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Intermodal emotion matching at 15 months, but not 9 or 21 months, predicts early childhood emotion understanding: A longitudinal investigation

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ABSTRACT
Emotion understanding is a crucial skill for early social development, yet little is known regarding longitudinal development of this skill from infancy to early childhood. To address this issue, the present longitudinal study followed 40 participants from 9 to 30 months. Intermodal emotion matching was assessed using eye tracking at 9, 15, and 21 months, and emotion understanding was measured using the Affective Knowledge Test at 30 months of age. A novelty preference on the emotion matching task at 15 months (but not at 9 or 21 months) significantly predicted emotion understanding performance at 30 months. However, linear and quadratic trajectories for emotion matching development across 9- to 21-months did not predict later emotion understanding. No gender differences were observed in emotion matching or emotion understanding. These results hold implications for better understanding how infant emotion matching may relate to later emotion understanding, and the role that infant emotion perception may play in early emotional development.

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The ability to identify emotional expressions and reactions, commonly referred to as emotion understanding, is an important social-cognitive skill because identifying others' emotional expressions provides insight into their internal states (Horstmann, 2003). Emotional reactions can shape a person's facial expression, vocal tone, body posture, and cognition (Lewis, 2008), and interpreting these reactions enables us to make inferences about others' emotional states and to make predictions about their likely future behaviours (Hesse & Cicchetti, 1982; Olson et al., 1988). Thus, emotion understanding can help a child to understand the behaviours and goals of those around them (Reschke et al., 2017), to react appropriately in social situations, and to maintain interpersonal relationships. Prior research has investigated preschool emotion understanding and its implications for later social development (e.g. Denham et al., 2003). Separately, research in the first year after birth has examined infants' ability to emotion match, or match emotional expressions across visual and auditory modalities (e.g. Walker, 1982). However, it remains unclear whether these two skills relate to one another across development. Recognising emotion across face and voice may provide a basis for later emotion understanding, but to date this possibility remains underexplored. To address this question, we investigated how emotion matching in infancy relates to emotion understanding at 30 months of age.

Emotion understanding in preschoolers encompasses both emotion recognition (perceptually identifying an emotion in one or more modalities such as facial expression, vocal tone, or body posture) and emotion knowledge (identifying potential and expected emotional reactions to scenarios) (Castro et al., 2016), and predicts social competence even when controlling for age, gender, and executive control (Denham et al., 2015). In addition, preschoolers' emotion language use relates to their likability among their peers (Fabes et al., 2001), and preschool emotion understanding predicts aggression

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(Denham et al., 2002), moral reasoning (Dunn et al., 1995; Lane et al., 2010), peer acceptance (Cassidy et al., 1992), social competence (Denham et al., 2003), and sympathy (Eggum et al., 2011) in later years. In addition, preschool emotion understanding relates to classroom adjustment (Shields et al., 2001) and predicts kindergarten academic success (Denham et al., 2012). Importantly, preschool emotion understanding also predicts a child's ability to understand emotions in later years: Brown and Dunn (1996) reported stability in individuals' emotion understanding trajectories from 3 to 6 years of age, and Pons and Harris (2005) demonstrated stability in emotion understanding trajectories across the age range of 7–12 years. Thus, emotion understanding ability at age 3 has important implications for a child's long-term social and cognitive development.

Emotion perception in infancy

Stability in emotion understanding from 3 years of age motivates studies of younger children to investigate its developmental origins. Yet measuring emotion understanding at younger ages, particularly in infancy, is challenging, as young children have limited verbal and motor abilities. To work within these limitations, researchers often use looking time paradigms to assess how much time infants spend looking to particular emotional stimuli. These study designs allow researchers to determine how infants perceive various emotional stimuli by assessing whether they can discriminate them or match them across modalities. By 6 months of age, for example, infants can discriminate between the static emotional faces of happy compared to neutral or angry (LaBabera et al., 1976) and fear compared to sadness (Schwartz et al., 1985). The intermodal preference technique (Spelke, 1976), in which infants are presented with two visual stimuli and one audio stimulus to determine whether infants will look more to the visual stimulus matching the audio, has been used to assess intermodal emotion matching. In such studies, 7-month-old infants have matched happy and sad emotions across asynchronous faces and voices (Walker, 1982), and matched emotions across modalities when the bottom third of the face was occluded (Walker-Andrews, 1986). Additionally, infants as young as 5 months matched expressions of other infants across face and voice (Vaillant-Molina et al., 2013), and 3.5-month-olds matched emotions across face and voice when their mother was the stimulus (Kahana-Kalman & Walker-Andrews, 2001).

Emotion perception and emotion understanding

Despite the knowledge gained in recent decades regarding infant emotion perception and early childhood emotion understanding, the relation between these two vital social skills remains unclear. Typical emotion understanding tasks measure a child's ability to identify emotional expressions, to label emotional expressions, and to express their knowledge of the emotion that would be elicited by certain situations. In contrast, infant emotion perception tasks, such as emotion matching, measure an infant's ability to discriminate between various emotions or to recognise the emotional tone of voice that should be associated with a particular facial expression. To fully understand others' emotions, to label them, and to know which emotions are commonly elicited by particular situations, it is likely necessary to first discriminate emotions and perceive consistencies across emotional faces and voices. Therefore, recognising matches in emotion across modalities may provide a base for later, more complex understanding of emotions across modalities and situations. That is, emotion matching may provide a necessary foundation on which emotion understanding builds.

