Infant and Maternal Responses to Emotional Facial Expressions: A Longitudinal Study

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A Thesis presented to the Graduate Faculty
of the University of Virginia in Candidacy for the Degree of
Master of Arts

Department of Psychology

University of Virginia
June 2023

Readers:
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Abstract

The current longitudinal study (N = 107) examined mothers' facial emotion recognition using reaction time and their infants' affect-based attention at 5, 7, and 14 months of age using eyetracking. Our results, examining maternal and infant responses to angry, fearful and happy facial expressions, show that only maternal responses to angry facial expressions were robustly and positively linked across time points, indexing a consistent trait-like response to social threat among mothers. However, neither maternal responses to happy or fearful facial expressions nor infant responses to all three facial emotions show such consistency, pointing to the changeable nature of facial emotion processing, especially among infants. In general, infants' attention toward negative emotions (i.e., angry and fear) at earlier timepoints was linked to their affect-biased attention for these emotions at 14 months but showed greater dynamic change across time. Moreover, our results provide limited evidence for developmental continuity in processing negative emotions and for the bidirectional interplay of infant affect-biased attention and maternal facial emotion recognition. This pattern of findings suggests that infants' affect-biased attention to facial expressions of emotion are characterized by dynamic changes.

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Processing different facial emotions is a key ability that is honed in early social development. The ability to discern and direct attention to different emotions is present early in infancy (Nelson, 1987) and likely serves as a foundation for later developing affective abilities (e.g., emotion understanding; Castro, Cheng, Halberstadt, & Grühn, 2015). These affective abilities contribute to skills that extend beyond the emotional domain, such as improved social competence (Denham et al., 2002), greater academic success (Izard et al., 2001), and higher peer acceptance (Lindsey, 2016). Numerous studies have examined potential underlying processes that give rise to infants' emerging affective abilities (Fu et al., 2020, Miguel et al., 2019, Morales, Fu, & Pérez-Edgar, 2016). However, to date, little is known about how factors outside the infant, such as their primary caregiver's emotion recognition abilities contribute to infants' emerging emotion processing capacities. The present study examined how characteristics of proximal systems surrounding the child, particularly mother's own emotion recognition skills, may shape how facial emotion processing develop in the infant.

During the first year of life, infants develop the capacity to discriminate among different facial emotions and also begin to differentiate emotional from neutral facial expressions (for review, see Grossmann, 2015). For example, in a visual-paired comparison task presenting emotional faces side-by-side with neutral faces, 7-month-old infants differentiate between fearful, angry and happy facial expressions as indexed by increased looking to fearful than happy and angry expressions (see Krol, Monakhov, Lai & Grossmann, 2015). When infants' emotion discrimination is examined by measuring looking time to emotional facial expression presented in isolation, 7-month-old infants showed longer looking times towards fearful faces compared to happy faces, whereas 5-month-old infants did not show this attentional pattern, suggesting that this ability to discriminate between these emotions emerges between 5 to 7 months of age (Peltola et al., 2009). As to the ability to attend to emotional faces and discern the different emotions develops, looking behavior toward the different emotions seem to vary across infancy. Infants showed longer looking times (looking preference) towards positive emotions at 4 months old (LaBarbera et al, 1976), then begin shift to their preferential looking towards fearful faces around 5 to 7 months old (Safar & Moulson, 2017; although see Safar & Moulson (2020) for evidence that a preference to fearful over happy faces emerges even earlier). However, the longitudinal evidence of this looking bias towards fearful faces seems to be mixed, where some researchers found that this fear bias persists among 36-month-old children (Leppänen et al, 2018), whereas another study found that preferential looking toward fearful faces begins to diminish after 7 months of age (Peltola et al., 2018). In a longitudinal study that followed infants from 5 months to 36 months, infants completed an eye-tracking paradigm that first fixated their gaze in the center and then was shown a visual stimulus (i.e., non-face pattern, happy, fear, or angry faces) in their visual periphery (Leppänen et al, 2018). This study found that infants at a group level showed longer looking times toward fearful faces as compared to happy faces when the infant was 7, 12, and 36 months of age, aligned with the notion that this looking bias towards fearful faces persists into early childhood. However, attentional bias towards fearful and angry faces during infancy was not associated to threat-biased attention towards these facial emotions at 3 years old suggesting greater change on the individual level (Xie et al., 2021). For a different longitudinal study that also measured infants' looking times towards facial emotions and non-face patterns through a similar eye-tracking paradigm, Peltola and colleagues (2018) found that infants displayed a large reduction in their dwell times toward fearful faces from 7 to 24 months of age. Although infants' ability to discriminate across emotions seems to be an early developing capacity, the developmental trajectory of attention allocation towards different emotions seems to vary across infancy. In addition, each of these aforementioned studies highlight infants' affect-biased attention toward the different emotional expressions (Todd et al., 2012), such that the affective salience of a facial emotion may elicit preferential attentional biases. Ongoing longitudinal studies (Pérez-Edgar et al., 2021) and the current study aim to further explore the variability in the developmental trajectory of affect-biased attention across infancy. Considering factors within and outside the infant can provide insight to the variability in infants' emotion processing towards different facial emotions over neutral faces.

Previous research has explored how psychological processes within the developing child may give rise to individual differences in emotion processing abilities. For instance, internal factors (e.g., temperament) have implications on how infants quickly and vigilantly direct their attention to emotional faces (Fu et al., 2019). Such individual factors play a role in the developmental trajectories of emerging attention mechanisms (Morales, Fu, & Pérez-Edgar, 2016). For example, 9- to 12-month-old infants with high negative affect and low attentional control demonstrated difficulty in disengaging their attention from fearful faces as compared to infants with higher attentional control (Conejero & Rueda, 2018). Although these aforementioned studies provide valuable insight as to how individual factors can shape the emerging psychological mechanisms related to processing facial emotions, there is a limited number of studies that examine how external factors may be linked to infants' emotion processing.

Examining the potential relation between parental and infant emotional processing can shed light on whether early developing emotion processing may be linked to emotional abilities of the social beings that care for the infant. The family, and in particular the primary caregivers, within the infant's microsystem (Morris & Bronfenbrenner, 2006), may play an instrumental role in infant's emotional development. For example, when 9-month-old infants were tasked with an intermodal matching paradigm that assessed their ability to match vocal modalities with an emotive face, infants' ability to accurately match happy vocalizations with the corresponding happy face was significantly related to their family's emotional expressiveness (Ogren et al., 2018). In addition, primary caregivers' own emotional expressivity has also been shown to relate to children's emotional development among toddlers such that primary caregivers who were more emotionally expressive had toddlers with higher emotion understanding (Ogren & Johnson, 2021). These studies point to the importance of the familial and primary caregiving context that surround the child in emotion development. However, one important limitation of previously reviewed work is the reliance on self-report questionnaire measures to index the emotional context of the familial microsystem. Although environmental factors surrounding the child (e.g., emotional qualities of the primary caregiver) may contribute to the development of children's emotion processing, further examining the relationship between mother and infant through longitudinal measures and beyond self-report questionnaire measures yields a unique perspective into how emotion processing unfolds given the proximal dynamic between infant and mother and their shared genetic influences.

When considering the relation between mother and infant emotion processing it is important to acknowledge that associations may be due to both genetic and environmental factors. Although the heritability of emotion processing between mother and child (i.e., any similarities in emotion processing being due to shared genetics) remains an open question, prior work has indirectly explored how mothers' own emotional traits may be linked to how their child process faces and emotions. For instance, mothers who reported higher levels of anxiety traits had infants who showed heightened neural responses to happy and fearful faces (Bowman et al., 2022). In another study, children who were characterized with high levels of persistent irritability and had a mother with a preexisting history of depression showed increased neural reactivity towards appetitive (e.g., happy faces) and aversive emotional stimuli (e.g., sad or angry people; Kessel, Kujawa, Dougherty & Hajcak, 2017). Both aforementioned studies highlight how children's processing of emotions and emotional stimuli can be associated with their mothers' emotional traits, but these studies do not directly explore the longitudinal and transactional associations for emotion processing between mother and child. The current study aimed to answer the question of how primary caregivers, particularly mothers, own emotion processing abilities may relate to infants' emotion processing through the use of behavioral measures that capture emotion processing in both mothers and infants across time.

Studies examining how parent's emotion abilities relate to infants' developing emotion processing through behavioral measures are limited, further emphasizing the need to understand the potential relationship of these concurrently evolving emotion processing mechanisms between infant and mother. Prior work looking at this relationship between parent and child emotional skills focused on older children. For example, one study explored the relationship of emotion recognition skills between parent and child (i.e., 8- to 11-years-old), where parent-child dyads were asked to identify the emotion of their partner when watching video clips of their recorded discussion on a contentious topic (Castro et al., 2015). Castro and colleagues found that parent's emotion recognition ability was positively correlated with their child's emotion recognition skills and attributed this to a transactional process between child emoting and parental response, but this was not directly tested. The *transactional model* posits that development is a product of the dynamic, bidirectional interactions between the child and their environment (Sameroff, 2009). The current study takes this model into consideration to examine the potential bidirectional nature of maternal and infant emotion processing mechanisms developing together over time. Furthermore, the longitudinal nature of the present study allows us to assess whether infant's own emotion processing to direct attention to different emotions has any relation to maternal emotion recognition and vice versa. The current study builds on prior work done with older children and addresses the gap of examining the potential relationship between parent and child emotion processing earlier in development among infants and their mothers.

