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Using Mobile Eye Tracking Technology to Examine Adolescent Daughters' Attention to Maternal Affect during a Conflict Discussion

Mary L. Woody[1], **Rebecca B. Price**[1,2], **Marlissa Amole**[2], **Emily Hutchinson**[2], **Kristy Benoit Allen**[3], **Jennifer S. Silk**[2,1]

[1]University of Pittsburgh, Department of Psychiatry

[2]University of Pittsburgh, Department of Psychology

[3]University of Tennessee, Department of Psychology

Abstract

Attention to socio-emotional stimuli (i.e., affect-biased attention) is an integral component of emotion regulation and human communication. Given the strong link between maternal affect and adolescent behavior, maternal affect may be a critical influence on adolescent affect-biased attention during mother-child interaction. However, prior methodological constraints have precluded fine-grained examinations of factors such as maternal affect on adolescent attention during real-world social interaction. Therefore, this pilot study capitalized on previously-validated technological advances by using mobile eye tracking and facial affect coding software to quantify the influence of maternal affect on adolescents' attention to the mother during a conflict discussion. Results from 7,500–9,000 timepoints sampled for each mother-daughter dyad (*n*=28) indicated that both negative and positive maternal affect, relative to neutral, elicited more adolescent attentional avoidance of the mother (ORs=2.68–9.20), suggesting that typically-developing adolescents may seek to avoid focusing on maternal affect of either valence during a conflict discussion. By examining the moment-to-moment association between in vivo displays of maternal affect and subsequent adolescent attention toward the mother's face, these results provide preliminary evidence that maternal affect moderates adolescent attention. Our findings are consistent with cross-species approach-avoidance models suggesting that offspring respond to affectively-charged conversations with greater behavioral avoidance or deference.

Keywords

Affect-Biased Attention; Maternal Affect; Adolescence; Mobile Eye Tracking; Facial Affect Coding

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Address correspondence to: Mary L. Woody, Ph.D., Department of Psychiatry, University of Pittsburgh, Pittsburgh, PA 15213, USA. woodyml@upmc.edu.

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Attention to emotional stimuli (i.e., affect-biased attention) is an integral component of emotion regulation. Process models of emotion regulation posit that attentional deployment is one of five types of emotion-regulation processes that can be utilized to influence emotions (Webb, Miles, & Sheeran, 2012). Specifically, when faced with an emotional stimulus, individuals can direct (or redirect) attention away from or toward the stimulus in order to change or maintain a mood state (Gross & Jazaieri, 2014). Notably, this emotion regulation strategy becomes available early on during neonatal development, thus serving as a foundation for later emotion regulation processes across the lifespan (Brodeur, Trick, & Enns, 1997; Posner & Rothbart, 2007).

Affect-biased attention may also be critical in regulating interpersonal emotion processes during social interaction. In fact, eye gaze, defined as the direction of one's gaze to another's face, is fundamental to human communication. The human eye evolved with high contrast between the white sclera and darker pupil specifically to expose gaze direction, which is unique among primates (Kobayashi & Kohshima, 1997). In many contexts, directed eye gaze toward another person represents an affiliative "approach" signal whereas gaze aversion represents an "avoidant" signal (Adams & Kleck, 2003, 2005). Compared to gaze aversion, direct eye gaze from another person typically elicits more approach-related neural activity and behavior, autonomic arousal, and positive facial affect in the receiver (Hietanen et al., 2018; Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008; Hietanen, Peltola, & Hietanen, 2020). However, in times of conflict or social threat, gaze aversion away from another person is often interpreted as a sign of deference to the receiver or an attempt to socially withdraw from the interaction (Kidwell, 2015).

