking data at 7 months, the distribution was: B = 37 (60%), A = 8 (13%), C = 6 (10%), and D = 11 (17%). These distributions were thus highly concordant with meta-analytic data on attachment distributions in Western samples (e.g., Van IJzendoorn, Schuengel, & Bakermans-Kranenburg, 1999), $\chi^2 < .58$, $p = .90$. The statistical analyses were conducted using the secure versus insecure grouping and the continuous D scores as dependent variables.

Results

First, an analysis of variance of the missing attention shift data at 7 months was conducted to test whether the infants included in the present sample show a similar pattern of attention to faces as has been observed in previous research. Replicating previous findings, the main effect of face stimulus was significant, $F(3, 183) = 41.34$, $p < .0001$, partial $\eta^2 = .40$, due to the proportion of missing attention shifts being significantly higher to fearful faces ($M = .52$; $SD = .25$) than to happy ($M = .36$, $SD = .25$) and neutral ($M = .36$, $SD = .25$) faces, or to the control stimuli ($M = .18$, $SD = .21$), all Bonferroni-corrected comparisons $p < .0001$, $d > .64$. Other preliminary analyses showed that missing attention shifts to faces at 7 months of age were not associated with gender or maternal sensitivity (*p*s = .16–.99). Attachment grouping (secure vs. insecure) was not associated with maternal sensitivity, $t(67) = .45$, $p = .66$, or age (in days) at attachment assessment, $t(71) = .49$, $p = .63$. There were more males than females with an insecure classification (20 vs. 7) as compared to the gender distribution within the secure group (21 vs. 25), $\chi^2 = 5.58$, $p = .018$. The continuous D scores were not associated with maternal sensitivity, $r = .05$, $p = .71$; age at attachment assessment, $r = .03$, $p = .79$; or gender, $t(71) = .40$, $p = .69$.

In the main analyses, logistic regression analysis was conducted to predict secure versus insecure attachment grouping and linear regression was used to predict attachment disorganization (the continuous D scores) on the basis of missing attention shift scores to faces and face-shaped control stimuli at 7 months of age (with the predictor variables mean centered). The regression analyses were first run with gender and maternal sensitivity included as predictor variables, but as no interactions involving these variables emerged (i.e., gender and maternal sensitivity did not interact with missing attention shift scores to predict attachment security or disorganization), they were excluded from the final analyses to reduce the number of predictors and to improve model fit.

The logistic regression model with attachment grouping (secure vs. insecure) as the dependent variable and missing attention shift scores as predictors was significant, $\chi^2 = 10.40$, $p = .034$, $R^2 = .15$. Attachment grouping was predicted significantly by the proportion of missing attention

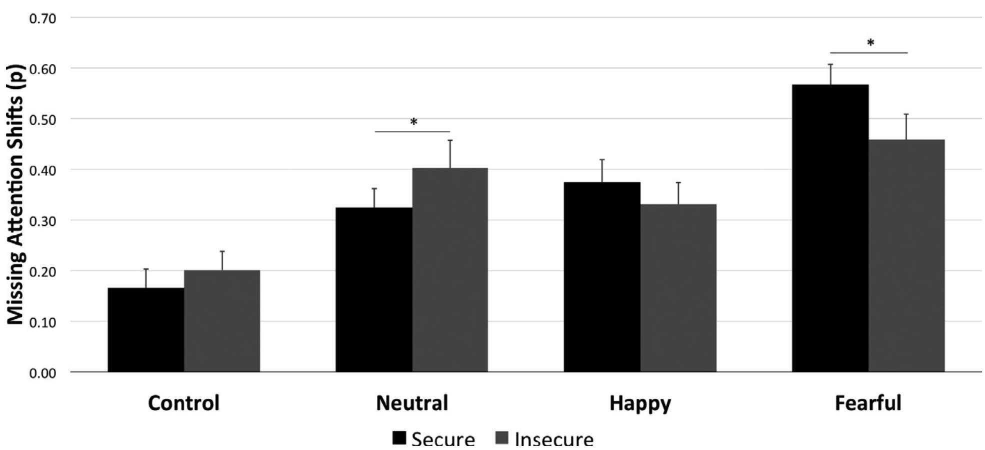

Figure 2. Mean proportion (*p*) of missing attention shifts in different stimulus conditions in 7-month-old infants, grouped by attachment security. Error bars represent the standard error of mean.
*$p < .05$.