Current Study

The current study examines how mothers' emotion recognition may be linked to their infants' affect-biased attention across time. Our analyses examining infants' attention in response to the three different emotions (i.e., anger, fear and happy faces) were largely exploratory. It is important to note that previous work indexes dynamic developmental changes in looking behavior towards these emotions across infancy (LaBarbera et al., 1976; Safar & Moulson, 2017; Leppänen et al., 2018; Peltola et al., 2018). Dynamic change can be viewed as discontinuity in the associations between preferential looking to each of the emotional expressions (happy, angry, and fearful) across time. Considering prior work that found facial emotion perception and recognition abilities are stable and in place in adulthood (Olderbak et al., 2018; Rodger et al., 2015; Thomas et al., 2007), but limited research directly examining maternal emotion recognition across time, we predicted consistent stability in the adult maternal emotion recognition across multiple timepoints. Next, we hypothesize a relation between maternal emotion recognition and infants' affect-biased attention based on a previous study finding a link between parents' emotion recognition skills and their children's emotion recognition abilities (Castro et al., 2014), and that this relation will be bidirectional in nature over time according to the transactional model suggesting development unfolds through continuous dynamic interactions between the child and their environment (Sameroff, 2009). The present study is among the first to examine how emotion processing relates between infant and mother across time using behavioral measures.

Method

Participants

Infant and mother dyads were drawn from a larger longitudinal study (*N* = 121) that examines infants' social and emotional development across infancy into toddlerhood. The present study includes three timepoints when the infants were: (a) 5 months old, (b) 7 months old, and (c) 14 months old. The current sample excluded 14 infant-mother dyads that had missing behavioral data at the first timepoint resulting in a sample size of 107 infant-mother dyads for the present analyses. Participants were recruited through a local hospital in a Mid-Atlantic college town. The sample is representative of the demographics in the surrounding area, with majority of the participants being Caucasian (84%), with a bachelor's degree or higher (62%), and from medium-income households (23% in $30,001 to $60,000; see Table 1 for sample demographic characteristics). All infants (57% male, 43% female) were born at term with normal birthweight (>2,500g) and no visual or hearing impairments. At the start of the study, mothers were 31.25 years old on average (*SD* = 5.36). Mothers were compensated with a $50 gift card for each completed visit. The attrition rate between Waves 1 and 2 was low (20%), but between Waves 2 and 3 had a notable attrition rate (58%) because of halting data collection due to the COVID-19 pandemic. The *Data Analysis* sections outlines in further detail how missing data were addressed and accounted for.

Procedure

For each visit, infants and mothers completed a battery of measures (i.e., behavioral, neural, and biological) to capture infants' socio-emotional development across the first two years of life. The visit at each timepoint took approximately 90 minutes in total, but the behavioral tasks used in the present study took approximately 20 minutes. The current study focuses on the behavioral measures that captures infants' and mothers' detection of emotion across each timepoint. In particular, both behavioral tasks aimed to measure the infants' and mothers' responses to emotional faces compared to neutral faces. All procedures were approved by the University of Virginia Institutional Review Board for Health Sciences (Protocol #20381).

Measures

Infant Eye Tracking Paradigm. Infants sat on their mother's lap and were about 60 cm away from the presentation screen. A Tobii x120 eye tracker was at the bottom of the computer monitor to record the infants' looking behavior. At the start of the task, infants went through the 5-point infant-friendly calibration system, where an animation was shown at five locations of the computer screen (all four corners and one in the center). The animation was presented with a tone to help to capture the infant's attention. To pass the calibration phase, the infant had to fixate their gaze on all the designated locations of the rattle on the screen. Infants who did not pass the initial calibration test went through the process again until successfully fixating on all designated locations. Infants had to successfully pass the calibration in order to proceed with the paradigm. This calibration process followed the same procedure as other eye-tracking publications (Grossmann, Missana, & Krol, 2018; Krol et al., 2015) and additional detail on the infant calibration process can be found in the Tobii user manual (available for free access at www.tobii.com).

There was a total of 9 trials with 3 trials for each emotion (i.e., angry, fear, happy) and there were 3 different young adult actresses used in the paradigm and these came from a published and validated stimulus set (FACES Collection; Ebner, Riediger & Lindenberger, 2010). The order of the stimuli presentation was pseudorandomized, such that no same emotion or actress were repeated twice in a row. In a single trial, the infant was presented with an emotive (i.e., happy, angry or fear) and neutral face side-by-side. The placement of the emotive face (left or right) was counterbalanced across the trials. Before the experimental trials with the faces, a 3-second attention getter was presented in the center of the screen. The experimental trials were presented for 15 seconds. The overall session took about 3 minutes. The area of interest for faces were created in Tobii Studio, and the individual fixation was defined to last between 50 to 600 ms. Missingness within an individual trial due to eyeblinks or head movement was handled through Tobii Studio's interpolation feature that creates a linear interpolation between neighboring valid data points (refer to Tobii Studio Manual for further detail at www.tobii.com). To index the different attention components (Armstrong & Olantunji, 2012), a series of eye tracking metrics were computed including the latency of infants' first fixation (indexing orienting to the emotional expression), total looking duration (indexing total fixation on an emotional expression), and preferential looking towards the facial emotion (indexing preferences to an emotion over a neutral expression). The latency of infants' first fixation is the time it took to orient to the emotional face. Total looking duration accounts for the total amount in seconds that the infant looked at the facial emotion in each trial. Preferential looking is the proportion of the total duration that the infant looked at the facial emotion divided by the total looking time towards both the emotional and neutral faces in each trial.

Dynamic Emotional Expression Recognition Task. Mothers completed the dynamic emotional expression recognition task (DEER-T) that measured their emotion recognition for various emotions. Mothers watched photographic stimuli of White actors dynamically morphing from neutral into the full emotion over the course of 3000 milliseconds. Photographs from the NimStim Face Stimulus Set were used in this task (Tottenham et al., 2009). Mothers were instructed to quickly and accurately press one of the six labelled response keys corresponding to the particular emotions (i.e., anger, happiness, fear, sadness, disgust, and neutrality). There were 12 trials per emotion for a total of 72 trials. For the current study, we focus on maternal emotion recognition for angry, happy, and fearful faces to align with the same emotions used in the infant emotion discrimination task. Mothers' reaction time for the correct answers was used for the present analyses to capture the time it took for mother to correctly recognize the target emotion.

Analytic Plan

All preliminary data analyses were executed in R. Preliminary analyses include calculating descriptive statistics on the sample, variables of interests, and assessing the data quality of eye-tracking data. Given that preferential looking scores require the infant to look at both the emotional and neutral face in a given trial, multiple imputation by chained equation package (MICE; van Buuren S, Groothuis-Oudshoorn K, 2011) was used to impute preferential looking scores for infants who had missing looking trials to the neutral face in a specific emotion trial type. Predictive mean matching imputes each missing entry based on the complete cases and estimates the value that is closest to the predicted value of the missing entry.

Cross-lagged panel analyses were conducted in R using the Lavaan package (Rosseel, 2012) to examine the potential stability and reciprocal relationships between infant affect-biased attention and maternal emotion recognition across time. To assess the stability of the affect-biased attention for the infant or emotion recognition for the mother, we examined the beta coefficient for a variable of interest regressed on the same variable within a subsequent time point (e.g., infant affect-biased attention at Time 1 regressed on infant affect-biased attention at Time 2). The stability estimates for mothers were included in each separate model to assess whether maternal emotion recognition had any link to each of the different infant attention measures. We also looked at paths between infant and mother measures within the same timepoint to see if these variables of interest are related at a single concurrent timepoint. We evaluated the estimated cross-lagged paths between the infant and maternal variables of interests across the timepoints to understand the potential bidirectional, reciprocal relationships of infant affect-biased attention and maternal emotion recognition across time. Bidirectionality of maternal emotion recognition and infant affect-biased attention would be evident in the model as significant cross-lagged paths that connect emotion processing from infant to mother and vice versa across time (e.g., infant preferential looking towards fearful faces at Time 1 related to maternal fear recognition at Time 2, or maternal happy recognition at Time 2 related to infant total looking duration toward happy faces at Time 3). A cross-lagged panel model was tested for each emotion (i.e., angry, fear & happy). Data for infant latency to the emotion faces, total looking duration, and maternal emotion recognition reaction times were positively skewed, which we then used the Box-Cox method to correct the positive skewness and normalize the distribution (Box & Cox, 1964). The missing data resulting from halting data collection due to the COVID-19 pandemic was classified as missing completely at random (MCAR; Rubin, 1976). With data missing completely at random, we estimated each cross-lagged panel model with full information maximum likelihood estimation (FIML) to account for the attrition across the waves.

Results

Preliminary Analysis

Descriptive Statistics. Descriptive statistics for each variable of interest across all three timepoints are summarized in Table 2. Bivariate correlations among the variables in each respective cross-lagged panel are shown in Table 3. Model fit indices for each model is summarized in Table 4, indicating that each cross-lagged panel model demonstrated excellent fit. Each figure (Figures 1-9) illustrating the cross-lagged panel models for each emotion includes the standardized regression weights for the model paths, and the unstandardized regressions weights are summarized in Table 5 for cross-lagged models with infant looking latency to the facial emotion and Table 6 for cross-lagged models with infant total looking duration to the facial emotion and Table 7 for cross-lagged models with infant preferential looking to the facial emotion.