To better capture how individuals allocate attention to socio-emotional stimuli during social interaction, researchers have looked to the recent advent of "wearables". Wearables track data during live dyadic interaction rather than during computerized tasks, which often lack ecological validity. In particular, technological advances in mobile eye tracking glasses have made it possible to track moment-to-moment changes in eye gaze during in vivo social interaction, which introduces novel opportunities to study affect-biased attention in the real-world (Franchak, 2017; Pérez-Edgar, MacNeill, & Fu, in press). Several mobile eye tracking paradigms have emerged to examine affect-biased attention during social interaction. For example, researchers have validated a social stress test to examine adolescent affect-biased attention to in vivo signs of positive and potentially critical evaluation while giving a speech to a panel of two judges (Allen et al., 2019). This work has also shown that internalizing symptoms, such as adolescent dysphoria, moderate attentional allocation to socio-emotional stimuli (Woody et al., 2019). In younger children, researchers have employed a modified version of the Strange Situation Task by examining how children attend to a stranger when he or she initiates a conversation, suggesting that traits such as behavioral inhibition moderate affect-biased attention (Fu, Nelson, Borge, Buss, & Pérez-Edgar, 2019).

Although these prior studies have provided innovative avenues for using mobile eye tracking to examine affect-biased attention during social interaction, they have relied on study confederates to display standardized socio-emotional cues. These standardized behaviors enhance internal validity, but at the expense of ecological validity. There are several reasons to expect that patterns of affect-biased attention may differ between standardized versus more real-world paradigms. First, by their very nature, standardized behaviors exhibited by study confederates are not idiographic to the participant, whereas, during naturalized assessments, stimuli are inherently idiographic. Further, there is evidence that standardized versus idiographic stimuli elicit differential emotional responses and are not always directly comparable (Demorest, Popovska, & Dabova, 2012; Kuo, Neacsiu, Fitzpatrick, & MacDonald, 2014). Finally, children and adolescents often behave in distinct ways when with family, peers, and strangers (Masten, Juvonen, & Spatzier, 2009; Padilla-Walker & Carlo, 2015). Therefore, it is imperative to use paradigms that capture the dynamics of various social microcosms to more fully understand the role of affect-biased attention in adolescent socio-emotional processes.

Thus, a component of what is missing from prior research is an examination of affect-biased attention when youth are interacting with important members of their social network, such as a parent. In this vein, our group has worked to develop a procedure to measure affect biased-attention via wearable technology during parent-child interaction using a well-known “Hot Topics” conflict discussion task (Hetherington et al., 1999). During this task, mothers and their daughters mutually identify a conflict they have recently experienced together and then spend five minutes discussing this issue. Using mobile eye tracking technology, initial work from our group has shown that both parent-child relationship quality and adolescent dysphoria influence how often the adolescent looks at her mother during the task (indexed by averaging gaze across the task) (Hutchinson et al., 2019). This initial work served to validate that mobile eye tracking could be used to examine adolescent attention during mother-child interaction. Thus, it was outside of its scope to examine more in vivo contextual influences, such as naturally-occurring affect in the mother, on adolescent attention allocation on a moment-to-moment basis.

Examining adolescent attention to the naturally-occurring affect of a social partner may be especially critical given that it is an exemplar of idiographic socio-emotional stimuli. Preliminary evidence suggests that adolescents differentially allocate attention when faced with emotional versus neutral facial expressions, largely based on results from computerized attention tasks. These studies demonstrate that youth modulate their attention for both positive and negative visual stimuli, relative to neutral, across behavioral and neurophysiological indices (Kujawa, Klein, & Proudfit, 2013; Rosen, Price, & Silk, 2019). Critical for mobile eye tracking technology, recent advances in facial coding software provide opportunities to successfully quantify moment-to-moment changes in affect during dyadic interaction (Messinger et al., 2014). Thus, automated facial affect coding highlights a previously validated pathway to test the impact of a social partner’s naturally-occurring affect on adolescent attention allocation during social interaction.