shifts to neutral ($B = -3.90$, $SE = 1.79$, $p = .03$) and fearful ($B = 3.39$, $SE = 1.61$, $p = .035$) faces (Figure 2). Separate t tests with the attentional bias scores showed that secure attachment was associated with a larger attentional bias to fearful faces, $t(60) = 2.59$, $p = .012$, $d = .67$, while the bias scores to neutral faces were larger in insecure than secure infants, $t(60) = 2.46$, $p = .017$, $d = .64$. As an exploratory analysis to estimate how these effects manifest in the different insecure subgroups, a multinomial logistic regression with the four-way attachment classification (A, B, C, D) as the dependent variable and missing attention shift scores as predictors was run. The model was significant, $\chi^2 = 23.40$, $p = .024$, $R^2 = .31$. Inspection of the parameter estimates (with secure attachment as the reference category) indicated that attachment avoidance was associated with a relatively larger bias to neutral ($p = .023$) but not fearful ($p = .79$) faces, whereas both resistant and disorganized attachment were associated with a smaller bias to fearful faces (ps = .039 and .012, respectively), but did not differ from secure attachment in attention to neutral faces (ps = .44 and .15, respectively).

The association with attachment disorganization was further tested with a linear regression analysis with the D score as the dependent variable and missing attention shift scores at 7 months as predictors. The model was significant, $F(4, 61) = 2.68$, $p = .041$, $R^2 = .16$, with attention to fearful faces as the only significant predictor of the D scores, $\beta = -.48$, $p = .004$. Finally, to test whether the attentional bias to fearful faces is equally strongly associated with disorganization and resistance, a partial correlation between fear bias scores and D scores was calculated while controlling for resistance scores (averaged across the two reunions during the SSP, with higher scores on a 7-point scale indicating higher resistance), and vice versa (i.e., correlating fear bias and resistance scores while controlling for D scores). This analysis showed that the negative association between fear bias and attachment disorganization ($r = -.35$, $p = .006$, i.e., higher D scores associated with a smaller attentional bias to fearful faces; see Figure 3) remained significant even while controlling for resistance scores ($r = -.26$, $p = .046$), whereas the correlation between fear bias and resistance ($r = -.28$, $p = .03$) became nonsignificant when the D scores were taken into account ($r = -.14$, $p = .28$), indicating that the decreased attentional bias to fearful faces was more strongly associated with attachment disorganization than resistance. A one-sample t test with the subgroup classified as disorganized further indicated an absence of fear bias in these infants, as the magnitude of their fear

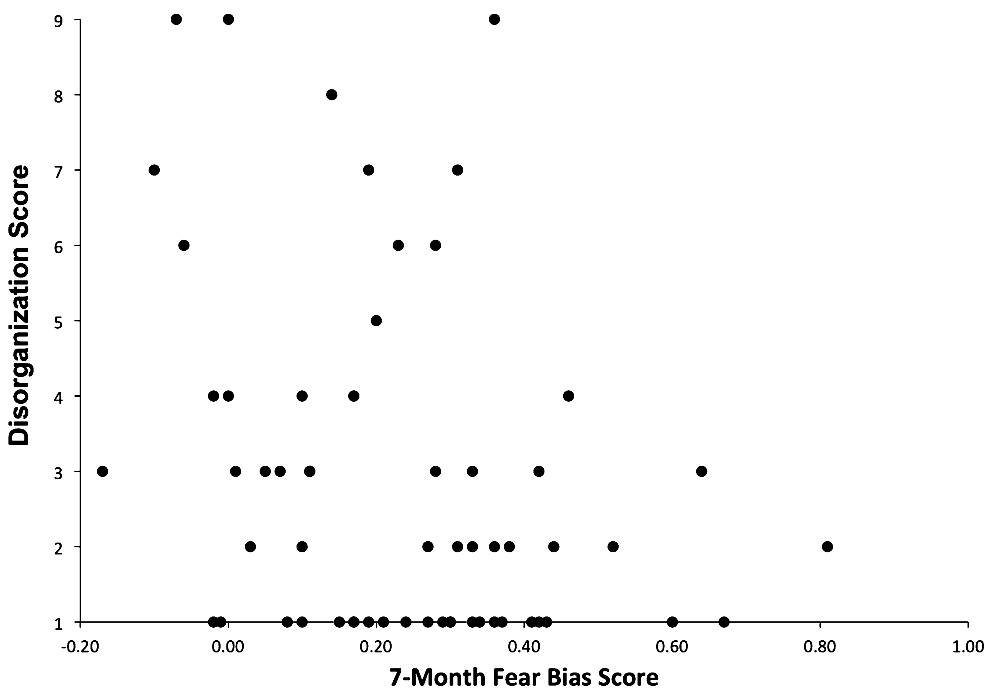

Figure 3. The correlation ($r = -.35$, $p = .006$) between attachment disorganization and attentional bias to fearful faces at 7 months of age.

bias (M = .09) did not differ from zero, $t(10) = 1.59$, $p = .14$.

