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An Eye Tracking Investigation of Attentional Biases Towards Affect in Young Children

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This study examines attentional biases in the presence of angry, happy and neutral faces using a modified eye tracking version of the dot probe task (DPT). Participants were 111 young children between 9 and 48 months. Children passively viewed an affective attention bias task that consisted of a face pairing (neutral paired with either neutral, angry or happy) for 500 ms that was followed by a 1,500-ms asterisk probe on 1 side of the screen. Congruent trials were trials in which the probe appeared on the same side of the screen as the emotional face and incongruent trials were trials in which the probe appeared on the opposite side of the emotional face. The latency to fixate on the probe, rather than the traditional task's button press latency, was measured for both types of trials and a bias score was calculated by subtracting the latency to the probe on congruent trials from that on incongruent trials. The results of the current study indicate positive internal reliability of this modified version of the DPT as well as the presence of a bias toward both angry and happy faces during the first 4 years of life. The successful use of the modified version of the DPT for use on the eye tracker presents a promising methodological tool for research on early attentional behavior and provides a tool for comprehensive longitudinal studies of identified risk factors for anxiety.

Keywords: emotion, attention bias, early childhood

Infants encounter emotional facial expressions regularly during their first months of life, and there is evidence that infants are sensitive to different emotional expressions very early in development. During the first week, infants have a basic preference for happy faces (Farroni, Massaccesi, Menon, & Johnson, 2007). By 4 months, infants can discriminate between emotional faces of opposite valence following exposure via a habituation paradigm (Walle & Campos, 2012). Further, when additional sensory information is provided (e.g., voice or dynamic facial expressions), 4-month-old infants can discriminate between different negative emotions (Happé & Frith, 2013). By 7 months of age, the emotional detection system has developed to the point that infants can visually discriminate between most of the basic human facial expressions, ranging from happy to angry faces (Hoehl, 2014).

In addition to the ability to discriminate between basic emotions, 7-month-old infants begin to show an overall visual preference for fearful faces (Peltola, Leppänen, Mäki, & Hietanen, 2009). This preference is further supported by evidence of neural signatures suggesting vigilance for fearful faces. Across studies utilizing event-related potentials (ERPs), an increased amplitude of the Nc (negative central) component is seen in 7 month olds viewing fearful compared with happy faces (deHaan, Belsky, Reid, Volein, & Johnson, 2004). The amplitude of the Nc component is classically related to attention allocation to a visual display. Even more striking is that the amygdala, a medial temporal brain structure related to emotion-attention interactions, reaches an adult like state during the same time that an infant's visual abilities begin undergoing increasing experience-driven growth and refinement (Adolphs, 2002; Leppänen & Nelson, 2009).

Threatening information in the environment is highly salient and is thought to automatically attract attention across the life span (LoBue, 2009; Öhman & Mineka, 2001). To measure this attentional allocation and response toward threatening stimuli in older populations, Macleod, Mathews, and Tata (1986) presented a novel visual attention paradigm, the dot probe task (DPT) to individuals with anxiety. This task has since been used in decades of research on attentional biases to threat and is now considered the "gold standard" for identifying attentional biases toward threatening stimuli. Attentional biases toward threatening information have been linked to anxiety symptomology across different age groups and multiple different clinical and subclinical populations (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007 for review). Some cognitive models of anxiety suggest that these attentional biases toward threatening stimuli play a critical role in the etiology and maintenance of clinical anxiety symptoms (Daleiden & Vasey, 1997; Hadwin, Garner, & Perez-Olivas, 2006). This pattern of attentional allocation as measured by the DPT has even been targeted in attentional training paradigms that, in some studies, have shown to alleviate anxiety

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levels (Bar-Haim, 2010; Hakamata et al., 2010; Waters, Pittaway, Mogg, Bradley, & Pine, 2013).

Researchers commonly utilize the DPT with emotionally valenced words or pictures to identify and quantify attentional biases (e.g., Koster et al., 2004; MacLeod et al., 1986; Mogg & Bradley, 1999; Mogg, Bradley, de Bono, & Painter, 1997; Salemink, van den Hout, & Kindt, 2007). The DPT with threatening stimuli has been used extensively in anxiety research, though many methodological variations of the task exist (for review see Bar-Haim et al., 2007). Some studies have used varying exposure time to the emotional stimuli (Mogg et al., 1997; Waters, Kokkoris, Mogg, Bradley, & Pine, 2010). Even the spatial layout of the task has varied, with some studies presenting the paired stimuli on the left and right side of the screen and some presenting the images on the top and bottom of the screen (see Bar-Haim et al., 2007 for review of common DPT variations). The classic administration of the task consists of a stimulus pairing (emotion related word or image paired with a neutral word or image) presented simultaneously on a screen. These stimuli rapidly disappear and are immediately followed by a simple visual probe (asterisk or cross-hair) presented on one side of the screen. The participant is instructed to push a button response as quickly and accurately as possible to indicate the side of the screen in which the probe appears. A faster response time to probes that appear on the side where the emotional face or word was presented indicates an "attentional bias" toward that emotional stimulus; that is, the individual's attention was drawn to that side of the screen causing him or her to more quickly detect the probe.