How is emotional development related from infancy to early childhood and later development? Little is known. To our knowledge there have been no published studies directly examining the developmental relation between infant emotion perception and early childhood emotion understanding. Considering the stability in emotion understanding from 3 to 6 years of age (Brown & Dunn, 1996), it is important to discover whether performance on emotion perception tasks among younger age groups is developmentally related to preschool emotion understanding.

The present study

In the present study, we investigated the relation between infant emotion perception and early childhood emotion understanding in a longitudinal design. We had 3 major goals for this study: 1) To characterise the development of emotion matching from early through late infancy, 2) To investigate whether emotion matching at any time point predicted later emotion understanding, and 3) To explore whether the trajectory for emotion matching development across infancy predicted later emotion understanding. To address these goals, we assessed infant emotion matching at 9, 15, and 21 months of age with a modified version of Walker's (1982) intermodal emotion matching paradigm to include more emotions, shorter trials, and a silent baseline condition. Prior research has shown that 7-month-olds are capable of emotion matching, but little is known about how this may develop through the second year after birth.

Thus, we designed the emotion matching task to be somewhat difficult, so as to elucidate individual differences. We assessed infant performance initially at 9 months and again after two 6-month intervals. These ages were selected because 9 months is slightly older than prior emotion matching studies (e.g. Walker, 1982; Walker-Andrews, 1986), reflecting the increased difficulty of our adapted emotion matching task. We then assessed emotion matching after 6-month intervals to provide a measure of emotion matching in late infancy, a developmental time period that has been under-explored for emotion matching. We utilised angry, happy, and sad video clips, each paired with a neutral video both in silence and with asynchronous emotional audio clips. Emotion matching was operationalised as the proportion of infant looking to the video matching the emotion of the asynchronous audio relative to looking to that same video in silence. At 30 months of age, one of the earliest ages for which emotion understanding tasks are developmentally appropriate, the children participated in Denham's (1986) Affective Knowledge Test, a commonly used measure of emotion understanding in early childhood.

Because this was the first study (to our knowledge) that assesses infant emotion matching longitudinally across the first and second year after birth and connects it to later emotion understanding, there were insufficient priors to make straightforward predictions. We hypothesised that emotion matching in late infancy (15, 21 months) but not earlier (9 months) would predict later emotion understanding at 30 months. This is because the ability to perceive emotion across faces and voices may provide a necessary foundation for emotion understanding, but emotion matching may not be developed enough to predict early childhood emotion understanding until late infancy. We considered that this may be particularly evident in our paradigm given the increased difficulty of the adapted emotion matching task, and because the first two years after birth are characterised by substantial changes in infant social-cognitive development (e.g. Brownell, 2012; Grossmann & Johnson, 2007), suggesting that emotion matching may not predict later emotion understanding due to the rapid social-cognitive development expected in the following year. Additionally, we hypothesised that linear change in emotion matching across infancy would predict later emotion understanding, as the *trajectory* of emotion matching development may be most predictive of later emotion understanding. Given that previous studies have shown increases in emotion matching from 5- to 7-months (Walker-Andrews, 1986), we reasoned that emotion matching performance would improve with age. However, we also reasoned that infants may demonstrate *less* emotion matching with time, as previous research has shown that infants show a novelty preference (looking more to the novel/non-matching stimulus) on tasks that are easy, due to boredom with the familiar stimulus (Hunter & Ames, 1988). Additionally, prior work has shown that infants may recognise an emotion match by looking *away* from the matching face (Palama et al., 2018). Thus, the present, preliminary study analysed for both looking more and less to the matching face, and how this changes with age.

Method

Participants

Forty healthy, full-term infants (20 female) participated in this longitudinal study. To determine this sample size, an a priori power analysis was conducted using G*Power 3.1 (Faul et al., 2009) based on the magnitude of the correlation ($r = .48$) between early childhood emotion understanding and emotion understanding years later in a longitudinal design (Brown & Dunn, 1996). This analysis revealed that the number of participants necessary to achieve power of 0.8 was 29. We recruited an additional 11 infants to account for an anticipated 25% data loss due to participant drop-out rates and fussiness, which are common in infant research. A second power analysis based on the effect size of $d = 0.91$ from Brown and Dunn (1996) indicates a necessary sample size of 20 boys and 20 girls to detect gender differences in emotion understanding, leading to our final sample size of 40. Infants were recruited from

Table 1. Participant Information.

	Mean Age (months)	SD Age	Age Range	Number of excluded participants
Time 1	9.15	0.63	7.82–10.38	2
Time 2	15.35	0.53	14.75–16.76	3
Time 3	21.12	0.43	20.30–22.21	3
Time 4	30.02	0.31	29.21–30.75	5

lists of birth records, and parents were informed that they would be asked to visit the lab when their infant was approximately 9, 15, 21, and 30 months of age (T1, T2, T3, and T4). Of the full sample, 36 infants had at least one parent who had completed four years of college. The ethnic and racial background of participants was as follows: Caucasian (N = 22), Multiracial (N = 11), Asian (N = 3), Latino (N = 2), African-American (N = 1), Pacific Islander (N = 1). Parents were provided with $30 in cash and a small gift (e.g. A T-shirt or sippy cup) at each time point for participating. Participant information, such as age and number of participants excluded, at each time point is presented in Table 1. Some analyses of data from the 9-month visit have been previously reported (Ogren et al., 2018).