Current Study

The current study was designed to capitalize on the recent advent of “wearables”, which can track data during dyadic interaction to provide a live view of the relation between maternal affect and adolescent attentional allocation to their mother’s face during a conflict discussion. Specifically, using previously validated facial coding software to quantify naturally-occurring maternal affect (FaceReader) (Den Uyl & Van Kuilenberg, 2005), the current study examined the effect of maternal affect displayed during an in vivo conflict discussion on adolescent girls' gaze direction toward the mother using mobile eye tracking glasses. We chose to examine adolescent girls' attentional allocation to their mother's face because the functional value of eye gaze as an emotional regulation strategy is enhanced in the mother-offspring relationship. Specifically, studies using naturalistic observation have shown that, beginning in infancy, directed attention toward or away from the mother is an essential mode of nonverbal communication from offspring to mother (Kaye & Fogel, 1980; Stern, 1974), and, across development, directed eye gaze remains an important emotion regulation strategy for children in the context of mother-offspring interaction (Frith & Frith, 2007). Further, given the strong link between maternal affect and offspring behavior more broadly (Park, Brain, Grunau, Diamond, & Oberlander, 2018), maternal emotional expressions, which mark the affective intensity of mother-offspring interactions, may be a critical process that influences adolescent emotion regulation strategies. Finally, we chose to examine the influence of maternal affect on adolescent gaze specifically among mothers and their adolescent daughters because rates of conflict rise dramatically during adolescence, especially between girls and their mothers, and are linked to negative psychological outcomes that also rise markedly during this developmental stage (Allison & Schultz, 2004).

We predicted that there would be a general tendency for adolescents to look away from their mothers' face, given prior research suggesting that behavioral withdrawal is the most common strategy used by adolescents during conflict discussions with their parents (Montemayor & Hanson, 1985; Branje, van Doorn, van der Valk, & Meeus, 2009). We hypothesized that the daughter's tendency to look away would be stronger during displays of negative maternal affect, relative to neutral, given prior research showing that typically-developing children look less at strangers displaying potentially critical social cues, compared to more neutral or positive cues (Woody et al., 2019). This hypothesis is also consistent with vigilance-avoidance models of emotion regulation in children, which suggest that strategic decisions to look away or distract from potentially threatening social stimuli may serve to reduce arousal (at least temporarily) via avoidance (Mogg & Bradley, 1998, 2016; Price et al., 2016; Rosen et al., 2019). We tentatively predicted that the tendency to look away would be weaker during displays of positive maternal affect, relative to neutral, given prior research showing that children attend more to strangers exhibiting happiness or positive evaluation, relative to neutral (Magrelli et al., 2013; Woody et al., 2019). However, the context of the mother-daughter conflict discussion used in the current study is critical, given cross-species research suggesting that offspring look away from the mother in affectively-charged situations as a display of deference to minimize conflict (Gómez, 1996; Kidwell, 2015). Therefore, we also acknowledged the potential that any intense displays of maternal emotional affect could increase the likelihood of looking away from the mother's face, relative to neutral affect.

Material and Methods

Participants

Participants in this study were 32 adolescent girls (ages 11–16) and their biological mothers (M = 45.10, SD = 6.33) recruited from the community through internet and flyer advertisements, and the University's Clinical and Translational Science Institute research portal. Mothers and daughters were not eligible to participate if either reported ongoing and serious health problems, were being treated with psychoactive medications or medications that would interfere with the cardiovascular system, or reported a history of autism spectrum disorders, bipolar disorder, psychosis, or active substance abuse. Due to eye tracking procedures, mothers and daughters were also ineligible if either had ocular conditions that would impede eye tracking measurement, were unable to see clearly without prescription eye glasses or contact lenses, or had a history of neurological disorder. Finally, based on the data preprocessing exclusion criteria described below, $n = 4$ subjects were excluded from analyses, leaving $n = 28$ for the final sample. Descriptive statistics and correlations among study variables can be found in Table 1. As seen in the table, demographic variables were not significantly related to other study variables.

Measures

"Hot Topics" Conflict Discussion.—As described in a previous publication (Hutchinson et al., 2019), mother-daughter dyads engaged in the well-known "Hot Topics" conflict discussion task (Hetherington et al., 1999), which was part of a larger dyadic interaction protocol. In brief, before the Hot Topics discussion, each mother and daughter separately completed an issues checklist, which lists several common topics of disagreement (homework, bedtime, chores, etc.) and were asked to endorse the frequency and intensity of their conflicts over each topic in the past month. The disagreement from the checklist that was mutually endorsed with the highest frequency and intensity ratings was selected for the five-minute Hot Topics discussion, during which they were asked to talk about the disagreement and attempt to come up with a solution.