Discussion

In the present study, attention to facial expressions at 7 months of age predicted attachment security at 14 months of age: As compared to securely attached infants, insecurely attached infants showed a smaller attentional bias to fearful faces and a larger bias to neutral faces (although the latter effect appeared to be restricted to the small subgroup of avoidantly attached infants). Further exploratory analyses showed that the smaller attentional bias to fearful faces was most clearly associated with increasing signs of attachment disorganization.

Together, these findings are consistent with the hypothesis that variations in attention to negative emotions, and possibly to cues signaling threat in particular, are associated with attachment formation and may provide a useful marker of infants' attachment status prior to the standard observational assessment of attachment after the first birthday. Regarding the potential mechanisms mediating this association, the results could be seen as consistent with the model of Dykas and Cassidy (2011) proposing that an acquired tendency to divert attention away from threat-related cues and suppress emotional overarousal is a marker of insecure attachment. It is unclear, however, whether the seemingly similar pattern of results implies that the same mechanisms (i.e., suppression of arousal) are functional in infants and adults, or whether other factors such as lower or even blunted sensitivity to the emotional signal conveyed by fearful faces (and potentially other expressions of negative valence) in insecurely attached infants are more likely responsible for the observed effects. Interestingly, our supplementary analyses showed that variations in attention bias at 5 months were not associated with later attachment status and that an increase in the attentional bias to fearful expressions from 5 to 7 months was more pronounced in securely attached infants than insecure and disorganized infants (see Data S1). Although tentative, these results raise the possibility that individual variations in the developmental emergence of an attentional bias to faces expressing negative emotions (such as fearful expressions) between 5 and 7 months of age are particularly informative for understanding attachment formation (cf. Leppänen & Nelson, 2012).

Whereas a robust attentional bias to fearful faces was related to secure attachment and low attachment disorganization scores, higher levels of attachment disorganization were characterized by a diminished attentional bias to fearful faces in this study. The absence of the age-typical (e.g., Forssman et al., 2014; Peltola et al., 2008) attentional bias to fearful expressions in disorganized infants is highly interesting in light of data on the associations between attachment disorganization in infancy and later emotional and behavioral outcomes. Meta-analytic data indicate that while attachment disorganization shows only a negligible association with later internalizing symptoms (e.g., anxiety and depression; Groh et al., 2012), disorganized attachment is associated with later externalizing symptoms (e.g., aggressive and oppositional behavior; see Fearon et al., 2010). Facets of externalizing symptomatology such as callous-unemotional traits and antisocial behavior have been linked with specific impairments in sensitivity to other individuals' fearfulness rather than a generalized impairment in processing emotion expressions (Dadds et al., 2006; Marsh & Blair, 2008), and conversely, higher sensitivity to detect fearful cues is related to higher prosocial tendencies (Marsh, Kozak, & Ambady, 2007). It is intriguing to hypothesize that a lower sensitivity to the distress signals of others could provide a remarkably early-emerging endophenotypic marker relating attachment disorganization in infancy to later externalizing problems.