Infant Eye-Tracking Data Quality Check. Given that infant eye-tracking data may be prone to data quality issues (Wass, Forssman & Leppanen, 2014), additional descriptive statistics were calculated to assess the infant eye-tracking data quality in the present study. No infants were excluded for unsatisfactory calibration given that all infants had to pass the calibration portion of the paradigm in order to proceed with the eye-tracking experiment. The criteria for a valid trial for preferential looking was to have at least one fixation to both the neutral and emotional face in any given trial. A valid trial for each emotion type would comprise of a fixation to the emotional face. Table 8 provides the average number of valid trials for each participant and the total proportion of valid trials across the sample in each wave. Each infant participant has the range of 0 to 3 valid trials for each emotion trial type, and the average valid trials was calculated for each trial type across all participants. For the percentage of the total valid trials, this percentage accounts for the total number of valid trials across all the participants, which equates to the sum of the total number of valid trials across the participants divided by total possible trials for a trial type across all participants in that timepoint.

Cross-Lagged Panel Models for Anger, Fear, and Happy Emotions

Infant Latency to Angry Face and Maternal Anger Recognition. We found evidence in support of stability in maternal emotion recognition towards anger across time (refer to Figure 1). Aligned with the general dynamic change of infants' affect-biased attention, we did not find any significant paths in infant latency to angry faces across the first year of infancy. We also did not find any significant paths between infant latency to initial fixation and maternal emotion recognition for angry faces within the same timepoint. In partial support for our hypothesis anticipating a bidirectional relationship between infant affect-biased attention and maternal emotion recognition, we did find one significant cross-lagged path from mothers' angry recognition at Time 2 linked to the latency of infant first fixating to the angry face (β = .29, p = .037).

Infant Total Looking Duration to Angry Face and Maternal Anger Recognition. When updating the cross-lagged model to include infant total duration toward the angry face, we found the same pattern in support of stability in maternal emotion recognition toward angry faces. For infants, we found that their total duration toward the angry face at 5 months (β = .33, p = .014) and 7 months (β = .46, p < .001) were both significantly related to their total duration toward angry faces at 14 months (refer to Figure 2). In addition, we found a significant relation between maternal anger recognition and infant duration toward angry faces when the infant was 5 months old (β = .27, p = .008).

Infant Preferential Looking to Angry Face and Maternal Angry Recognition. We continue to find evidence in support of the stability in maternal emotion recognition toward angry faces when the model was updated with infant preferential looking toward angry faces (see Figure 3). However, the paths for infants' preferential looking toward angry faces across each timepoint are no longer significant. We continue to find a significant relation between maternal anger recognition and infant preferential looking toward angry faces when the infant was 5 months old (β= .24, p = .008).

Infant Latency to Fearful Face and Maternal Fear Recognition. For fear (Figure 4), we found partial support for stability in mother's emotion recognition ability towards fearful faces. Interestingly, the path between maternal fear recognition between Time 2 and 3 was non-significant (β = .13, p = .53), while the paths from Time 1 to 2 (β = .68, p <.001) and Time 1 to 3 (β = .52, p = .002) were significant. We did find that infant's latency to fearful faces at an earlier wave were linked to their latency to fearful faces at a later wave, where the path between Time 1 and 3 was significant (β = -.36, p = .026). We did not find any significant paths between infant and maternal emotion recognition skills for fearful faces within the same timepoint. We also did not find any significantly cross-lagged paths between infant and maternal emotion recognition for fearful faces. Unique to the fear model, we were unable to drop the path from maternal fear recognition at Time 1 to infants' latency to initial fear face fixation (β = .08, p = .75) without worsening the model fit. Anger and happy cross-lagged panel models did not have this path, but we had to keep this path in place for the fear model to maintain acceptable fit.

Infant Total Looking Duration to Fearful Face and Maternal Fear Recognition. We continue to find the same pattern for maternal fear recognition when we updated the cross-lagged model to include infant total looking duration toward fearful faces. We found a positive relation between infant total duration toward fearful faces at 5 months old and at 14 months old (β = .29, p = .044, refer to Figure 5). We also found a significant relation between infant total duration toward fearful faces and maternal fear recognition when the infant was 7 months old (β = .33, p = .008).

Infant Preferential Looking to Fearful Face and Maternal Fear Recognition. Maternal fear recognition continues to show the same significant path pattern when we updated the cross-lagged model to include preferential looking toward fearful faces (Figure 6). We did not find any significant paths across the timepoints for infant preferential looking toward fearful faces. We continue to find a significant relation between infant preferential looking toward fearful faces and maternal fear recognition when the infant was 7 months old (β = .27, p = .045). We did find one significant cross-lagged path, such that infant preferential looking toward fearful faces at 5 months was significantly related to maternal fear recognition when the infant was 14 months old (β = -.25, p = .029).

Infant Latency to Happy Face and Maternal Happy Recognition. We found evidence suggesting significant relations in maternal emotion recognition for happy faces across time (refer to Figure 7). It is important to note how the beta coefficient switches direction across the timepoints, such that the path from Wave 1 to 2 had a positive beta coefficient (β = .76, p < .001), whereas the paths between Time 1 to 3 (β = -.41, p = .005), and Time 2 to 3 (β = -.42, p = .004) have negative beta coefficients. We did not find any evidence in support of infants' stability of attention to happy faces across the timepoints, aligned with our hypothesis anticipating dynamic change for infants. The paths between infant and maternal emotion recognition skills for happy faces within the same timepoints were all nonsignificant. Similar to the fear cross-lagged panel model, we did not find any support of the bidirectional relationship between infant and maternal emotion recognition for happy faces.

Infant Total Looking Duration to Happy Face and Maternal Happy Recognition. When we included infant total duration toward happy faces in the cross-lagged model, we continue to find the same pattern in maternal happy recognition as described above. Interestingly, we found a significant relation between maternal happy recognition at Time 1 and infant total duration to happy faces at Time 3 (β = .42, p = .026, refer to Figure 8).

Infant Preferential Looking to Happy Face and Maternal Happy Recognition. The cross-lagged model with infant preferential looking towards happy faces looks identical to the cross-lagged model with infant total looking duration to the happy face (Figure 9). With the infant preferential looking model, we were able to drop the path from infant preferential looking at 5 months to their preferential looking at 14 months while achieving acceptable modeling fit.

Robustness Analyses

Given the high attrition rate by the third timepoint and the potential nonnormality of the data, we conducted robust structural equation modeling analyses for each cross-lagged panel model to test the robustness of our results (Yuan & Zhang, 2011). We used the *rsem* package in R to execute this robustness check. This robust method package has two stages: (1) obtaining the M-estimates for the saturated mean vector and covariance matrix for all variables; and (2) using these M-estimates to estimate model parameters and generate all the corresponding test statistics and standard errors. Tables 5, 6, and 7 summarize all the unstandardized beta coefficients and their corresponding standard error for each cross-lagged panel model. From conducting these analyses, the unstandardized beta coefficient estimates from our main analyses (Tables 5, 6 & 7) identically match the unstandardized beta coefficients in this robustness check (Tables 9, 10 & 11). There is slight variation in the standard errors between the main analyses and robustness check. Overall, this robustness check supports the findings we found from our original analyses.

Discussion

The present study examined how emotion processing in the infant-mother dyad relate and unfold over time using behavioral measures for both infant and mother. Only maternal emotion recognition for angry faces at earlier time points was consistently positively associated to their anger recognition in subsequent waves, partially supporting our hypothesis predicting stability in maternal emotion processing. Aligned with our hypothesis expecting dynamic change in infants' affect-biased attention across the first year, most of infants' affect-biased attention at earlier time points were not linked to affect-biased attention at later time points. Our hypothesis predicting a relation between infant's affect-biased attention and mother's emotion recognition within the same timepoint was supported with significant relations for angry faces at Time 1 and fearful faces at Time 2. For our hypothesis expecting a bidirectional relationship between infant's affect-biased attention and mother's emotion recognition skills over time, we did find evidence for: (a) mother's recognition of angry faces at Time 2 being significantly linked to the latency for infant's initial fixation for angry faces at Time 3; (b) mother's recognition of happy faces at Time 1 being significantly linked to infant's total looking duration and preferential looking toward happy faces at Time 3; and (c) infant's preferential looking toward fearful faces at Time 1 being significantly linked to maternal fear recognition at Time 3.

In general, mothers' ability to recognize angry facial emotions seems to be stable across time. It is important to note how the cross-lagged panel models for the negative emotions (i.e., angry and fear) had significantly positive paths for the mothers, whereas the positive emotion (i.e., happy) shifts from positive to negative coefficients across the timepoints. A possible explanation for this finding could be a practice effect whereby mothers become better at recognizing the happy emotion in the emotion recognition task because it is the only positive emotion among the six target facial expressions (i.e., anger, happiness, fear, sadness, disgust, and neutrality). Alternatively, the facial cues depicting anger and fear might be more difficult to discern earlier in the dynamic videos of the actors' face changing from neutral to the full emotion.

For infants, we generally found support that their affect-biased attention toward negative emotions (i.e., angry and fear) at earlier timepoints are linked to their attentional patterns for these emotions at 14 months. We found that infants' attention to fearful faces at 5 months was negatively correlated with their attention to fearful faces at 14 months, such that the latency to fixate on the fearful face becomes quicker by 14 months. We also found that infants' total duration of looking towards fearful and angry faces at 5 months was positively linked to their total duration of looking towards fearful and angry at 14 months respectively. In addition, we found that infants' total duration of looking towards angry faces at 7 months was linked to their total duration of looking towards angry faces at 14 months. When examining how infants' preferential looking unfolds over time, we also obtained a pattern in support of the notion of greater instability as none of the pathways between timepoints were significant. Moreover, we did not find a significant association between infants' attention towards fearful faces at 5 months of age (Time 1) relating to their attention to fearful faces at 7 months of age (Time 2), which is the age range that prior work had identified as the period when preferential looking to fear emerges (Leppänen et al, 2018, Safar & Moulson, 2017, Vaish et al., 2008). Considering evidence suggesting developmental changes between 5 and 7 months (Peltola et al. 2009) in infants' fear processing, the absence of an association between attention to fear at 5 and 7 months might not be surprising. Given that we generally found greater instability in infants' affect-biased attention to facial emotions with limited developmental continuity towards negative emotions, it remains a concern whether this instability in infant responses is attributable to discontinuity in emotion processing or may be due to the reliability issues associated with infant measures. Our robustness analyses yielding the same coefficient estimates as our cross-lagged models seems may offer further evidence in support of the discontinuity in emotion processing for infants.