Eye Tracking.—To track daughters' directed eye gaze toward their mothers, daughters wore binocular Tobii Pro Glasses 2 (Tobii Technology, Inc., Falls Church, VA) during the Hot Topics discussion (see Figure 1 for mock subjects wearing the glasses). Tobii eye tracking glasses look similar to reading glasses but are equipped with a high definition camera that captures the participant's visual field, measuring approximately 80° horizontal and 52° vertical. The glasses feature four eye tracking sensors with a sampling rate of 50 Hz, as well as infrared (IR) illuminators that brighten the eye and support the eye tracking sensors. Advanced image-processing algorithms were used to estimate the eye's position and gaze point using Tobii's standard software. In a white paper (Tobii AB, 2017), Tobii published a series of quality tests to determine the accuracy and precision of the Tobii Pro Glasses 2, which revealed that the average difference between the fixation target location and the measured gaze location was 0.62° (Tobii AB, 2017).

Eye tracking data were processed using Tobii Pro Glasses Analyzer (Tobii Technology, Inc., Falls Church, VA). Consistent with published research from our group (Allen et al., 2019; Hutchinson et al., 2019; Woody et al., 2019), a customized specified filter was used to classify eye movements (e.g., fixations, saccades), and fixations were identified by a consecutive chain of raw data points below the velocity threshold of 30 degrees/second. The Tobii Real-World Mapping function was used to automatically map fixations to areas of interest (AOI) using proprietary Tobii algorithms. In brief, an AOI was created around the mother's face, and regions of interest analyses were used to identify whether or not the daughter's eye gaze was fixated on the mother's face at each sampling point. To do so, the automatic mapping procedure mapped raw gaze data and fixations from the video captured by the glasses camera onto a still snapshot, which was created using a representative still image, generated from a single frame, taken from each daughter's glasses camera. To ensure that this procedure was accurate, a research assistant verified frame by frame whether the automatic mapping data matched the fixation data captured by the eye tracking sensors and glasses camera. If there was a discrepancy (e.g., due to the participant moving their head), then the error was manually corrected by a research assistant. Daughters who did not 1) achieve adequate eye-tracking calibration, 2) had less than 25% valid gaze data (i.e., where gaze coordinates could be estimated by Tobii) and/or 3) exhibited fixations less than 20% of the time toward any visual region during the task were excluded from analysis ($n = 3$).

Maternal Affect Coding.—FaceReader 7.1 (Noldus Information Technology, Inc., Leesburg, VA) was used to continuously quantify naturally-occurring maternal affect throughout the Hot Topics discussion. Mothers' faces were videotaped from cameras mounted on the wall opposite of them using a sampling rate of 25 to 30 Hz.[1] Videos were later imported into FaceReader using the Observer XT program (Noldus Information Technology, Inc., Leesburg, VA). To circumvent the need for labor-intensive behavioral coding, FaceReader uses a cascaded classifier algorithm to identify the face and its position and then employs two affect classification methods to achieve convergence (Loijens & Krips, 2016). The first, the Active Appearance method, synthesizes an artificial face model using over 500 key points on the face and uses the locations of these points to infer the shape of facial features and thus classify facial expressions (Den Uyl & Van Kuilenberg, 2005). This facial modeling algorithm was developed based on thousands of manually annotated images, which led to an artificial neural network that was trained on the location of these points to classify the six universal emotional expressions (happy, sad, angry, surprised, scared, disgusted) (Ekman, 1992) and neutral expressions. The second method uses an artificial neural network to identify patterns from image pixels to classify facial expressions without relying on face modeling, which allows FaceReader to classify emotional expressions even in the presence of certain participant characteristics such as glasses, beards, and hair/hands/objects obstructing parts of the face (Loijens & Krips, 2016). These two methods are combined to reach classification convergence, which generates an output in which each type of possible affect classification (neutral and 6 emotion types) is assigned an intensity percentage (0–100%), with higher numbers reflecting greater intensity within each sample measurement. Cross-validation efforts have supported the accuracy of these methods (see Supplement).