The DPT is specifically designed to investigate the attentional reaction to the presence of affect rather than processing of affect itself. The DPT is not aiming to investigate exogenous attentional patterns to overt visual exploration of the faces, especially given the quick speed with which the faces are often shown. At this rapid presentation rate we would not expect differential looking patterns to the faces (e.g., more looking to the eyes in fearful faces vs. neutral faces), but the task is instead designed to investigate reaction to a more gestalt processing of the presence of the faces.

Although attentional biases (specifically those toward threatening information) are commonly investigated in the anxiety literature, their presence is rarely investigated in typically developing populations. Although there is evidence that adults with clinical levels of anxiety (but not those without anxiety) are likely to be attentionally biased toward threat (Bar-Haim et al., 2007), it is unknown if that pattern develops over time or if it is present early in life. Some studies have shown that threat related attentional biases are typical for all children, regardless of anxiety level (Ehrenreich & Gross, 2002; Kindt, Bierman, & Brosschot, 1997; Kindt, Brosschot, & Everaerd, 1997; Morren, Kindt, van den Hout, & van Kasteren, 2003). Waters, Lipp, and Spence (2004) showed that although anxious 9- to 12-year-old children showed a greater attentional bias toward affective stimuli overall, both anxious and nonselected children showed attentional biases toward threatening stimuli. In a separate study, Waters, Wharton, Zimmer-Gembeck, and Craske (2008) showed that nonanxious children ages 8 to 12 years showed no attentional bias.

Some have theorized that nonanxious individuals learn to inhibit this threat bias as they age, while children with anxiety do not (Kindt & van den Hout, 2001). If this is the case, one would expect to see a threat-related bias in all young children. Other researchers have posited that attentional biases toward threat are specifically linked to anxiety that develops early during development (Kindt & van den Haut, 2001). Thus, although there is some evidence to support the theory that all young children have a bias toward threat that goes away over time, the literature remains unclear, and the lack of a task that is comparable to the one used in older children and adults has prevented researchers from investigating the development of these biases in very young children. Development of such a task is an important step toward understanding the developmental trajectories of these biases.

Although the DPT is widely used to measure attentional biases across many diverse experimental conditions, and presents as a strong candidate task for this purpose, problems with reliability and internal consistency are commonly reported. Schmukle (2005) reviewed these discrepancies and investigated internal consistency and test–retest reliability of both a threatening word and a threatening image version of the DPT. Both versions of the task showed poor internal consistency and poor test–retest reliability. Numerous other studies have shown poor reliability measurements of the classic version of the DPT (Kappenman, Farrens, Luck, & Proudfit, 2014; Staugaard, 2009). Conversely, some studies that have investigated reliability of the DPT have shown the task to have good internal consistency (Bar-Haim, 2007). The literature remains mixed as to the reliability of the traditional manual reaction time (RT) version of the task for consistently measuring attentional behavior.

To try to better capture true, reliable attentional behavior on the DPT, multiple different neuroimaging techniques have been employed, though none deal with developmental populations. Kappenman et al. (2014) used an ERP version of the task that would be better able to capture the initial attention shift to the emotional stimulus. The ERP component N2pc acts as a measure of attention that can be time-locked to the presentation of the affectively arousing stimulus to better measure attentional biases directly. Using these methods, Kappenman et al. (2014) showed a group level bias toward threatening images that was related to an attention shift that occurred 186ms after the onset of the image, a shift so rapid that it would not have been picked up by the standard button response. Along a similar vein, Carlson, Reinke, & Habib, (2009) showed backward masked fearful faces in an fMRI DPT and only presented the emotional faces for 33 milliseconds, providing support for the attentional system's ability to very rapidly orient to emotional stimuli. Price et al. (2014) also utilized the DPT in the fMRI environment with two different conditions, a face presentation time of 200 ms and 2,000 ms. They showed that anxious participants were vigilant for threat on the short trials but showed avoidance of threat on the long trials, providing insight into the neural processes underlying the task and giving support to maintaining a short presentation time of the face stimuli in the DPT to capture group differences in emotional biases.

In the classic administration of the DPT, the behavioral button press response to the location of the probe represents multiple distinct neural processes that are occurring between the presentation of the visually presented stimuli and the motoric identification of the probe location. This potentially presents a challenge with the classic administration of the task, in that the attentional processes that are related to the processing of the stimulus are occurring temporally before the motor response to the probe. Therefore, the task is measuring related, but downstream attentional behavior and is only indirectly measuring the attentional system's response to the presence of the emotional stimuli. Research has shown that visual attention shift can occur in under 100 ms (Müller & Rabbitt, 1989); which, in the case of the classic administration of the dot probe task, indicates that after initially attending to the emotional stimuli an individual's attentional system may become disengaged before the probe appears. This may contribute to the lack of reliability in the versions of the DPT that utilize different stimulus presentation times.

Along with mixed findings on reliability of the task, another shortcoming of the classic administration of the DPT is that it requires a level of compliance and basic cognitive capacity that is either not present or insufficiently developed in populations under 5 years. The dot probe task has been used in developmental populations down to 5 years, but it is thought that 5 years is the cusp of when the traditional version of the dot probe task can be performed reliably, given the instructional demands and response requirements (Perez-Edgar et al., 2010). Because of this methodological limitation, little is known about attentional biases toward affective information in populations under 5 years, or how these specific biases potentially change across the first few years of life. If an attentional bias to threat in individuals with anxiety is shown to be a persistent pattern present from infancy, the presence of that bias presents a potential candidate for early detection of anxiety.