Materials

Surveys

Parents of all participants provided written informed consent prior to any data collection in accordance with the University of California, Los Angeles Institutional Review Board project titled "Emotion Discrimination Development" (ID #15-001555). At each time point, parents completed a demographic questionnaire.

Emotion matching stimuli

To create audio and video stimuli of happy, sad, angry, and neutral emotions, a female model was recorded as she read 10-s, child-appropriate scripts. Each script read by the female model contained linguistic content that matched the emotional tone. An example sad script is "My favorite toy broke. I dropped it. My mom says it can't be fixed. Now I don't know what to play with." Two different scripts were recorded for each emotion (angry, happy, sad) and three scripts were recorded for the neutral stimuli because they were presented most often. The mean numbers of syllables per emotion were as follows: Angry = 29.5; Happy = 26; Neutral = 24.3; Sad = 26.5. Because the number of syllables did not substantially differ across conditions, it is unlikely that the infants could match the emotion of the audio and video using only rate of speech.

During stimulus recording, the model was asked to think about a time when she felt the target emotion, and to convey the emotion through her face and voice. She was seated against an off-white background while she read each script facing directly toward the camera. She was recorded from the shoulders up, and utilised only small, natural head movements during each recording. Each clip was separated into independent video and audio files.

Emotion matching stimulus validation

A Qualtrics survey was used with adults to validate the emotional content of the video and audio clips. Fifty-eight adults (13 male) viewed each audio and video clip independently, with no sound during the video-only clips, and only a plain blue screen visible during the audio-only clips. The adults were asked to identify whether the emotion presented in each clip was afraid, angry, happy, neutral, or sad. Based on these responses, the best two examples of angry, happy, and sad video and audio clips were selected. Three neutral audio and video clips were selected. On average, the adult raters correctly identified the audio and video clips 91% of the time (Audio clips: Angry = 80%, Happy = 93%, Sad = 92%, Neutral = 89%; Video clips: Angry = 96%, Happy = 98%, Sad = 93%, Neutral = 87%). Of the selected clips, no two audio clips and no two video clips involved the model following the same written script.

Apparatus

An eye tracker (SR Research EyeLink 1000) was used to record infants' visual fixations to the stimuli. Experiment Builder, the stimulus presentation software associated with the eye tracker, was used to programme the experiment. Two video clips were shown side-by-side on every trial. Each video was presented to the infants at approximately 30.0° x 22.5° visual angle from their 60-cm viewing distance.

Procedure

Eye tracking task

Infants engaged in the same eye tracking task at time points T1, T2, and T3 (9, 15, and 21 months). At each time point, infants sat on a parent's lap approximately 60 cm from a 56-cm monitor. Eye movements were recorded at 500 Hz. Prior to exposure to the stimuli, each infant's gaze was calibrated using the standard calibration routine provided by the eye tracker. An attention-getting stimulus was presented at the four corners and centre of the screen as the infant tracked its location, progressing through the locations once the child had fixated on the prior location. After calibration was completed, the calibration was validated by presenting the attention-getting stimulus at the same five locations again. If the validation fixations were within 1° visual angle from the calibration fixations, the calibration was considered acceptable, and the experiment immediately advanced to the stimulus presentation. If not, the calibration was repeated until this threshold was met.

During the task, infants were presented with 18 trials of paired video clips. One video always represented a neutral emotion, and the other was one of the remaining emotions (happy, sad, or angry). This allowed us to assess matching for the three emotions under comparable conditions. Each emotion was always paired with a stimulus of neutral valance. Stimulus presentation was separated into three blocks, each containing six trials. Two different happy, sad, and angry video clips were presented per block in random order. Additionally, the side of presentation (left vs right) was randomised, with the condition that no more than two neutral videos were presented on the same side in a row. The first block of clips was presented in silence to determine each infant's individual baseline visual preference for the paired video stimuli, and to control for these baseline preferences when investigating emotion matching. Figure 1 depicts a still image example of the visual stimuli.

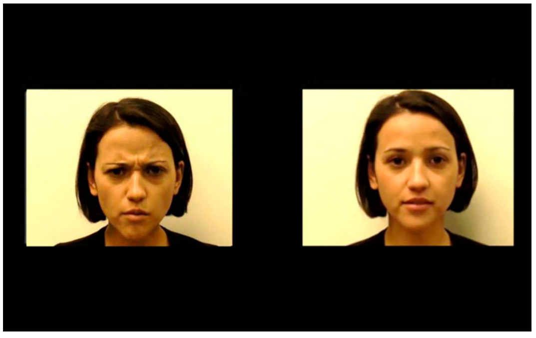

Figure 1. Still image example of angry-neutral emotion matching stimulus. In this example, an angry face is presented on the left and a neutral face is on the right.