We anticipated a relation between infant affect-biased attention and mother emotion recognition in the same timepoint based on a previous study that found a significant relationship between parent and child emotion recognition skills on a task asking both recipients to identify their partner's emotions from recorded video clips (Castro et al., 2014). Although prior research has examined the relationship of parents' and infants' behavioral attention and pupil responses to facial emotions (Aktar et al., 2021; Aktar et al., 2022), the study conducted by Castro and colleagues (2014) was one of the few studies to examine the ability to identify emotions between the parent and child through behavioral measures. In light of this previous study, we did find two timepoints where infant total duration and preferential looking toward angry faces were significantly linked to maternal angry recognition at 5 months and infant total duration and preferential looking toward fearful faces were significantly linked to maternal fear recognition at 7 months. It is important to point out that we mainly found these significant relations between infant and mother emotion processing for only the negative emotions, which may highlight both infant's and mother's processing of social cues related to threat conveyed in angry and fearful faces (LoBue & Larson, 2010; Vaish et al., 2008)

For assessing the bidirectional relation of infant affect-biased attention and mother emotion detection skills across time, we found (a) that mothers' recognition of angry faces when the infant was 7 months of age was related to the latency of infants' attention to angry faces at 14 months of age; (b) mothers' recognition of happy faces at 5 months was linked to infants' total looking duration and preferential looking to happy faces at 14 months; and (c) infant preferential looking toward fearful faces at 5 months was linked to maternal recognition of fearful faces at 14 months. The finding that mother's recognition of angry faces presented the only stable emotion processing effect in our study indicates threat processing may represent a trait-like process in mothers' processing of social threat. Furthermore, mothers with greater social threat bias may predispose their infant as having greater threat bias, which may be one potential reason why we found a link between maternal and infant threat processing around 14 months when infants' face processing for angry faces begins to resemble adult-like visual processing (Grossmann, Striano, Friederici, 2007). We also found that infant preferential looking to fear at 5 months was linked to maternal recognition of fearful faces at 14 months, such that infants who showed greater preferential looking toward fearful faces at Time 1 had mothers who displayed faster recognition of fearful faces at Time 3. This effect and its specific developmental pattern are difficult to explain because the association is seen between early infant attention to fear and later maternal recognition of fear. It is unclear how such an association may emerge, and future work is needed to test whether this represents a replicable effect or is a spurious result. In regards to positive emotion processing, no prior work has directly identified a link between infant attention to, and maternal recognition of, happy faces. One potential explanation for the obtained association may be related to evidence showing that positive maternal engagement impacts the infants' oxytocin system and in turn enhances attention to happy faces (Krol et al., 2014 ; Krol et al., 2015; Krol et al., 2019).

The present study is limited as it examined emotion processing of the mother as the only potential factor within the infants' social environment, which may impact infants' own emotion processing. Future work should extend this approach by, for example, explicitly examining the quality of the infant-mother relationship by using measures such as maternal sensitivity (Ainsworth, 1969). Another important extension of the current study is to examine how internal factors, such as temperament, interact with social experience and may make infants more or less susceptible to their social experience (Pluess & Belsky, 2010). Given that our analyses around infant affect-biased attention were exploratory in nature, future studies can consider computing a difference score on latency to first fixation between neutral faces and emotional faces to capture another element of affect-biased attention. Another limitation to the present study was how the two behavioral tasks between infant and mother were different, such that we measured how infants responded to emotional faces when presented side-by-side with a neutral face, while we captured the accuracy and speed of mothers' facial emotion recognition. Future studies are needed that match the methods by infant and maternal emotion processing. Furthermore, the evidence presented in the current study is correlational in nature and cannot reveal causal relations between maternal and infant emotion processing. Critically, our results are thus unable to examine heritability of emotion processing.

Future studies should specifically target this open question by further exploring whether and to what extent shared genetic influences and/or environmental contribute to similar emotional processing between infant and mother.

In conclusion, the present study builds upon our knowledge around the relationship between infant and maternal emotional skills. The findings from this study provide valuable insight as to how mothers emotional abilities that relate to how infant emotional development unfolds across the first year of life.

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Table 1

Sample Demographic Characteristics (*N*=107)

Charateristic	*n* (%) / *M* (SD)
Infant Gender (Female)	46 (43%)
Parent Gender (Female)	107 (100%)
Mother's Age at Time 1	31.25 (5.36)
Child Race	
Black	7 (6.54%)
White	79 (73.8%)
Hispanic	5 (4.7%)
South Asian (Pakistani/Indian/Bangladeshi)	1 (.9%)
Multiracial/Other	15 (4.7%)
Parent Race	
Black	7 (6.5%)
White	90 (84.1%)
Hispanic	1 (.9%)
Asian	2 (1.9%)
South Asian (Pakistani/Indian/Bangladeshi)	1 (.9%)
Pacific Islander	1 (.9%)
Multiracial/Other	5 (4.7%)
Maternal Education	
Some High School	3 (2.8%)
High School Diploma / GED	16 (15%)
Some College / Associate's Degree	22 (20.6%)
Bachelor's Degree	26 (24.3%)
Graduate degree	40 (37.4%)
Household Income	
Less than $15,00	8 (7.5%)
$15,001 - $30,000	15(14.0%)
$30,001 - $45,000	16 (15.0%)
$45,001 - $60,000	9 (8.4%)
$60,001 - $75,000	0 (0.0%)
$75,001 - $90,000	0 (0.0%)
$90,001 - $110,000	14 (13.1%)
$110,001 - $125,000	0 (0.0%)
$125,001 - $175,000	13 (12.1%)

Table 2

Descriptive Statistics on Variables of Interest

Measures	**Time 1 Mean (*SD*)**	**Time 2 Mean (*SD*)**	**Time 3 Mean (*SD*)**
Infant			
Latency to Angry Face	2.59 (*2.13*)	2.59 (*2.55*)	1.70 (*1.88*)
Latency to Fearful Face	2.73 (*2.60*)	1.68 (*1.48*)	1.87 (*1.99*)
Latency to Happy Face	3.07 (*2.61*)	2.14 (*2.05*)	1.40 (*1.33*)
Total Duration to Angry Face	3.40 (*1.82*)	3.76 (*2.10*)	10.93 (*6.23*)
Total Duration to Fearful Face	4.51 (*2.28*)	5.02 (*2.13*)	14.50 (*7.45*)
Total Duration to Happy Face	4.17 (*2.50*)	4.85 (*2.31*)	11.43 (*6.33*)
Preferential Looking to Angry Face	0.48 (*0.16*)	0.49 (*0.16*)	0.74 (*0.09*)
Preferential Looking to Fearful Face	0.57 (*0.17*)	0.60 (*0.14)*	0.77 (*0.12*)
Preferential Looking to Happy Face	0.53 (*0.20*)	0.57 (*0.15*)	0.73 (*0.13*)
Mother			
Anger Recognition Reaction Time	1.84 (*0.27*)	1.74 (*0.30*)	1.81 (*0.22*)
Fear Recognition Reaction Time	1.97 (*0.25*)	1.86 (*0.27*)	1.93 (*0.25*)
Happy Recognition Reaction Time	1.49 (*0.27*)	1.43 (*0.27*)	1.48 (*0.25*)

Table 3

Bivariate Correlations Among Variables of Interest Across Each Emotion

Anger Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Infant Latency to Angry Face T1	-											
2. Infant Latency to Angry Face T2	0.02	-										
3. Infant Latency to Angry Face T3	-0.02	-0.16	-									
4. Infant Duration to Angry Face T1	-0.34***	0.00	-0.11	-								
5. Infant Duration to Angry Face T2	-0.15	0.46***	-0.09	0.07	-							
6. Infant Duration to Angry Face T3	-0.22	0.09	-0.44**	0.22	0.44**	-						
7. Infant Preferential Looking to Angry Face T1	-0.38***	-0.01	-0.05	0.46***	0.12	0.06	-					
8. Infant Preferential Looking to Angry Face T2	-0.02	0.13	0.21	0.00	0.33**	0.26	0.12	-				
9. Infant Preferential Looking to Angry Face T3	0.05	0.16	-0.45**	0.03	0.16	0.37*	-0.04	0.12	-			
10. Mother Anger Recognition T1	0.03	0.04	0.17	0.28**	0.12	-0.08	0.24*	-0.06	0.08	-		
11. Mother Anger Recognition T2	0.20	-0.02	0.27	0.09	0.02	-0.21	0.11	-0.07	-0.09	0.73***	-	
12. Mother Anger Recognition T3	0.01	-0.04	0.17	-0.01	0.05	-0.06	0.27	0.08	0.00	0.61***	0.72***	-
Fear Variables	13	14	15	16	17	18	19	20	21	22	23	24
13. Infant Latency to Fearful Face T1	-											
14. Infant Latency to Fearful Face T2	0.13	-										
15. Infant Latency to Fearful Face T3	-0.32*	-0.07	-									
16. Infant Duration to Fearful Face T1	0.41***	0.14	-0.28	-								
17. Infant Duration to Fearful Face T2	0.04	0.24*	0.15	0.22	-							
18. Infant Duration to Fearful Face T3	0.13	0.22	-0.49***	0.29	0.11	-						