Infrared eye tracking provides a promising opportunity to circumvent the timing related criticism of the DPT as well as adjusting the task to be more appropriate for younger populations. Eye tracking can be used across all ages and is ideal for use in infancy due to the passive viewing component (Oakes, 2010, 2012). Although ERP can provide a temporally more precise measurement of the neural processing related to attentional bias, it has some limitations including lengthy administration time, the requirement that the participant be able to tolerate having an EEG cap placed on their head and strict nonmovement requirements. Infrared eye tracking can be carried out via completely passive viewing, has a briefer administration time and can allow for greater (though still limited) participant movement. Thus, eye tracking is appropriate for infant populations as well as populations with developmental disorders that would preclude successful administration of either the classic or the ERP versions of the task. Transitioning the DPT into an eye tracking task also allows collection of an independent measure that is not complicated by the inclusion of the motor response and should help the measure better represent true attentional behavior. The neural pathway that the information is traveling (especially at the current speeds) is important because it precludes a lot of attentional control modulation and motor impacts that can confound the findings on the traditional version of the DPT. These variables are sometimes thought to be factors in reducing internal consistency and reliability and could be mitigated using eye tracking methodology.

The central timing and stimulus spacing parameters of the dot probe task lend themselves well to conversion to an eye tracking measure. Converting the button press response to a comparable eye tracking metric is simple given that the button press already exists as a proxy of visual processing speed and direction. Fixation latency is arguably a better measurement of this type of processing speed, so altering the task to measure latency to fixate to the probe rather than latency to press the button indicating the side of the probe may improve accuracy of the task (Price et al., 2014). This modified version of the original task is more directly tapping into the attentional and neural mechanism underlying the affective biases themselves. Previous eye tracking versions of the DPT that have been used in older populations have shown positive reliability measurements (Armstrong & Olatunji, 2012).

Although the proposed use of eye tracking version of the DPT in very young children in the investigation of attentional biases toward emotional faces is novel, there are currently a select number of studies that have used an eye tracking version of the dot probe task in other investigative contexts (Fashler & Katz, 2016; Yang, Jackson, Gao, & Chen, 2012). Though these studies do not necessarily focus on investigating attentional biases toward emotion, they demonstrate a useful application of the modified DPT in other populations and experimental contexts. These studies provide insight and promise into novel uses of eye tracking methodology in the DPT task.

Attentional biases toward threatening faces have been investigated across ages; however, few studies have also presented in-depth analysis of the DPT trials that use happy faces. In one such study, Waters et al. (2008) showed that seven- to 12-year-old children with generalized anxiety disorder showed an attentional bias toward both happy and angry faces. The lack of detail about performance to happy face trials in most dot probe studies leaves questions as to the developmental progression and endpoint of attentional patterns to both happy and angry faces. Is the attentional pattern shown by anxious individuals always threat specific? Or does that threat specificity develop from a more global vigilance for emotional faces? The present study is designed to address this question. We do not anticipate an overall attentional bias toward threat *specifically* given that the sample is an unselected community sample without an increased risk for anxiety. However, given the age range of our sample, we predict that there will be a significant bias toward affect overall— to both happy and angry faces. Given that it has been reported that typically developing adolescents and adults do not show attentional biases to threat, we hypothesize that magnitude of attentional bias will be negatively correlated with age, with the oldest children in the sample showing less attentional biases than the infants.

In the current study, we must first investigate the feasibility of utilizing a passive viewing dot probe paradigm administered on an infrared eye tracker to investigate attentional biases for happy and angry faces in a clinically nonselected population of infants and young children. Considering the mixed reliability results of the traditional version of the task in older populations, we must also document the internal reliability of the task within subject in this young age group. Given the previously demonstrated inconsistency of DPT reliability measurements, it is important to investigate the psychometric properties of this new version of the task before interpreting the results of the task. We hypothesized that this eye tracking version of the DPT would have a high participant completion rate given that it employs passive viewing, has a shorter task duration compared with the original, and it utilizes social stimuli that tend to capture attention well. Given acceptable psychometric properties, the current study then aims to identify the distribution of attentional biases toward both angry and happy faces in the first 4 years of life.

Method

Participants

A total of 128 children were recruited for the current study. Twelve children were excluded from the final sample, seven for bias scores that qualified as outliers (greater or less than three standard deviations away from the mean), five for fussiness before the task was administered and five for providing data on an insufficient number of trials (less than 20% or 16 total trials). The excluded participants did not differ from the larger sample on age, gender or ethnicity. A total of 111 children (47 female) between the ages of 9 months and 48 months (mean age = 23 months 12 days; range = nine months 13 days—48 months 28 days) made up the final sample in the current study. Sixty-eight of the participants were Caucasian, four were Asian, four were African American, 35 identified with multiple races, and race was not reported for two participants. Across these racial groups, seven were reported to be Hispanic. Fifty-nine percent of the mothers had earned at least a bachelor's degree. Children were recruited through letters to families in surrounding areas around Davis, California and were given a certificate and a children's book for participating in the study. The Institutional Review Board of UC Davis approved the experimental protocol, and informed consent was obtained from a parent or caregiver of each participant.