In the second and third blocks, audio clips were introduced. One audio clip was played on each trial, and it matched the emotional tone of one of the videos presented on the screen, but was always asynchronous with both videos. (Asynchronous presentation ensured that the infants did not simply match emotions based on temporal synchrony of voice and lip movement, which has been reported in infants as young as 3.5-months; Bahrick, 1992). Order of the audio clips was randomised with the constraints that no more than two neutral audio clips were presented in a row, and that the audio matched the emotional tone of one of the videos presented, but did not follow the same script in order to ensure asynchrony. In other words, because each emotion contained at least two possible scripts, if the model visually displayed was saying the 1st angry script and the audio was angry, the audio would have to be of the 2nd angry script to avoid synchrony. Because there were nine unique video and audio clips (two for each emotion and three for neutral), video and audio clips repeated across the blocks, but the same clip was never presented twice within a block.

During the task, each 10-s trial was preceded by a small attention-getting stimulus in the centre of the screen to re-center the child's gaze. An experimenter in an adjacent room monitored infant eye gaze and controlled progression of the attention-getting stimulus. Parents were asked to hold their infant on their lap and allow their child to look freely during the experiment. Parents were instructed not to point to the screen, direct their child's attention, or otherwise interact with their child unless the child had completely disengaged their attention on the prior trial, in which case the parent was asked to turn the infant's body back toward the screen while the attention-getting stimulus was presented. An experimenter monitored the task via live video feed to ensure that parents adhered to these instructions and did not influence infant looking. The testing time for the emotion matching task at T1, T2, and T3 was approximately five minutes.

Live action task

Participants took part in Denham's Affective Knowledge Test (AKT; Denham, 1986) at T4 (30 months). This is a commonly used measure of emotion understanding among preschool-aged children, and has previously been used with 2-year-olds (Denham & Couchoud, 1990; Ensor et al., 2011) to assess understanding of the emotions "angry," "happy," "sad," and “afraid,” which are words that are commonly produced by 2 years of age (Wellman et al., 1995). Participants took part in three components of the AKT: Expressive, receptive, and stereotypical situations. We did not assess the non-stereotypical situations component of the task, as it is too complex for children under the age of 3 (Ensor et al., 2011).

At the beginning of the task, participants were presented with four faces made of felt, each depicting a stereotypical emotional expression (anger, fear, happiness, or sadness). For the expressive component of the task, the experimenter began by asking the child to identify the emotion of each face (i.e. “How does he/she feel?”). After receiving responses from participants for each of the faces, the experimenter shuffled the order of the faces on the table, then began the receptive component of the task. Here, the experimenter asked the child to identify which face matched a particular emotion label (e.g. “Point to the *happy* face”). After the child responded to all four receptive questions, the experimenter provided the child with the correct labels for each of the four faces, along with appropriate facial and vocal emotional tone (e.g. “This is the angry face,” while pointing to the angry face with furrowed brows and a gruff vocal tone).

After describing the faces, the experimenter began the stereotypical situation component of the AKT. The experimenter portrayed eight brief vignettes in which a protagonist puppet felt one of the four emotions (anger, happiness, fear, or sadness). Each puppet response was a stereotypical response to the situation (e.g. expressing fear when left alone in the dark). The experimenter acted out each vignette, providing the child with facial and vocal cues of each emotion. After each situation, the experimenter asked the child to identify which of the four faces the puppet felt (i.e. “How does he/she feel?”). The three components of the AKT thus require children to recognise and to label emotional faces, and to identify the most appropriate facial expressions for emotional scenarios. The total testing time for the AKT was approximately 10–15 minutes per child.

For each individual question asked of the child during the AKT, they could receive a score of 0, 1, or 2. A child received a 2 for their response if they provided the correct answer. A child received a 1 if they provided an incorrect answer, but of the correct emotional valence (positive or negative; e.g. if the correct answer was “sad”, but the child’s response was “afraid”). A child received a 0 if their response was incorrect and of the incorrect valence. Thus, for the expressive and receptive components, the maximum possible score was 8 and the minimum possible score was 0. For the stereotypical situation component, the maximum possible score was 16 and the minimum possible score was 0. From these values, a “total AKT” score was calculated for each child, which was an aggregate of their scores in the three AKT components. Therefore, the maximum total AKT score was 32 and the minimum possible score was 0.

Results

Statistical analyses

For time points T1, T2, and T3 emotion matching scores were calculated from infant looking times in the eye tracking task. First, we computed the proportion of looking to one face divided by total time spent looking to either face for a given trial. The emotion matching score was then calculated as the proportion of looking to the face that matched the emotion of the voice minus the proportion of looking to that face in silence. This was then averaged across the emotional- and neutral-voiced trials to produce one DV for each emotional trial type (angry-neutral, happy-neutral, and sad-neutral). This value indicated overall how much the child increased their looking to the face matching the emotional tone of voice from the silent to audio trials for each trial type.

Neutral looking was only compared across trials of the same emotion. For example, looking to neutral when paired with a sad face was never compared to neutral looking when paired with a happy face. All emotion matching scores were averaged to create a composite “overall matching” score for each time point. The overall matching score allowed us to measure developmental changes in individual infants’ overall emotion matching ability for angry, happy, and sad emotions. This was our primary outcome variable of interest because it most closely mirrors the result of the AKT by assessing multiple emotions at once. However, we also planned analyses to explore effects of each emotion separately to determine whether performance on any given emotional trial appeared more predictive than others.