19. Infant Preferential Looking to Fearful Face T1	0.27**	-0.02	-0.30*	0.55***	0.02	0.04	-					
20. Infant Preferential Looking to Fearful Face T2	-0.05	0.11	0.10	-0.08	0.41***	-0.17	-0.06	-				
21. Infant Preferential Looking to Fearful Face T3	0.23	0.16	-0.52***	0.11	-0.06	0.71***	0.00	-0.19	-			
22. Mother Fear Recognition T1	0.09	0.06	0.05	0.08	0.06	-0.27	-0.03	-0.05	-0.25	-		
23. Mother Fear Recognition T2	0.15	0.11	0.02	0.02	0.27*	-0.12	-0.11	0.10	-0.16	0.70***	-	
24. Mother Fear Recognition T3	0.05	0.05	0.14	-0.08	0.22	-0.10	-0.14	-0.04	-0.04	0.60***	0.50***	-

Happy Variables	25	26	27	28	29	30	31	32	33	34	35	36
25. Infant Latency to Happy Face T1	-											
26. Infant Latency to Happy Face T2	-0.05	-										
27. Infant Latency to Happy Face T3	-0.09	-0.05	-									
28. Infant Duration to Happy Face T1	0.32**	-0.02	0.04	-								
29. Infant Duration to Happy Face T2	-0.09	0.49***	-0.02	-0.20	-							
30. Infant Duration to Happy Face T3	0.00	0.04	-0.34*	-0.13	0.07	-						
31. Infant Preferential Looking to Happy Face T1	-0.26**	-0.07	0.19	-0.42***	0.19	0.10	-					
32. Infant Preferential Looking to Happy Face T2	-0.11	0.40***	0.12	-0.21	0.58***	-0.07	0.02	-				
33. Infant Preferential Looking to Happy Face T3	0.05	-0.02	-0.18	0.12	0.00	0.65***	0.07	0.01	-			
34. Mother Happy Recognition T1	0.00	-0.09	0.00	0.15	-0.14	0.46**	0.01	-0.10	0.38**	-		
35. Mother Happy Recognition T2	-0.01	-0.08	-0.08	0.09	-0.12	0.40**	0.07	0.02	0.26	0.76***	-	
36. Mother Happy Recognition T3	0.09	-0.06	0.08	0.00	-0.11	-0.24	0.03	-0.13	-0.14	-0.68***	-0.69***	-

Note. *$p < .05$, **$p < .01$, ***$p < .001$

Table 4

Model Fit Statistics for Each Emotion Cross-Lagged Panel Model

Model	RMSEA	CFI	TLI	χ2 (*Df*)
Anger				
Infant Latency & Mother Anger Recognition	0.00	1.00	1.06	1.23 (2)
Infant Duration & Mother Anger Recognition	0.00	1.00	1.05	1.23 (2)
Infant Preferential Looking & Mother Anger Recognition	0.00	1.00	1.01	1.94 (2)
Fear				
Infant Latency & Mother Fear Recognition	0.00	1.00	1.02	0.91(1)
Infant Duration & Mother Fear Recognition	0.00	1.00	1.06	0.65 (1)
Infant Preferential Looking & Mother Fear Recognition	0.00	1.00	1.14	0.24 (1)
Happy				
Infant Latency & Mother Happy Recognition	0.04	1.00	0.97	2.41 (2)
Infant Duration & Mother Happy Recognition	0.00	1.00	1.12	0.76 (1)
Infant Preferential Looking & Mother Happy Recognition	0.00	1.00	1.14	0.12 (2)

Note. Satisfactory Model Fit Statistics: RMSEA <.05; CFI & TLI values close to 1

Table 5

Unstandardized Beta Coefficients and Standard Error for Each Emotion Cross-Lagged Panel Model (Infant Looking Latency & Mother Emotion Recognition)

Paths	Anger		Fear		Happy	
	b	***SE***	***b***	***SE***	***b***	***SE***
Infant						
$Infant_1 \rightarrow Infant_2$	0.01	0.04	0.17	0.15	-0.02	0.05
$Infant_2 \rightarrow Infant_3$	-0.85	0.68	-4.03	12.81	-0.42	1.19
$Infant_1 \rightarrow Infant_3$	-0.24	0.26	-44.11	19.80	-0.27	0.52
Mother						
$Mother_1 \rightarrow Mother_2$	0.58	0.06	0.45	0.05	0.90	0.08
$Mother_2 \rightarrow Mother_3$	2.30	0.58	0.29	0.46	-0.21	0.07
$Mother_1 \rightarrow Mother_3$	0.69	0.51	0.76	0.25	-0.24	0.09
Covariance						
$Infant_1 \rightarrow Mother_1$	0.00	0.01	0.00	0.00	-0.00	0.00
$Infant_2 \rightarrow Mother_2$	-0.00	0.00	0.00	0.00	-0.00	0.00
$Infant_3 \rightarrow Mother_3$	-0.03	0.03	0.01	0.01	0.00	0.00
Cross-Lagged Paths						
$Infant_1 \rightarrow Mother_2$	0.13	0.07	6.82	7.05	0.01	0.06
$Infant_2 \rightarrow Mother_3$	-0.41	1.09	5.93	17.07	-0.08	0.09
$Mother_1 \rightarrow Infant_2$	0.02	0.03	0.00	0.00	-0.06	0.07
$Infant_1 \rightarrow Mother_3$	-	-	-	-	-	-
$Mother_2 \rightarrow Infant_3$	0.48	0.23	0.07	0.35	-0.37	0.60
$Mother_1 \rightarrow Infant_3$	-	-	0.07	0.19	-	-

Note. $_1$ 5-months; $_2$ 7-months; $_3$ 14-months

Table 6

Unstandardized Beta Coefficients and Standard Error for Each Emotion Cross-Lagged Panel Model (Infant Looking Duration & Mother Emotion Recognition)

Paths	Anger		Fear		Happy	
	b	***SE***	***b***	***SE***	***b***	***SE***
Infant						
$Infant_1 \rightarrow Infant_2$	0.07	0.16	0.18	0.10	-0.23	0.15
$Infant_2 \rightarrow Infant_3$	3.53	0.99	0.45	0.58	0.27	0.43
$Infant_1 \rightarrow Infant_3$	3.87	1.58	0.94	0.47	-0.82	0.45
Mother						
$Mother_1 \rightarrow Mother_2$	0.60	0.06	0.45	0.05	0.91	0.08
$Mother_2 \rightarrow Mother_3$	2.34	0.56	0.16	0.45	-0.21	0.07
$Mother_1 \rightarrow Mother_3$	0.72	0.50	0.78	0.24	-0.23	0.08
Covariance						
$Infant_1 \rightarrow Mother_1$	0.04	0.02	0.05	0.06	0.02	0.01
$Infant_2 \rightarrow Mother_2$	-0.01	0.01	0.09	0.03	-0.01	0.01
$Infant_3 \rightarrow Mother_3$	0.10	0.48	0.10	0.32	0.03	0.02
Cross-Lagged Paths						
$Infant_1 \rightarrow Mother_2$	-0.03	0.03	0.00	0.01	-0.00	0.00
$Infant_2 \rightarrow Mother_3$	0.17	0.12	0.03	0.03	-0.00	0.00
$Infant_1 \rightarrow Mother_3$	-	-	-	-	-	-
$Mother_1 \rightarrow Infant_2$	0.33	0.33	0.41	0.81	-2.66	3.39
$Mother_2 \rightarrow Infant_3$	-4.76	3.36	3.20	10.03	10.74	13.44
$Mother_1 \rightarrow Infant_3$	-	-	-8.92	5.35	36.09	16.18

Note. $_1$ 5-months; $_2$ 7-months; $_3$ 14-months

Table 7

Unstandardized Beta Coefficients and Standard Error for Each Emotion Cross-Lagged Panel Model (Infant Preferential Looking & Mother Emotion Recognition)

Paths	Anger		Fear		Happy	
	b	***SE***	***b***	***SE***	***b***	***SE***
Infant						
$Infant_1$ → $Infant_2$	0.14	0.10	0.02	0.09	0.03	0.08
$Infant_2$ → $Infant_3$	0.10	0.09	-0.22	0.17	0.04	0.15
$Infant_1$ → $Infant_3$	-	-	-	-	-	-
Mother						
$Mother_1$ → $Mother_2$	0.60	0.06	0.45	0.05	0.90	0.08
$Mother_2$ → $Mother_3$	2.28	0.57	0.22	0.42	-0.20	0.07
$Mother_1$→ $Mother_3$	0.75	0.51	0.87	0.25	-0.24	0.08
Covariance						
$Infant_1$→ $Mother_1$	0.01	0.01	-0.00	0.00	0.00	0.00
$Infant_2$ → $Mother_2$	-0.00	0.00	0.01	0.00	0.00	0.00
$Infant_3$ → $Mother_3$	0.00	0.00	0.01	0.01	0.00	0.00
Cross-Lagged Paths						
$Infant_1$ → $Mother_2$	-0.11	0.10	-0.13	0.08	0.01	0.03
$Infant_2$ → $Mother_3$	0.64	0.65	0.18	0.41	-0.03	0.03
$Infant_1$ → $Mother_3$	-	-	-0.62	0.27	-	-
$Mother_1$ → $Infant_2$	-0.08	0.06	-0.04	0.06	-0.15	0.22
$Mother_2$ → $Infant_3$	-0.14	0.08	0.13	0.18	-0.8	0.32
$Mother_1$ → $Infant_3$	0.14	0.07	-0.15	0.10	0.78	0.37