During the visit parents completed a demographic form and an age appropriate version of the Carey Temperament Scales (CTS). These scales were selected for the current project given the age range with which the scales reliably measure temperament and the wide age range of our study population. There are five different versions of the CTS, each appropriate for a different age range between 1-month and 12-years and each standardized to measure the same nine temperament subscales: activity, rhythmicity, approach, adaptability, intensity, mood, persistence, distractibility and threshold. We utilized the Revised Infant Temperament Questionnaire, which is appropriate for 4-to-11-month-old infants, the Toddler Temperament Scale which is appropriate for 1-and-2-year-old children and the Behavioral Style Questionnaire, which is appropriate for 3-to-7-year-old children.

Apparatus

Stimuli were presented on a 17-inch Tobii 1750 LCD binocular eye tracker (1,280 × 1,024 pixels resolution) to record infants' fixations during the task. Eye tracking data were collected at a sample rate of 50 Hz. The average accuracy of the recorded eye coordinates was about 0.5°, which is approximately 0.5 cm at a viewing distance of 60 cm. The average accuracy in timing was 25–35 ms. Drifts are compensated with an average error of 0.5°. When one eye could not be measured, data from the other eye were used to determine the gaze coordinates. The recovery time to full tracking ability after an offset was about 100 ms. Fixations were defined using the Tobii fixation filter, such that maximum angle between fixations was 0.5° and fixations had to be longer than 60 ms. Video stimuli were created using iMovie and were displayed using Tobii Studio. A standard five-point Tobii calibration was completed for all participants. Recalibration occurred if any single point was missed and the task was not started until all 5 points had a successful calibration.

Stimuli

For the sake of experimental control considering the major task response modification, timing parameters of the modified DPT were consistent with other dot probe tasks that have been completed with young populations (Perez-Edgar et al., 2010). The dot probe task was presented in two blocks, each consisting of 40 trials (See Figure 1 for task details). The task began with a 1,000-ms central fixation cross, followed by a 500-ms face pairing that was followed immediately by a 1,500-ms asterisk probe that appeared in the same spatial location as one of the previous faces (see Figure 1). There were three categories of face pairings: 31 angry paired with neutral, 32 happy paired with neutral, and 17 neutral paired with neutral. Expressions were modeled by 28 different actors from the NimStim stimulus set (Tottenham et al., 2009). The angry, happy, neutral closed mouth images of 14 male and 14 female Caucasian, African American and Asian faces were used. Images were trimmed so that all hair was edited off the image leaving a standardized oval space filled with only the face of the actor. Identity, sex and race of the face as well as emotion and probe side were all randomized. A trial was identified as congruent if the probe appeared in the same location as the immediately preceding emotional face, and incongruent if it appeared on the opposite side of the screen (in the same place as the preceding neutral face). Trail congruency was counterbalanced and randomized throughout the task.

Data Analysis

A trial was included in the analysis if the participant fixated the probe during the 1,500-ms probe presentation time. An overall bias score was calculated for each participant by subtracting the average latency to fixate to the asterisk probe on congruent trials from the average latency to fixate to the asterisk probe on incongruent trials. A positive value thus represented a vigilance for or bias toward the emotional face, a score around zero indicated no bias toward the emotional face and a negative score indicating a bias away from or an avoidance of the emotional face.

Given the wide age range of the current study, analyses were carried out using age as a continuous variable and again with age

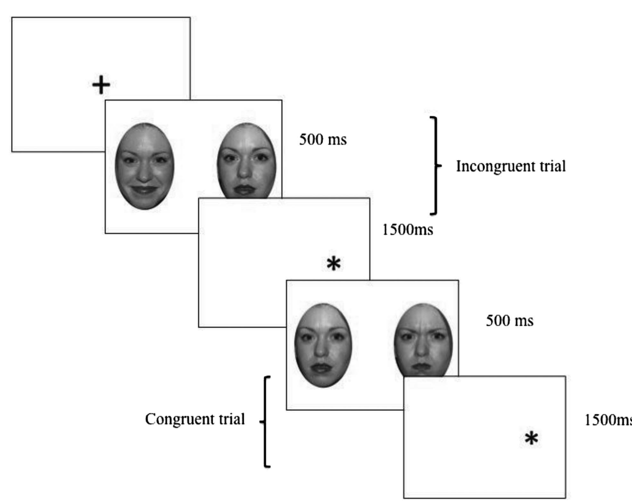

Figure 1. Trial sequence of the dot probe task. Error bars represent standard errors.

treated as a categorical variable to investigate not only any effects related to continuous development, but the potential presence of changes by developmental stages giving the vast development that occurs across the first four years of life. The sample was separated into three age groups representing the youngest, middle and oldest children in the sample. This age breakdown is presented in Table 1.

Infants were also grouped based on their bias patterns, with individuals with a score above 40 being placed into a "biased towards" group, those with a score between 40 and −40 being placed into a "no bias" group and those with a score less than −40 being placed into a "biased away" group (Perez-Edgar et al., 2010). Given the novel dependent measure, we chose to define these cutoffs based on similar cutoffs from previous versions of the task (Perez-Edgar et al., 2011). A tercile split of the threat vigilance group's mean bias scores in Perez-Edgar et al. (2011) resulted in a cutoff of 40. Therefore, we centered our groups at zero to investigate the magnitude of the scores in either the biased or the avoidant direction, with scores between −40 and 40 indicating no significant difference from zero and scores above 40 and below −40 indicating a bias toward or away from the emotion, respectively. Infants were grouped based on these parameters to angry and happy trials separately to investigate possible differences in affective biases.