Individual trials were removed from analyses if the child looked to the screen for less than two seconds of the 10-s trial. Outliers more than 3 standard deviations from the mean on any variable were excluded from analyses (T1 Happy emotion matching ($N = 1$); T3 Angry emotion matching ($N = 2$)). Emotion matching scores (T1, T2, T3) or AKT scores (T4) were used as dependent variables in all analyses.

Exploratory analyses conducted in the present study included independent samples *t*-tests to analyse for gender differences in emotion matching and emotion understanding. One-sample *t*-tests were used to determine whether infants as a group successfully emotion matched for each condition. An ANOVA was used to compare emotion matching across all 3 time points and emotions. Spearman rank-order correlations were used to determine whether emotion matching scores or a linear slope of change for emotion matching across 9–21 months predicted AKT scores. Additionally, a multiple regression analysis was used to assess whether a quadratic slope of change for the emotion matching trajectory across infancy predicted AKT scores.

Gender differences

To investigate gender differences, we ran independent samples *t*-tests on infant emotion matching (overall and separately for each emotion) and AKT (total score, as well as expressive, receptive, and situational component scores). No gender differences reached significance (all t's < 1.97, all p's > .05). Thus, gender was not included as a factor in any subsequent analyses.

Emotion matching development

To characterise infant emotion matching performance, we assessed whether infants, as a group, emotion matched at each of the first three time points. Emotion matching scores for each emotional condition are provided in Table 2. One-sample, two-tailed *t*-tests were used to assess whether infants' overall matching scores differed significantly from 0. To account for multiple comparisons based on the 3 time points, we used a conservative Bonferroni correction to an alpha level of .017. Overall emotion matching was not greater than 0 at T1 ($t(37) = .20$, $p = .842$, $d = .03$, *95% CI* [-.02, .03]),

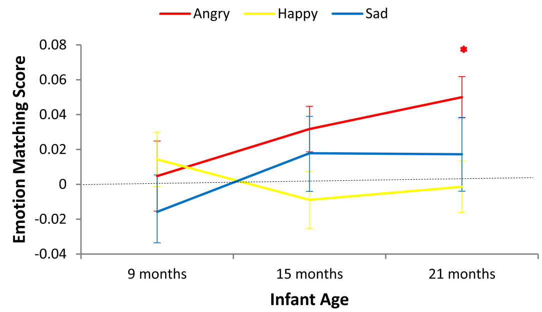

Figure 2. Infant emotion matching scores, with each age group and emotion category depicted separately. The dashed line represents emotion matching performance that is at chance. Error bars indicate standard error. A red asterisk above the 21-month time point indicates significant positive emotion matching for the angry condition at this age.

T2 ($t(36) = 1.36$, $p = .183$. $d = .22$, *95% CI* [-.01, .03]), or T3 ($t(36) = 2.03$, $p = .050$, $d = .33$, *95% CI* [.00, .04]). Overall time spent looking to the screen was comparable across the 9-month ($M = 133.02$ s, $SD = 22.39$), 15-month ($M = 129.51$ s, $SD = 25.82$), and 21-month ($M = 130.65$, $SD = 30.05$) time points.

To investigate whether emotion matching was modulated over time or by emotion, we conducted a 3 × 3 repeated measures ANOVA. The results revealed no significant main effect of time point ($F(2, 48) = .52$, $p = .598$, *partial* $\eta^2 = .02$), no significant main effect of emotion ($F(2, 48) = .18$, $p = .837$, *partial* $\eta^2 = .01$), and no significant interaction between time point and emotion ($F(4, 96) = 1.88$, $p = .121$, *partial* $\eta^2 = .07$). Thus, group emotion matching performance did not change significantly as infants got older, and their performance did not differ significantly for the three emotions (see Figure 2).

We analysed performance for each emotion at each time point, accounting for the familywise error rate across 9 distinct tests using a conservative Bonferroni correction to adjust the alpha level to .006. The only condition for which average infant performance were significantly above chance was Angry at T3 ($t(32) = 3.81$, $p = .001$, $d = .66$, *95% CI* [.02, .08]). Infant

Table 2. Emotion Matching Scores (Higher values indicate increased preference for matching face, lower values indicate increased preference for mismatching face).

	Time 1 (9 months)		Time 2 (15 months)		Time 3 (21 months)	
Condition	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Angry	0.01	0.13	0.03	0.08	0.05	0.08
Happy	0.01	0.10	−0.01	0.10	0.00	0.09
Sad	−0.02	0.11	0.02	0.14	0.02	0.13
Overall	0.00	0.08	0.01	0.06	0.02	0.06

Table 3. Number of infants with each looking preference.

	Familiarity Preference	No Preference	Novelty Preference
Time 1	18	6	14
Time 2	18	8	11
Time 3	18	11	8

performance on the eye tracking task across time points was not correlated (T1 to T2: ρ=.06, $p = .747$; T2 to T3: ρ=.22, $p = .207$; T1 to T3: ρ=-.001, $p = .995$), indicating a lack of stability in emotion matching performance from 9- to 21-months, which was expected given the substantial developmental change that occurs across these 6-month intervals in infancy. Importantly, this also suggests that infants do not demonstrate significant linear improvement in emotion matching across 9- to 21-months.

We grouped infants at each time point based on whether they exhibited a familiarity preference, novelty preference, or no preference (Table 3). Although the majority of infants at each time point exhibited a preference, they were inconsistent in terms of whether it was for familiarity or novelty. Moreover, 21 of the infants changed preferences from T1 to T2, and 19 infants changed preference from T2 to T3.