What is not fully revealed by the current results is the causal direction of associations, that is, whether variation in attentional biases to emotional stimuli is an inherent characteristic of the infant imposing independent effects on the emergence of attachment security, or whether attentional biases are shaped by the caregiving environment at 7 months of age and could be more readily interpreted as an early correlate of the attachment relationship rather than an independent determinant. Partly related to this question, Tharner et al. (2011) showed that attachment disorganization at 14 months was predicted by anatomical variation in 6-week-old infants' subcortical structures (i.e., the diameter of the gangliothalamic ovoid). As this structure is linked to the limbic areas subserving the processing of emotional information, such findings indicate potentially inherent neurobiological factors that may predispose infants to be differentially sensitive to emotional stimuli. Although such findings and the absence of associations between attentional biases and maternal sensitivity in the present study could be seen to favor the independent role of attentiveness to emotional signals on determining later attachment, we hesitate to draw such strong conclusions given potential limitations in our assays of maternal sensitivity. For example, the association between attachment security and sensitivity was not found in this study although it has been extensively documented meta-analytically (De Wolff & van IJzendoorn, 1997) and with behavior genetic (Fearon et al., 2006) and intervention (Bakermans-Kranenburg, van IJzendoorn, & Juffer, 2003) designs. Multiple factors have likely contributed to this null effect, including modest sample size, limited variance in maternal sensitivity scores, and the relatively unconstrained free-play observation, as it has been proposed that sensitivity to infant distress signals in stress-inducing contexts provides a better estimate of the influence of sensitivity on attachment than nondistressing assessments (Leerkes, 2011). Furthermore, apart from the global assessment of caregiving sensitivity used in the present study, the influence of more focal interactive behaviors on infants' processing of emotional signals has not been investigated. Specific facets of interactive behavior such as atypical parental mirroring of infant affect (DeOliveira, Bailey, Moran, & Pederson, 2004; Gergely, 2004) as well as frightened and frightening emotion displays toward the infant (Main & Hesse, 1990; Schuengel, Bakermans-Kranenburg, & van IJzendoorn, 1999) have been related to the development of attachment disorganization, and suggested to be partly mediated by infants' ability to recognize their own and others' emotions (DeOliveira et al., 2004). A potentially fruitful agenda for future studies is to investigate in more detail how such focal aspects of parenting are associated with infants' perceptual processing of emotion signals.

In a wider context, the present results showing that infants' attentional bias to fearful faces is associated with an apparently positive developmental outcome (secure attachment) are of interest as previous studies have linked attentional biases to threat-related stimuli (such as angry and fearful faces) with exposure to stress (Forssman et al., 2014) and proneness to anxiety (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). First, the present results suggest that the absence of age-typical attention biases, not only heightened levels of this bias, may be informative as a marker of early childhood development. Second, the present results call for caution in interpreting infants' attentional biases to threat-related stimuli as "risk factors," even though this interpretation appears plausible in light of several studies in adults linking the bias with anxiety (Bar-Haim et al., 2007). In particular, the present results raise the possibility that the presence of threat-related attentional biases in infancy is an important and potentially transient (see Peltola et al., 2013) aspect of typical socioemotional development. The results also call for further work to examine infants' attentional biases to fearful faces and other threat-related stimuli not only in the context of ordinary variations in parental depression and stress symptoms (Forssman et al., 2014) but also under more severe conditions.

Limitations

In the future, the links between attachment and social information processing need to be investigated in ethnically and socioeconomically more diverse samples to assess the generalizability of the effects (the present study being restricted to a Caucasian, middle-class sample). Likewise, although the association between attentional biases and later attachment security was not influenced by gender in this study, a replication of these findings in a larger sample without boys being overrepresented in the insecure category is needed. A larger sample will also be important to enable more reliable analyses of the patterns of attentional bias within each insecure attachment subgroup. Finally, it is important to stress that the present results do not unequivocally permit interpreting the observed attention effects to be specific to fearful expressions instead of a more general bias to threat-related or negatively valenced emotion expressions, and a further investigation of the scope of the observed effects will be important. Considering the idea that attachment representations impose a generalized influence on the deployment of processing resources toward potential threats in the environment (e.g., Dewitte & De Houwer, 2008; Dykas & Cassidy, 2011), it could be expected that the observed effects replicate with other threat-related stimuli such as expressions of anger directed toward the infant. We believe, however, that fearful expressions are a particularly suitable class of stimuli to start investigating the links between attachment and processing of emotional stimuli in infancy as there is currently no evidence for a similarly robust attentional bias to other negatively valenced facial expressions, such as anger or sadness in infants in the same age range (e.g., Grossmann et al., 2007; Soken & Pick, 1999).

Conclusions

Notwithstanding the limitations of the present study, the investigation of infants' attention to facial expressions as a precursor of attachment represents a novel approach to the study of early attachment relationships and adheres to calls to integrate experimental paradigms and measurement tools from other domains of developmental research to the study of socioemotional development in infancy (Olson & Dweck, 2009). The main finding was a smaller attentional bias to fearful faces in insecure versus secure infants, and this effect was most clearly associated with attachment disorganization. While we consider this as an initial finding in need of a replication in a larger sample and with a broader range of negative emotional expressions, it is consistent with proposed models of attachment and social information processing (Dykas & Cassidy, 2011) and suggests altered sensitivity to threat-related cues in infancy as a testable trait linking attachment disorganization to later behavioral outcomes.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

Data S1. Analyses of the 5-Month Data