Results

Reliability Analysis

On average, participants successfully fixated the probe on 68.7 out of 80 trials or on 85.88% of the task. Number of trials completed was positively correlated with age $r(109) = 0.32$, $p < .001$, with the older children contributing more trials than the youngest participants. Regardless of this correlation, all age groups completed an average of greater than 80% of the total trials, showing that although age is related to completion percentage, adequate completion of the task is not contingent on age. See Table 1 for a breakdown of number of trials completed per age group.

To measure internal consistency on the modified DPT, within subject split-half correlations were calculated. Split-half correlations have been reported for multiple versions of the dot probe with similar number of trials before (Brown et al., 2013, Schmukle, 2005). Split-half methodology was selected to investigate how individuals' performance on similar types of trials correlated within each individual's task session, rather than investigating correlations between individuals. Correlations were calculated separately for congruent and incongruent trials. All trials in which the participant never fixated on the probe were excluded from the calculations. This resulted in individual participants providing latencies to detect the probe on a range between 18 and 30 congruent trials and 20–48 incongruent trials with an average number of 26.68 congruent trials (out of a total of 31) and 40.87 incongruent trials (out of a total of 49). The proportion (out of the total number of trials of the type) of congruent and incongruent trials was not significantly different, $t(109) = 1.83$, $p = .07$, $d = 0.24$.

These latencies were randomized within subject to prevent any possible trial order effect and were separated into two equal halves. When there was an unequal amount of trials a single latency value was selected at random and deleted. The two halves were then correlated with one another. Those correlation values were averaged across all participants, and those averages were corrected for length using the Spearman–Brown formula. The average correlation coefficient for the total sample on congruent trials was $r = .50$, $p < .001$ and was $r = .41$, $p < .001$ for incongruent trials. Although both were significantly correlated, a paired samples t test revealed that the correlation values between the two halves of congruent trials were significantly greater than the correlation values between the two halves of incongruent trials $t(110) = 3.70$, $p < .001$, $d = .66$. Age was not correlated with reliability correlation values for either congruent, $r = -.05$, $p > .05$ or incongruent, $r = .04$, $p > .05$ trials.

Task Performance

Group mean and standard deviation values for bias toward angry and happy faces are presented in Table 1. To investigate group level performance on the task, average bias scores to happy and angry faces were directly compared. There was not a significant difference between the samples' average bias scores to the two emotion conditions, $t(110) = .52$, $p = .61$. The group level bias to angry faces was significantly greater than zero, $t(110) = 4.54$, $p < .001$, as was the bias toward happy faces, $t(110) = 3.69$, $p < .001$. Bias toward happy and angry faces was not significantly correlated, $r = -.18$, $p > .05$. Age in months (as a continuous variable) was not significantly correlated with either happy bias or angry bias. After grouping the children by age into three equally sized age groups, a repeated measures analysis of variance (ANOVA) showed no main effects of emotion or age group and no interaction, indicating that the biases toward emotion did not systematically differ by age. There was no significant difference between genders for either angry or happy bias scores (ps >.05).

Although the bias scores did not change with age, the raw fixation speeds on incongruent and congruent trials were themselves negatively correlated with age. The average latency to

Table 1
Number of Trials and Performance to Emotion by Age Group

Participants	Age range	Number of trials		Angry bias		Happy bias	
	M (range)	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range
Whole group (*N* = 111)	23.27 (9.13–49.14)	68.66 (9.57)	37–80	42.14 (97.72)	−179.81–248.50	34.70 (99.19)	−194.07–253.34
Younger age group (*N* = 35)	11.21 (9.13–13.29)	65.26 (10.99)	40–80	34.95 (104.90)	−179.81–223.32	50.63 (108.68)	−194.07–223.74
Middle age group (*N* = 36)	20.15 (15.20–24.28)	67.42 (9.67)	37–80	50.17 (105.81)	−117.17–248.50	26.36 (89.98)	−128.20–226.72
Older age group (*N* = 40)	38.08 (25–49.14)	72.75 (6.34)	58–80	41.22 (84.77)	−141.60–194.12	28.27 (99.25)	−179.95–253.34

Note. Age = months.days.

congruent trials (the trials in which the emotional faces and the probes are on the same side) were negatively correlated with age, $r = -.30$, $p = .001$ and the average latency to incongruent trials (the trials in which the emotional faces and the probes are on opposite sides) was negatively correlated with age, $r = -.38$, $p <$ .00. These correlations indicate that the older children have faster latencies overall. The latencies on congruent and incongruent trials were highly positively correlated, $r = .72$, $p < .00$, showing good internal consistency for the task. This also provides support for using the traditional bias score, which is a difference score between latencies on incongruent and congruent trials, which will standardize this age difference across this wide age range so the magnitude of the initial latencies is not the variable being use, but, more correctly, the difference between the incongruent and congruent trails' latencies.

To investigate the variability in the continuous bias scores, temperamental profiles were measured using the Carey Temperament Scales (Carey & McDevitt, 1995). No significant correlations were found between the *Z* scores for each temperament subscale and either happy or angry bias scores (all *p*s >.05). Similarly, no differences were found between *Z* scores for all nine temperament subscales when compared between bias categories for both happy and angry trials (all *F*s < 1). When investigating across the whole sample, only the Activity subscale was correlated with age, $r = .25$ ($p < .05$). Table 2 presents mean and standard deviations value for each subscale of the Carey Temperament Scales.