Note. $_1$ 5-months; $_2$ 7-months; $_3$ 14-month

Table 8

Infant Eye-Tracking Data Quality Descriptive Statistics

Trial Type	**Average Valid Trials (*SD*)**			**Percentage of Total Valid Trials**		
	Time 1	Time 2	Time 3	Time 1	Time 2	Time 3
Anger	2.35 (0.89)	2.48 (0.87)	2.70 (0.62)	78%	91%	94%
Fear	2.34 (0.90)	2.56 (0.85)	2.68 (0.56)	78%	94%	93%
Happy	2.40 (0.88)	2.49 (0.87)	2.57 (0.74)	80%	91%	90%

Table 9

Robustness Analyses - Unstandardized Beta Coefficients and Standard Error for Each Emotion Cross-Lagged Panel Model (Infant Looking Latency & Mother Emotion Recognition)

Paths	Anger		Fear		Happy	
	b	***SE***	***b***	***SE***	***b***	***SE***
Infant						
$Infant_1$ → $Infant_2$	0.01	0.05	0.17	0.15	-0.02	0.07
$Infant_2$ → $Infant_3$	-0.85	0.91	-4.03	13.42	-0.42	1.50
$Infant_1$ → $Infant_3$	-0.24	0.27	-44.11	22.61	-0.27	0.61
Mother						
$Mother_1$ → $Mother_2$	0.58	0.07	0.45	0.05	0.90	0.10
$Mother_2$ → $Mother_3$	2.30	0.56	0.29	0.37	-0.21	0.07
$Mother_1$ → $Mother_3$	0.69	0.49	0.76	0.22	-0.24	0.11
Covariance						
$Infant_1$ → $Mother_1$	0.00	0.01	0.00	0.00	0.00	0.00
$Infant_2$ → $Mother_2$	0.00	0.00	0.00	0.00	0.00	0.00
$Infant_3$ → $Mother_3$	-0.03	0.03	0.01	0.01	0.00	0.00
Cross-Lagged Paths						
$Infant_1$ → $Mother_2$	0.13	0.07	6.82	7.94	0.00	0.07
$Infant_2$ → $Mother_3$	-0.41	1.24	5.93	20.43	-0.08	0.12
$Infant_1$ → $Mother_3$	-	-	-	-	-	-
$Mother_1$ → $Infant_2$	0.02	0.04	0.00	0.00	-0.06	0.07
$Mother_2$ → $Infant_3$	0.48	0.28	0.07	0.34	-0.37	0.67
$Mother_1$ → $Infant_3$	-	-	0.07	0.20	-	-

Note. $_1$ 5-months; $_2$ 7-months; $_3$ 14-months

Table 10

Robustness Analyses - Unstandardized Beta Coefficients and Standard Error for Each Emotion Cross-Lagged Panel Model (Infant Looking Duration & Mother Emotion Recognition)

Paths	Anger		Fear		Happy	
	b	***SE***	***b***	***SE***	***b***	***SE***
Infant						
$Infant_1 \rightarrow Infant_2$	0.07	0.24	0.18	0.11	-0.23	0.07
$Infant_2 \rightarrow Infant_3$	3.53	0.87	0.45	0.52	0.27	0.41
$Infant_1 \rightarrow Infant_3$	3.87	1.46	0.94	0.39	-0.82	0.11
Mother						
$Mother_1 \rightarrow Mother_2$	0.60	0.07	0.45	0.0\4	0.91	0.11
$Mother_2 \rightarrow Mother_3$	2.34	0.49	0.16	0.38	-0.21	0.06
$Mother_1 \rightarrow Mother_3$	0.72	0.51	0.78	0.22	-0.23	0.09
Covariance						
$Infant_1 \rightarrow Mother_1$	0.04	0.01	0.04	0.06	0.02	0.00
$Infant_2 \rightarrow Mother_2$	-0.01	0.01	0.09	0.04	-0.01	0.02
$Infant_3 \rightarrow Mother_3$	0.10	0.44	0.10	0.38	0.03	0.02
Cross-Lagged Paths						
$Infant_1 \rightarrow Mother_2$	-0.03	0.03	0.00	0.01	0.00	0.00
$Infant_2 \rightarrow Mother_3$	0.17	0.11	0.03	0.02	0.00	0.00
$Infant_1 \rightarrow Mother_3$	-	-	-	-	-	-
$Mother_1 \rightarrow Infant_2$	0.33	0.28	0.41	0.83	-2.66	3.52
$Mother_2 \rightarrow Infant_3$	-4.76	3.75	3.20	10.09	10.74	11.27
$Mother_1 \rightarrow Infant_3$	-	-	-8.92	4.88	36.09	13.70

Note. $_1$ 5-months; $_2$ 7-months; $_3$ 14-months

Table 11

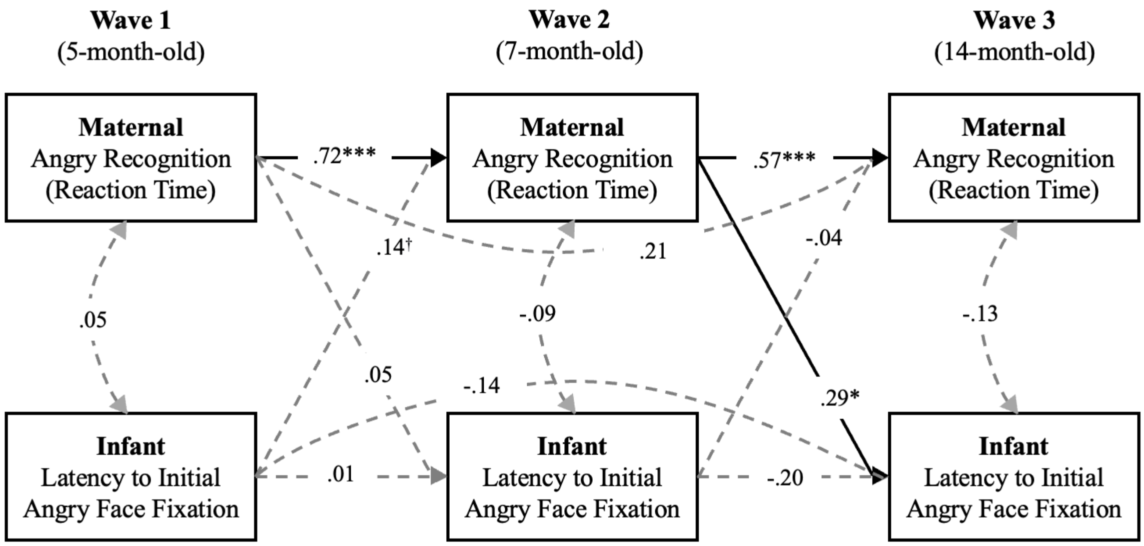
Robustness Analyses - Unstandardized Beta Coefficients and Standard Error for Each Emotion Cross-Lagged Panel Model (Infant Preferential Looking & Mother Emotion Recognition)

Paths	Anger		Fear		Happy	
	b	***SE***	***b***	***SE***	***b***	***SE***
Infant						
$Infant_1$ → $Infant_2$	0.14	0.10	0.02	0.10	0.03	0.11
$Infant_2$ → $Infant_3$	0.10	0.09	-0.22	0.16	0.04	0.14
$Infant_1$ → $Infant_3$	-	-	-	-	-	-
Mother						
$Mother_1$ → $Mother_2$	0.60	0.06	0.45	0.05	0.90	0.11
$Mother_2$ → $Mother_3$	2.28	0.54	0.22	0.33	-0.20	0.07
$Mother_1$ → $Mother_3$	0.75	0.52	0.87	0.19	-0.24	0.09
Covariance						
$Infant_1$ → $Mother_1$	0.01	0.00	0.00	0.01	0.00	0.00
$Infant_2$ → $Mother_2$	0.00	0.00	0.00	0.00	0.00	0.00
$Infant_3$ → $Mother_3$	0.00	0.01	0.00	0.01	0.00	0.00
Cross-Lagged Paths						
$Infant_1$ → $Mother_2$	-0.11	0.12	-0.13	0.09	0.01	0.04
$Infant_2$ → $Mother_3$	0.64	0.55	0.18	0.35	-0.03	0.03
$Infant_1$ → $Mother_3$	-	-	-0.62	0.27	-	-
$Mother_1$ → $Infant_2$	-0.08	0.06	-0.04	0.06	-0.15	0.21
$Mother_2$ → $Infant_3$	-0.14	0.05	0.13	0.16	-0.08	0.24
$Mother_1$ → $Infant_3$	0.14	0.07	-0.15	0.11	0.78	0.29

Note. $_1$ 5-months; $_2$ 7-months; $_3$ 14-months

Figure 1

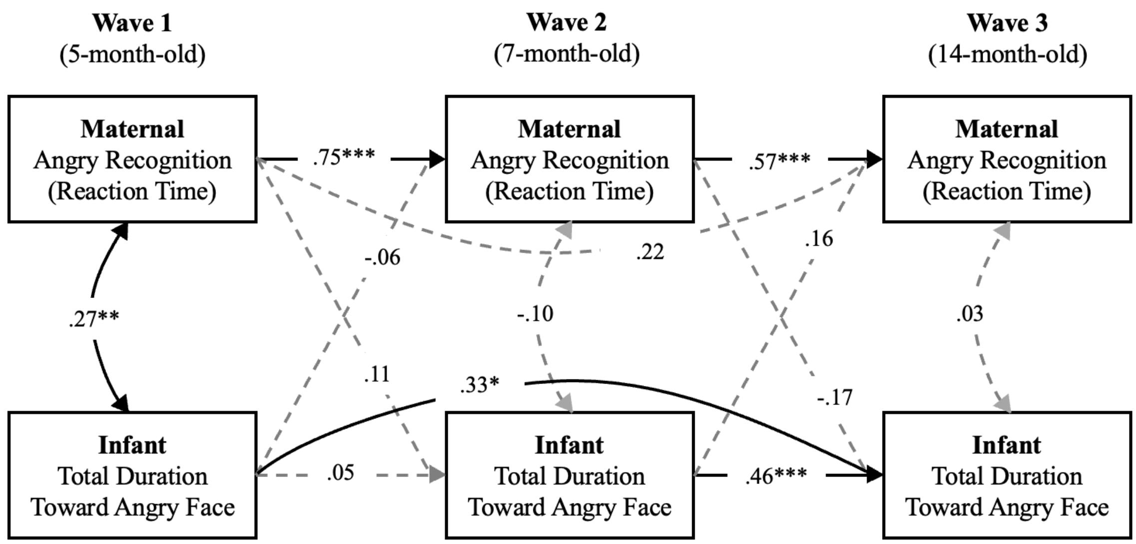
Cross-Lagged Panel Model for Angry Recognition and Latency to Face Fixation



Note. $\chi 2 = 1.23$, $df = 2$, $p = .54$, $RMSEA < .01$, $CFI = 1.00$, $TLI = 1.06$. †$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.
Black solid lines are statistically significant at $p < .05$. Grey dotted lines are non-significant $p > .05$.