Emotion understanding

Scores on the AKT at T4 are presented in Table 4. The AKT does not have cut-offs to indicate passing or failing. Higher values indicate higher levels of emotion understanding, and chance levels of performance would result in an overall AKT score of 8. We observed substantial variability in performance (scores ranged from 2–24 out of possible scores from 0-32) on the AKT, despite the narrow participant age range (29.21-30.75 months). Cronbach's alpha for the total AKT was .68. The 30-month-old participants in this study received an average total AKT score of 14.69 ($SD = 5.09$), which is comparable to the average score of 15.43 ($SD = 8.47$) among 2- to 3-year-olds in Denham's (1986) contextual validation study. The validation study, however, did include an additional six non-stereotypical puppet scenarios which may have contributed to the slightly higher mean and larger standard deviation than the present study. Therefore, if the average participant's proportion correct out of the total possible score is calculated, the participant scores for this study ($M = 0.46$) are slightly higher than that of the validation study ($M = 0.35$).

Table 4. Affective Knowledge Test Scores.

Category	Mean	Standard Deviation	Observed Range
Expressive	3.09	2.50	0–7
Receptive	4.57	2.56	0–8
Situational	7.03	2.44	0–11
Total	14.69	5.09	2–24

Predicting emotion understanding from emotion matching

Next, we investigated whether individual infant performance on the emotion matching task at T1, T2, or T3 predicted performance on the AKT at T4 (Figures 3–5). Overall emotion matching was used as the DV for these analyses, because typical emotion understanding tasks (e.g. Denham, 1986) test infant understanding of multiple emotions at once. When significant relations were observed, we followed up with analyses for each emotion separately to ascertain

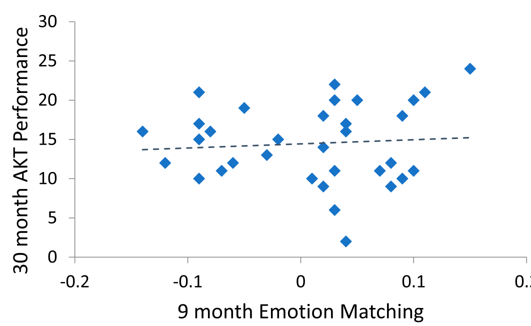

Figure 3. Scatterplot displaying the relation between emotion matching at 9 months and emotion understanding at 30 months. Dashed line represents linear line of best fit.

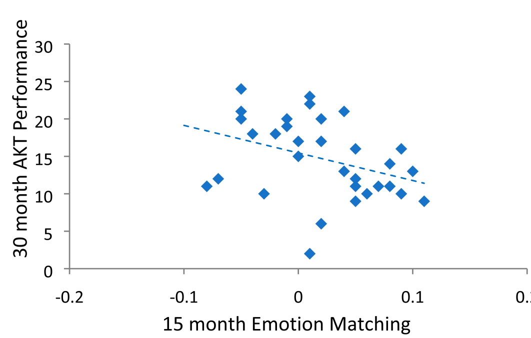

Figure 4. Scatterplot displaying the relation between emotion matching at 15 months and emotion understanding at 30 months. Dashed line represents linear line of best fit.

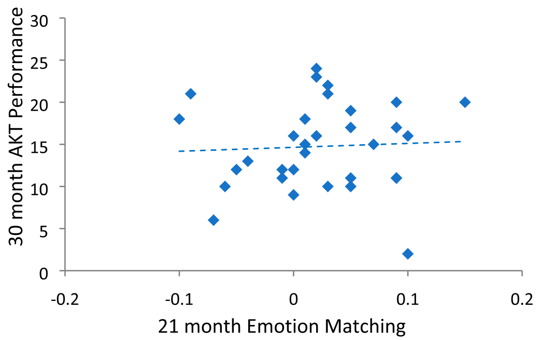

Figure 5. Scatterplot displaying the relation between emotion matching at 21 months and emotion understanding at 30 months. Dashed line represents linear line of best fit.

whether any emotion was particularly predictive of later performance.

We accounted for familywise error rates based on the 3 eye tracking time points using a Bonferroni correction to adjust the alpha level to .017. Results revealed that AKT performance was predicted by emotion matching performance (in particular, looking away from the matching face) at T2, but not T1 (9 months) or T3 (21 months) (Table 5). Inspection of the scatterplots presented in Figures 3–5 revealed no apparent bimodal distributions except for possibly at T1. However, a *t*-test comparing infants at T1 with emotion matching scores above and below 0 on their T4 emotion understanding revealed no significant difference between these two groups ($t(31) = .23$, $p = .823$).

We followed up on the significant relation at T2 by investigating the relation between AKT performance and T2 emotion matching for each emotion category separately (again adjusting the alpha level to .017 based on the three emotions), but none of these relations reached significance (Angry: ρ=-.08, $p = .671$; Happy: ρ=-.30, $p = .094$; Sad: ρ=-.25, $p = .170$). We also assessed whether overall T2 emotion matching related differently to the three components of the AKT. At an alpha level of .017, results revealed significant inverse relations to the expressive (ρ=-.45, $p = .009$), but not receptive (ρ=-.37, $p = .039$) or situational (ρ=-.04, $p = .825$) components of the AKT.