A great amount of variability exists in the current sample, making it challenging to interpret analyses that utilize mean values. This variability in bias scores can be seen in Figure 2. To mitigate for this large sample variability, and to further investigate performance on the task, a chi-square analysis was carried out with the proportion of the sample falling into each bias group (away, toward, no bias) compared with chance distribution for both happy and angry face trials. These bias score distributions can be seen for happy trials in Table 3 and for angry trials in Table 4. This analysis revealed significant biases for both happy, $\chi^2(2, N = 111) = 18.04$, $p < .001$, $r = .40$, $d = .88$, and angry, $\chi^2(2, N = 111) = 18.42$, $p < .001$, $r = .41$, $d = .89$, face trials. This indicates that a significant proportion of the sample is showing a bias toward these affective faces in the context of the passive viewing eye tracking task.

Table 2
Mean (Standard Deviation) Z Scores for the Subscales of the Carey Temperament Scales

Subscale	*M* (*SD*)
Activity	.18 (.85)
Rhythmicity	.19 (.90)
Approach	.20 (.98)
Adaptability	.07 (.97)
Intensity	−.15 (.83)
Mood	.01 (1.04)
Persistence	.49 (.88)
Distractibility	.01 (.92)
Mood	−.30 (.91)

Secondary Analyses

Once the primary analysis of latency to fixate on the probe was completed, an additional exploratory analysis was performed to investigate looking behavior to the face pairings themselves. Although the current timing parameters for the face pairings (500 ms) are rapid for a detailed analysis of looking behavior, we conducted the analyses to investigate any relation between looking patterns to the faces and looking to the subsequent probe. Each trial for each participant was analyzed for whether the individual was primarily fixating the neutral or the emotional face (either happy or angry depending on trial type) during the brief (500 ms) presentation of the face pairing. Mean looking times on trials in which participants either fixated the emotional or the neutral face, separated by trial type (angry or happy) are presented in Table 5. Importantly, no significant correlations were found between time fixating either the emotional or neutral faces and bias scores to the probe (all *p*s > .05). This indicates that actual visual fixation to the 500-ms face pairings is not directly related to latency to the probe at the current presentation speed.

To further explore time fixating the faces, we performed a repeated measures ANOVA with two within-subjects factors: trial type (angry or happy) and the face the child fixated (neutral or emotional) and two between-subjects factors: gender (male or female) and age group (younger, middle, or older). There was a significant main effect of trial type, $F(1, 109) = 12.29$, $p = .00$, $\eta_p^2 = .11$, and a significant trial type by gender interaction, $F(1, 109) = 15.28$, $p = .00$, $\eta_p^2 = .13$. Post hoc independent-samples *t* tests revealed that when comparing angry trials to happy trials, females (but not males) spent significantly more time fixating the angry faces than the happy faces, $t(90) = 2.36$, $p = .02$, and fixating the neutral faces on angry trials than the neutral faces on happy trials, $t(90) = 3.03$, $p < .00$, (see Figure 3). This indicates that regardless of which face the females are fixating on a given trial, overall they are looking for a greater amount of time on angry trials than on happy trials, although males are looking comparably to both faces on both angry and happy trials.

Discussion

Reliability

The first goal of the current study was to investigate the feasibility of modifying the dot probe task into an infrared eye tracking task that is appropriate for use in infancy and toddlerhood. We showed that this modified version of the task (removing the button press response and replacing it with latency to visually fixate on the probe) was successfully completed across all ages tested, validating the feasibility of administration of this version of the task to young populations. Although participants completed more trials of the task as they got older, the group as a whole, regardless of age completed on average 85% of the task (68.66/80 possible trials), and all age groups completed on average greater than 80%. At a group level the measure showed acceptable internal consistency with significant split-half correlations for both congruent and incongruent trials. This indicates that children are performing similarly on similar types of trials throughout the task. Keeping in mind that these types of attentional biases have been linked to anxiety, investigating split-half correlations within subjects is a