Figure 2

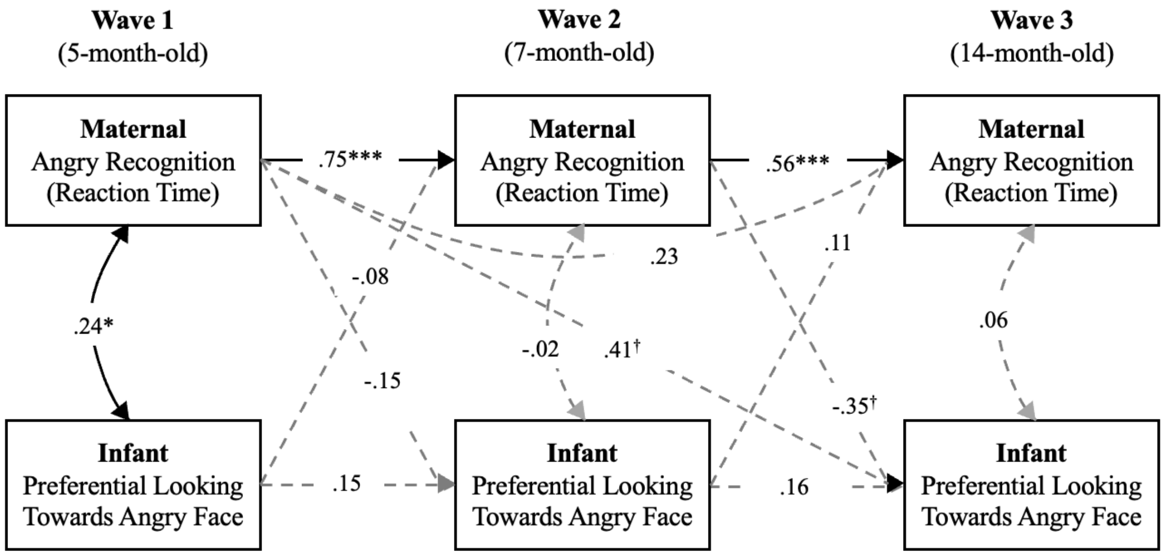
Cross-Lagged Panel Model for Angry Recognition and Total Looking Duration to Face Fixation



Note. $\chi2 = 1.23$, $df = 2$, $p = .54$, $RMSEA < .01$, $CFI = 1.00$, $TLI = 1.05$. †$p < .10$,*$p < .05$, **$p < .01$, ***$p < .001$. Black solid lines are statistically significant at $p < .05$. Grey dotted lines are non-significant $p > .05$.

Figure 3

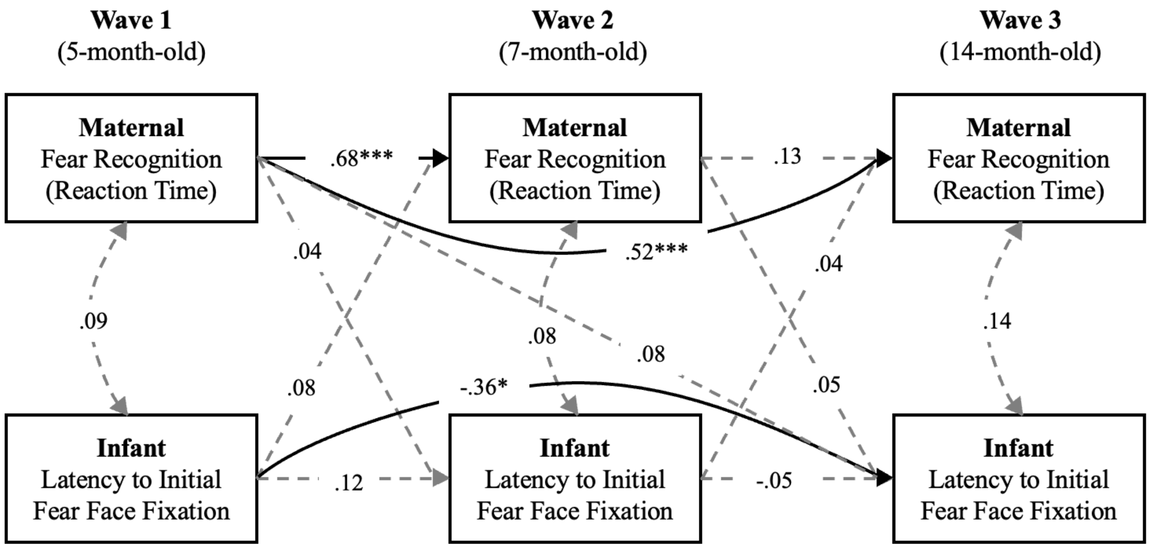
Cross-Lagged Panel Model for Angry Recognition and Preferential Looking to Face Fixation



Note. $\chi 2 = 1.94$, $df = 2$, $p = .38$, $RMSEA < .01$, $CFI = 1.00$, $TLI = 1.01$. †$p < .10$,*$p < .05$, **$p < .01$, ***$p < .001$. Black solid lines are statistically significant at $p < .05$. Grey dotted lines are non-significant $p > .05$.

Figure 4

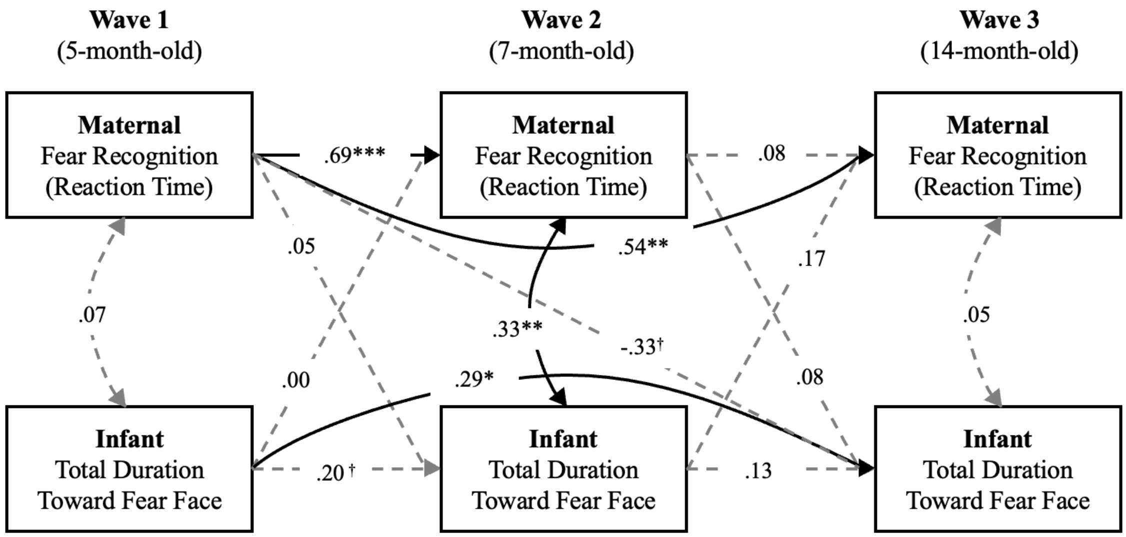
Cross-Lagged Panel Model for Fear Recognition and Latency to Face Fixation



Note. $\chi2 = 0.91$, $df = 1$, $p = .34$, *RMSEA* < .01, *CFI* = 1.00, *TLI* = 1.02. †$p < .10$,*$p < .05$, **$p < .01$, ***$p < .001$.
Black solid lines are statistically significant at $p < .05$. Grey dotted lines are non-significant $p > .05$.