Table 5. Relations between 30-month emotion understanding and infant emotion matching.

	9-month emotion matching	15-month emotion matching	21-month emotion matching
Spearman's rho	−0.09	−0.42	0.1
p-value	0.632	0.016	0.580

Emotion matching trajectories and emotion understanding

Additional exploratory analyses were conducted to address the possibility that particular longitudinal trends across 9–21 months (rather than performances within an individual time point) were predictive of children's later emotion understanding. We did not have the sample size to conduct latent growth curve modelling, and so we computed each individual participant's linear slope of change and quadratic slope of change across the three emotion matching time points to determine whether either of these rates of change predicted later emotion understanding. Individual trajectories are depicted in Figure 6. Results revealed that the linear slope of change in overall emotion matching across 9-, 15-, and 21-months did not predict 30-month emotion understanding (ρ=-.12, $p = .512$). Similarly, a multiple regression analysis revealed that a quadratic pattern of change over time on the emotion matching task did not significantly predict early childhood emotion understanding ($F = 2.07$, $p = .147$).

Discussion

In the present study, we assessed infant emotion matching at 9, 15, and 21 months of age and early childhood emotion understanding at 30 months in a longitudinal design. Results revealed that as a group, infants did not significantly emotion match at 9, 15, or 21 months of age. We also found a significant *inverse* relation between 15-month emotion matching

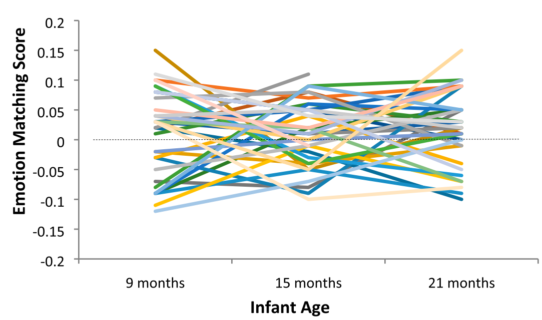

Figure 6. Line graph depicting change in emotion matching over time for each of the infant participants.

and 30-month emotion understanding. No other emotion matching time points were significantly predictive, contrary to our hypothesis that 21-month emotion matching would also predict later emotion understanding. Additionally, developmental trajectories of emotion matching across 9- to 21-months did not predict emotion understanding, and we did not observe any gender differences in emotion matching or emotion understanding.

Surprisingly, we did not observe significant developmental change in emotion matching from 9 to 21 months of age. As noted, prior work has demonstrated significant differences between groups of infants as young as 5- and 7-months in emotion matching (Walker-Andrews, 1986), and we anticipated that we would observe change in performance on our emotion matching task across the age range we tested. We observed reasonable variability in individual performance (see Table 2), and this may have made group-level change difficult to detect. It may be possible in future research to test a larger sample to determine whether any group-level change emerges. Additionally, a lack of developmental change as well as lack of significant emotion matching at each time point may reflect the fact that some infants demonstrated a novelty preference while others demonstrated a familiarity preference, thereby averaging to no significant matching in either direction. Despite a lack of group matching, individual differences may be informative for identifying whether a novelty preference vs familiarity preference was most predictive of later emotion understanding, as we identified among our 15-month-olds. It seems likely that infants may have been employing different strategies for how to engage with the audio-visual stimuli across the three time points, resulting in no significant overall change in performance across time. Thus, the present study adds valuable information to the literature regarding how to characterise typical emotion matching development from early to late infancy, as well as the lack of stability in individual differences for emotion matching across this age range.

Predicting emotion understanding across early development

Considering that emotion understanding appears to be stable in individuals from 3 to 6 years (Brown & Dunn, 1996), we investigated whether infant emotion matching at 9, 15, or 21 months would predict 30-month emotion understanding. We found that only 15-month overall emotion matching performance predicted emotion understanding, and it did so inversely. That is, a novelty preference on the emotion matching task at 15 months predicted later emotion understanding. Consistent with our hypotheses, performance at 9 months did not significantly relate to emotion understanding, perhaps due to the higher variability in emotion matching at this time point, which may reflect that the task was more challenging for this age group. Contrary to our predictions, however, 21-month emotion matching performance also did not predict later emotion understanding. This result may stem from a lack of suitability of our emotion matching task for older infants. Although our results indicated that the infants across all time points spent roughly equal amounts of total time looking to the screen, it is possible that the older infants were not engaging with the task in the same manner. For example, we speculate that 21-month-old infants may have been more concerned with identifying words in the speech stream than emotional content *per se*. Future research should investigate how infant processing of emotional speech may change across the first two years after birth.

The 15-month time point may have represented an age where the task was not too difficult for the infants, but the infants still attempted to emotionally match the stimuli. Additionally, overall emotion matching at 15 months (not any single emotion in isolation) predicted later emotion understanding. The infants who looked away from the matching face consistently across multiple emotions were more likely to have higher levels of emotion understanding in early childhood, indicating the potential importance of development of multiple emotion concepts (as opposed to one emotion being particularly important) within the first two years after birth. Also contrary to our initial predictions, linear and quadratic emotion matching development trajectories across 9- to 21-months did not predict later emotion understanding, perhaps because infant engagement with the task itself undergoes developmental change across these three time points.