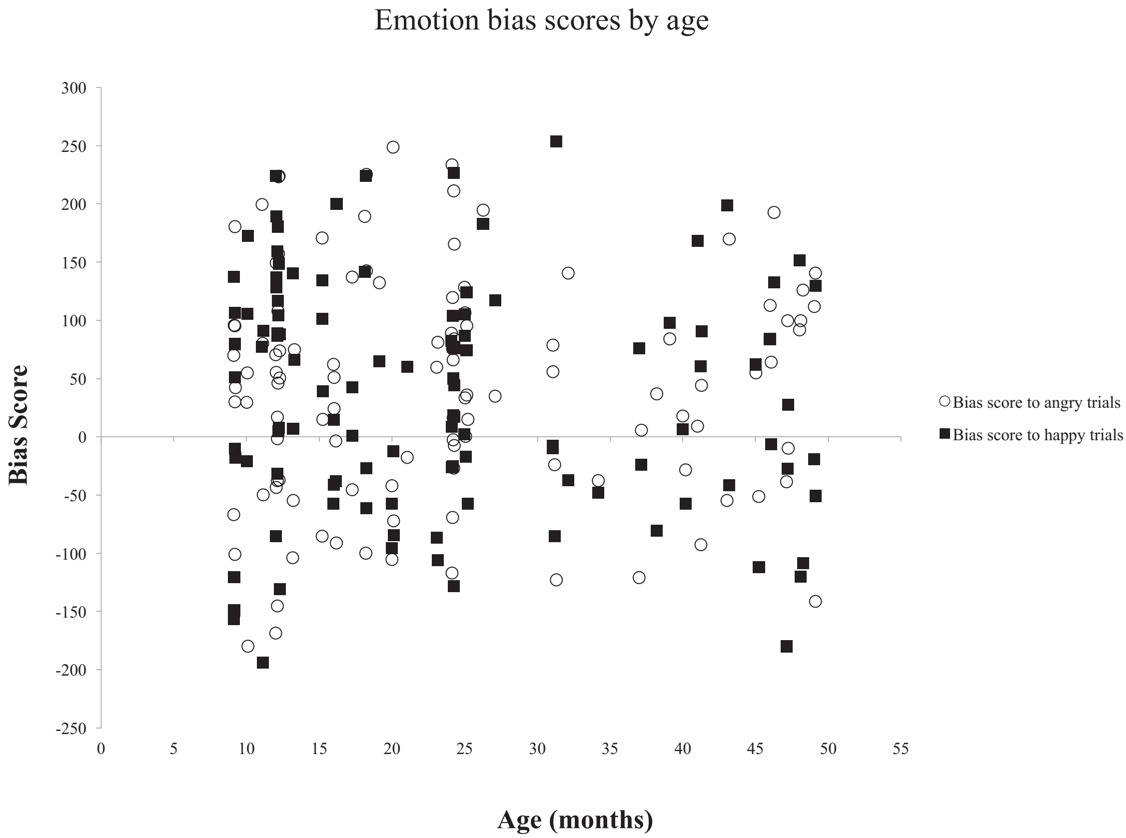

Figure 2. Emotion bias scores by age. Error bars represent standard errors.

better way to examine the reliability of the task than investigating correlations of performance between subjects who are expected to exhibit individual differences on the measure. Although significant correlations were observed for both congruent and incongruent trials, congruent trials showed a significantly higher split-half reliability correlation. This is perhaps not surprising given that over half of the sample was attentionally biased toward the emotional faces, so that trials in which the emotional faces are priming the location of the probe will have more consistent performance and thus show a higher correlation between trials. By contrast, the incongruent trials, although still showing a significant correlation between trials, are not as highly correlated as incongruent trials, given that there is no systematic priming for the location of the upcoming probe.

These results indicate that eye tracking can be a reliable and successful method with which to measure attentional biases using the DPT. The timing of the task (less than 3 min) was great enough to provide a large number of trials while remaining brief enough to make the task appropriate for use in infancy. The development of the modified eye tracking version of the DPT will allow for an expansion of research on attentional biases toward emotion in very young populations and possibly research into the developmental etiology of anxiety.

Task Performance

The second goal of the current study was to investigate how young children would perform on this modified version of the dot probe task given that DPT performance has never been reported for children less than 5 years of age. The current sample of typically developing children ages 9 to 48 months showed no significant difference between attentional patterns to trials with

Table 3
Distribution of Sample into Bias Groups for Happy Trials

Variable	Happy bias	No bias	Happy avoidance
Total *N*	56	29	26
Average age	22.08	24.18	26.20
Age range	9.13–49.14	9.14–49.05	9.13–49.11
Gender	22/34	12/17	13/13

Note. Sex = female/male; Age = months.days.

Table 4
Distribution of Sample into Bias Groups for Angry Trials

Variable	Angry bias	No bias	Angry avoidance
Total *N*	59	28	24
Average age	23.28	25.18	21.25
Age range	9.13–49.11	9.21–47.26	9.13–49.14
Gender	25/34	11/17	11/13

Note. Sex = female/male; Age = months.days.

Table 5
Mean (Standard Deviation) for Looking Durations to Faces

Participants	Looking to angry face	Looking to happy faces	Looking to neutral faces on angry trials	Looking to neutral faces on happy trials
Whole group	395.68 (80.55)	380.21 (71.36)	390.08 (71.11)	368.86 (78.95)
Females	402.58 (76.66)	367.12 (68.28)	397.12 (71.59)	345.76 (91.62)
Males	390.27 (83.71)	390.39 (72.63)	384.47 (70.84)	387.27 (62.05)

angry faces versus trials with happy faces, though both differ significantly from nonemotional trials. The biases to both angry trials and happy trials significantly differed from zero indicating that for both emotions participants were faster to visually detect the probe on congruent rather than incongruent trials. This indicates that a significant proportion of the sample's attention was drawn toward the emotional face when it was present. Evidence has been presented in the literature that indicates a lack of attentional bias toward affect in populations over age five that are not at risk for developing anxiety (Bar-Haim et al., 2007). The current data, demonstrating that a significant proportion of 9-month-old to 4-year-old children show attentional biases toward emotion, provides support for the theory that general attentional biases toward emotion are present in a large percent of the population early on. What remains to be seen is whether people's biases will lessen as they age, and whether the individuals whose bias toward threat specifically remains stable are at greater risk for developing anxiety (Kindt & van den Hout, 2001). The sample presented here is part of a longitudinal study measuring change in attentional biases toward affect through early childhood, and its link to anxiety symptomology, to better address these questions.