Figure 5

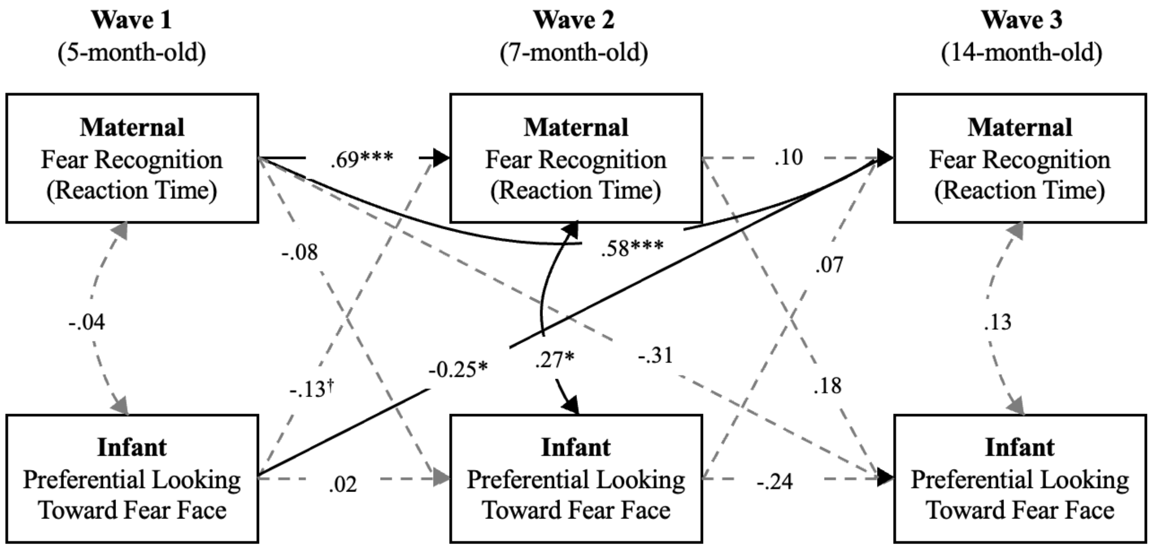
Cross-Lagged Panel Model for Fear Recognition and Total Looking Duration to Face Fixation



Note. $\chi 2 = 0.65$, $df = 1$, $p = .42$, $RMSEA < .01$, $CFI = 1.00$, $TLI = 1.06$. †$p < .10$,*$p < .05$, **$p < .01$, ***$p < .001$. Black solid lines are statistically significant at $p < .05$. Grey dotted lines are non-significant $p > .05$.

Figure 6

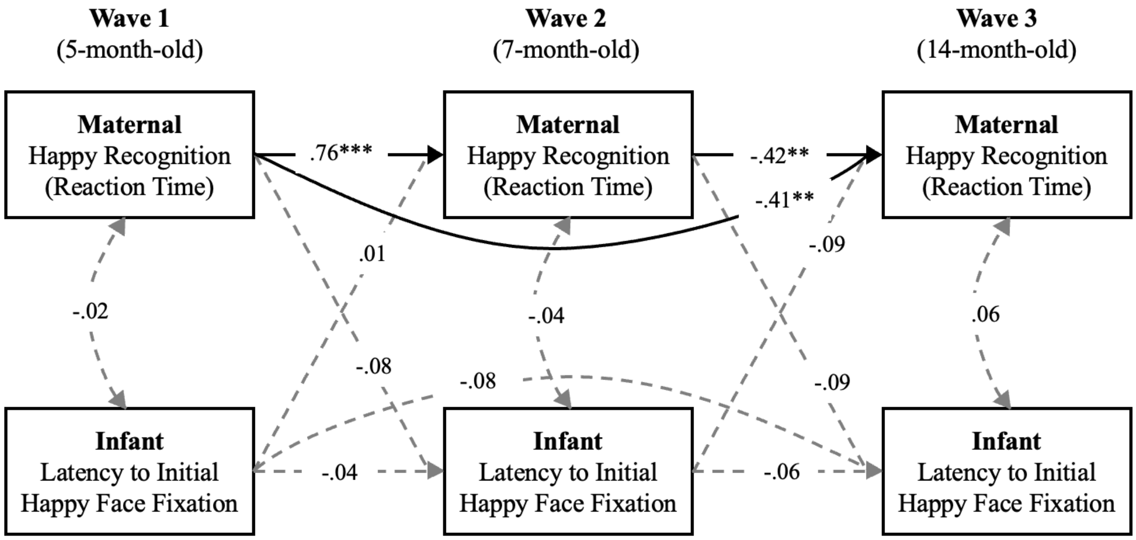
Cross-Lagged Panel Model for Fear Recognition and Preferential Looking to Face Fixation



Note. $\chi 2 = 0.24$, $df = 1$, $p = .62$, *RMSEA* < .01, *CFI* = 1.00, *TLI* = 1.14. †$p < .10$,*$p < .05$, **$p < .01$, ***$p < .001$. Black solid lines are statistically significant at $p < .05$. Grey dotted lines are non-significant $p > .05$.

Figure 7

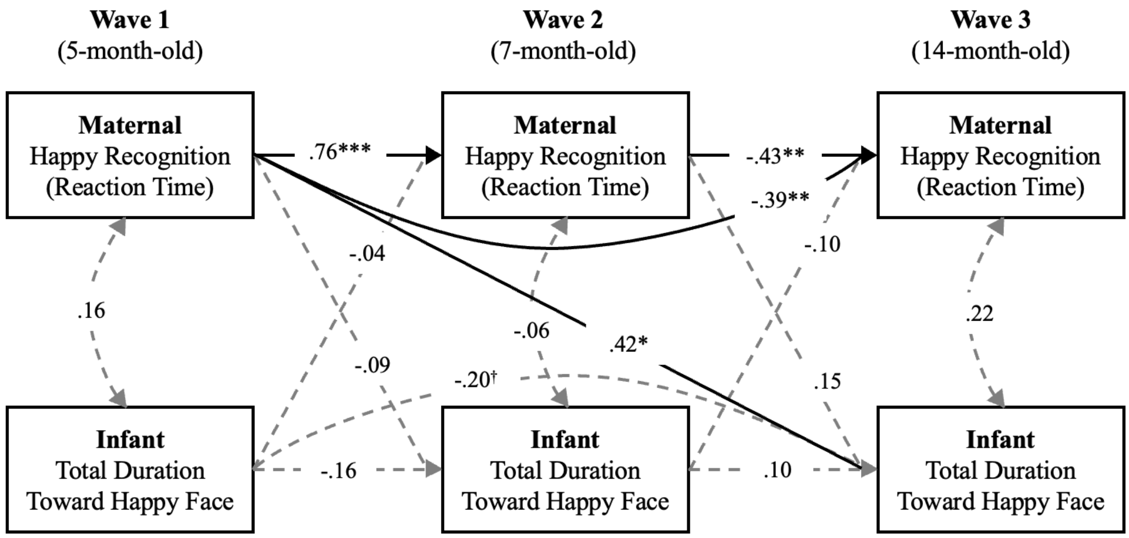
Cross-Lagged Panel Model for Happy Recognition and Latency to Face Fixation



Note. $\chi 2 = 2.41$, $df = 2$, $p = .30$, $RMSEA = .04$, $CFI = 1.00$, $TLI = 0.97$, †$p < .10$,*$p < .05$, **$p < .01$, ***$p < .001$. Black solid lines are statistically significant at $p < .05$. Grey dotted lines are non-significant $p > .05$.

Figure 8

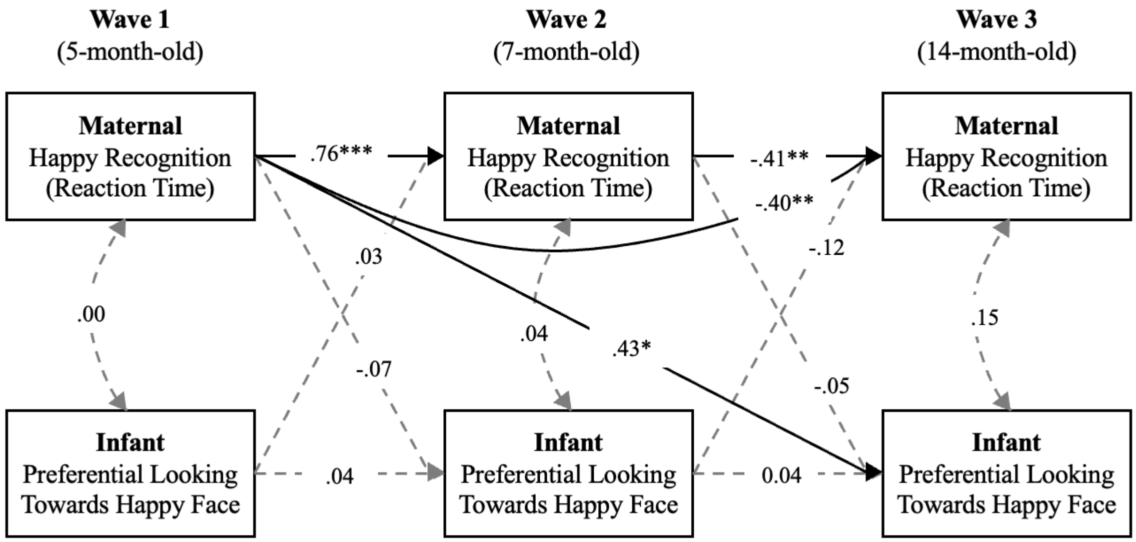
Cross-Lagged Panel Model for Happy Recognition and Total Looking Duration to Face Fixation



Note. $\chi2 = 0.76$, $df = 1$, $p = .39$, *RMSEA* < .01, *CFI* = 1.00, *TLI* = 1.03, †$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$. Black solid lines are statistically significant at $p < .05$. Grey dotted lines are non-significant $p > .05$.

Figure 9

Cross-Lagged Panel Model for Happy Recognition and Preferential Looking to Face Fixation



Note. $\chi 2 = 0.12$, $df = 2$, $p = .94$, $RMSEA < .01$, $CFI = 1.00$, $TLI = 1.14$, †$p < .10$,*$p < .05$, **$p < .01$, ***$p < .001$. Black solid lines are statistically significant at $p < .05$. Grey dotted lines are non-significant $p > .05$.