Much remains unknown regarding performance on the intermodal emotion matching task over developmental time. Infants can exhibit a familiarity preference (looking more toward the familiar/matching stimulus),a novelty preference (looking more to the novel/non-matching stimulus), or neither. Typically, infants demonstrate a familiarity preference on tasks that are difficult, perhaps due to a continued interest in the familiar stimulus, and a novelty preference on tasks that are easy, due to boredom with the familiar stimulus (Hunter & Ames, 1988). In our task, 15-month-old infants demonstrating the novelty preference (presumably those who may have found the task easier) had higher levels of emotion understanding at 30 months, while 15-month-olds demonstrating the familiarity preference (those who found the task difficult) had lower levels of emotion understanding at 30 months. This finding is consistent with previous studies of emotion matching in infants (e.g. Palama et al., 2018), suggesting that infants recognise the match by looking *away* from the matching face (i.e. looking to the face that is novel relative to the voice). Our results with 15-month-old infants suggest that early in the second year after birth, a novelty preference on emotion matching tasks may be most indicative of developing emotion understanding. A question for future research is how other measures of infant emotion perception (e.g. habituation tasks, social referencing) might relate to later emotion understanding.

Additionally, it is important to note that 15-month emotion matching predicted some aspects of the AKT better than others. That is, 15-month emotion matching significantly predicted the expressive portion of the AKT (labelling faces), but not the receptive or situational portions (identifying faces that match emotion labels and recognising which emotional face is an appropriate response to a situation). This pattern of results aligns with the possibility that perceiving consistencies across emotional faces and voices may provide a foundation for later emotion understanding, such that emotion understanding skills develop and relate to one another in a hierarchical fashion. That is, emotion matching may directly predict the more basic aspects of emotion understanding early in life (e.g. emotion labelling), and the knowledge of emotions in more complex scenarios may build on this skill later in the preschool years. If this is the case, we may expect that emotion matching predicts emotion labelling at 30 months, and situational aspects of emotion understanding later in the preschool years. This question also remains for future research.

Gender differences

We observed no gender differences in emotion matching or emotion understanding at any time point in this longitudinal study. Prior work has been mixed on this topic. Some studies reported gender differences, with girls outperforming boys in early emotion understanding and perception tasks (e.g. Brown & Dunn, 1996; Caron et al., 1982; Denham et al., 2015; Dunn, Brown, Slomkowski, et al., 1991; Ontai & Thompson, 2002) and infant girls showing more expressions of interest than boys (Malatesta & Haviland, 1982), but other studies found no gender differences in emotion understanding or emotion word production (e.g. Dunn, Brown, and Beardsall, 1991; Fabes et al., 2001; Grazzani et al., 2016). Although our study may have been underpowered to detect a gender difference, we observed little indication of gender differences in emotion matching and emotion understanding from 9- to 30-months after birth. We see two possible reasons. First, gender differences in emotion understanding may emerge at a later age, and are not yet present within the first 30 months. This would be consistent with findings that girls perform better than boys on emotion understanding tasks at age 3, but not age 2 (Ensor et al., 2011). Secondly, gender differences in emotion perception may be diminishing across generations. Prior research has shown that parents discuss emotions differently with their sons than with their daughters (Adams et al., 1995; Fivush et al., 2000). However, gender equality movements have led to less stereotyped representations of gender (Leaper & Friedman, 2007), and a recent meta-analysis suggests that there are currently minimal differences in parenting of sons and daughters (Endendijk et al., 2016). Thus, perhaps parent discussions of emotions with their children may be less gender stereotyped, facilitating comparable emotion matching and emotion understanding performance among young boys and girls. Further research is necessary to explore this possibility.

As the first study to address how emotion matching in infancy relates to later emotion understanding, some of our analyses were exploratory. Future research should follow up on these results with an independent sample to confirm this pattern of results. In addition, the test-retest reliability of eye tracking emotion matching tasks remains largely unknown and should be clarified. Also, as infants may demonstrate an understanding of matching information via either a familiarity preference or a novelty preference, interpreting these results can be complex and it remains for future research to confirm the finding that a novelty preference at 15-months is predictive of later emotion understanding. Lastly, based on parental education, our infants seem to be generally from higher socio-economic status backgrounds. This may impact the generalizability of the results.

Conclusion

The present longitudinal study found a significant relation between individual differences in 15-month-olds' performance on an emotion matching task and emotion understanding at 30 months, building on prior research that has demonstrated stability in emotion understanding from 3 to 6 (Brown & Dunn, 1996) and 7 to 12 (Pons & Harris, 2005). Our results suggest that developmental continuity in emotion understanding may have its origins in infancy, and that emotion matching may serve as a developmental precursor to emotion understanding. However, this was only the case for emotion matching at 15 months of age. Future research is necessary to identify why emotion matching at this age may be particularly important for later emotion understanding, as well as how wide the age range may be that predicts early childhood emotion understanding.

To conclude, this longitudinal study provides novel insight into the development of early emotion understanding. Our results suggest that infant emotion matching at 15 months is predictive of child emotion understanding performance at 30 months. Thus, it can be inferred that infant emotion perception holds implications for long-term emotional development. Ultimately, these results extend our knowledge of how emotion understanding develops and provide a potential timeline for when this skill may begin to stabilise.

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