Although a significant proportion of the current sample fell into the "bias towards" emotion group, there was a significant amount of variability in the sample. This variability provides a key opportunity to investigate individual differences on attentional biases toward emotion. Previous research has shown that temperamental variables linked to behavioral inhibition are related to attention biases toward threat (Perez-Edgar et al., 2010, 2011). Perez-Edgar et al. (2011) showed that attention bias to threat moderates the relationship between a behavioral inhibited temperament and social withdrawal in early childhood. The current investigation failed to find a direct relation between temperamental variables and attentional biases to either angry or happy faces in this young sample, but given the indirect role between attention bias, temperament and anxiety outcomes reported in Perez-Edgar et al. (2011), we believe that temperament may still be a useful variable in understanding the attentional bias variability in the current dataset. It is possible that the relationship between these variables is not linear and additional longitudinal data linking temperament and attentional biases collected in infancy to later anxiety outcomes will be crucial to fully unpack the variability in bias scores on this modified DPT. Although the current study presents cross-sectional data, these data lend support to the idea that attentional biases toward emotional faces are stable across the first few years of life. Our ongoing longitudinal follow up of the current sample will shed greater light on the developmental trajectories of these types of attentional biases toward angry and happy faces. It is possible that with development these biases resolve, as Kindt et al. (1997) has hypothesized typically developing children learn to inhibit this bias as they develop and gain more advanced social abilities to draw upon. So as a child develops through middle childhood, into

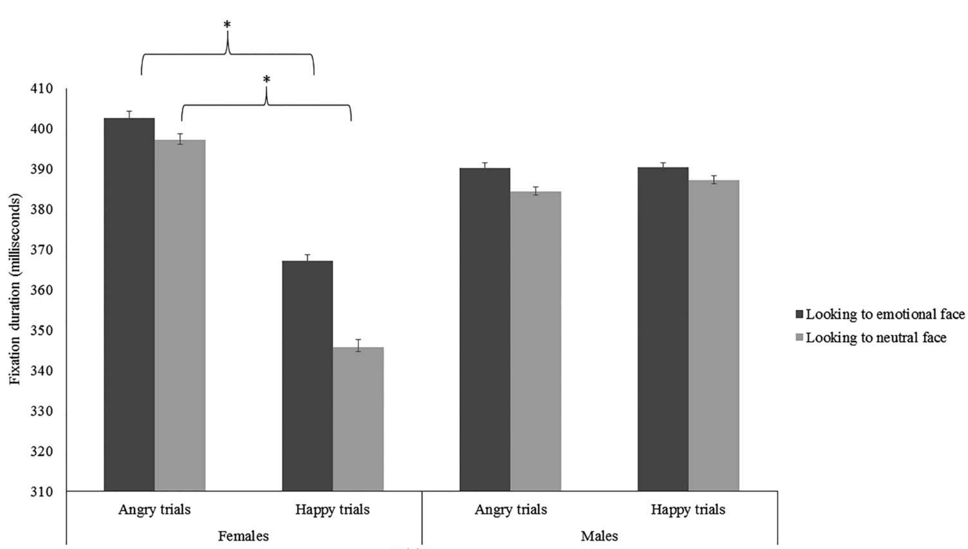

Figure 3. Average looking times to emotional and neutral faces. Error bars represent standard errors. Asterisks in this figure indicates $p < .05$.

adolescence and then throughout adulthood, emotion-processing abilities become more flexible and environmentally dependent (Lepännen & Nelson, 2009), but the current sample has an insufficient age range to directly investigate this question.

Secondary Analyses

The patterns in looking to the faces were not predictive of response latencies to the probes. Indeed, given the rapid speed of the face presentation, this is not all together surprising, Although it may continue to be valid to analyze looking to the faces on this new modified version of the DPT, the current study supports the traditional analytical approach of looking at latencies to the probe as the most informative metric for use with this novel, modified version of the task. Although visual attention to the presence of the face during the 500-ms presentation time is important in this task, actual visual fixation to the emotional stimuli is not. It seems that there is an overall effect of implicit attentional being drawn toward the emotional faces regardless of whether visual fixation upon the emotional face occurs.

The patterns that emerged with gender differences in attentional allocation to these rapidly presented faces indicate that females show a greater vigilance in the presence of angry faces than in the presence of happy faces. By contrast, males are showing this vigilance in the presence of both angry and happy faces. This seems to indicate a threat-specific vigilance in the female participants. Despite these differences in initial looking to the rapidly presented faces, however, no gender differences were observed in the latency-to-probe data.

Although the current study provides important validation measures of a new version of the DPT that will expand the literature for investigating attentional biases' impact on development, there are a number of limitations of the current work. Although the overall sample size is large for a study on young children, the sample sizes of each of the age groups is small and could be obscuring possible age effects. Future studies using this task (which has in the present paper been validated for use in infants as young as 9 months) should compare larger groups of infants at various age bands.

This early investigation of attentional biases toward both threatening and happy faces is a key step toward understanding the development of attentional biases toward emotion that have been linked to the etiology of anxiety in older populations. Shedding light upon these processes earlier in development can potentially provide an opportunity for early intervention to alter the outcome of anxiety in individuals who show a specific attentional bias toward threat. The current study shows that the DPT, a task that has classically been used to identify attentional biases toward threatening stimuli in the environment, can be successfully modified for use in younger populations and can provide insight into attention patterns toward emotionally salient information in the environment.

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