In the current study, we used these classification and intensity ratings to identify the predominant affect displayed (i.e., the emotional or neutral expression with the highest intensity rating that was displayed with at least 50% intensity). We separated predominant affect codes into three bins: neutral, negative (angry, disgusted, sad, scared), and positive (happy). Because the valence (positive vs. negative) of surprised affect is dependent on context (Fontaine, Scherer, Roesch, & Ellsworth, 2007) and because there were not enough instances of predominantly surprised affect (0.3% of samples) to warrant its examination as a separate affect category, we excluded instances of surprised affect from our analyses. In addition, participants who had less than 25% of samples successfully classified during analysis were excluded from analysis ($n = 1$).

Table 2 displays the average intensity of each maternal affect type, averaged across the timepoints classified as predominantly neutral, negative, or happy, respectively. As shown in the table, each predominant affect type was accompanied by non-zero intensity of the other types of maternal affect. This suggests that *in vivo* maternal facial expressions, while clearly exhibiting one dominant affect type, may have contained a complex mixture of features and therefore may be more ambiguous than the “pure” displays of facial affect often used when normalized, static stimuli are presented. Studies examining emotion classification of mixed emotional expressions suggest that children become sensitive in detecting emotional faces at medium intensities [i.e., an emotional expression “morphed” with a neutral expression becomes identifiable around the midpoint (50%) of the morphed continua] (Burkhouse et al., 2016; Pollak & Kistler, 2002). Therefore, we believe that coding dominant maternal affect at levels of 50% intensity or higher provided reasonable signal strength for our analyses.

Procedure

Upon arrival at the laboratory, mothers were asked to provide informed consent and daughters were asked to provide assent to be in the study. Prior to the mother-daughter discussion tasks, mother-daughter dyads put on the eye tracking glasses and were seated about five feet across from each other. Participants also completed a calibration procedure in which they were instructed to look at a specific target on a small card while a research assistant checked the equipment for accuracy. Following a neutral task and support discussion, mother-daughter dyads engaged in the Hot Topics discussion. Mothers were compensated $60 and daughters were compensated $90. All study procedures were approved by the university’s Institutional Review Board.

Analytic Plan

To examine the impact of maternal affect on daughters’ attention toward the mother, we downsampled Tobii output data to match the FaceReader sampling rate (i.e., 25 or 30 Hz depending on the original FaceReader sampling rate). This allowed us to examine our independent and dependent variables on the same time scale and provided 7,500 to 9,000 potential timepoints per dyad. After implementing the data exclusion criteria outlined above, we had a sample of 28 dyads for analyses.

We used Hierarchical Linear Modeling (HLM) (Raudenbush, Bryk, Cheong, Congdon, & Du Toit, 2004) to examine whether maternal affect would moderate daughters’ attention toward the mother. HLM was chosen in part to account for measurements nested within dyads and the variability in the number of samples across the Hot Topics task. Specifically, we examined if, relative to neutral maternal affect, predominantly negative or positive maternal affect displayed at one measurement point would be associated with the probability that the daughter would be attending to her mother’s face at a subsequent measurement point [10 timepoints later (~200–240 ms)]. In an *a priori* decision, we chose this lagged approach because prior research has shown it takes about 200 ms for an individual to perceive an emotional facial expression (Allison et al., 1994). Therefore, a lagged approach that examined gaze direction 10 timepoints following the measurement of maternal affect allowed adequate time (i.e., ~200–240 ms) for daughters to process and perceive maternal affect. To measure the impact of maternal negative and positive affect, compared to neutral, on daughters' attention toward their mothers' faces, we used a non-linear HLM model with the logit link function to account for the dichotomous nature of our dependent variable (i.e., daughter directing gaze to mother's face: yes, no) during each measurement point.

$$\log\left(\frac{\phi ji}{1-\phi ji}\right) = \eta_{\mathrm{ij}}$$

Where η_{ji} represents the log of the odds of success for participant *j* at measurement point *i* and ϕ_{ij} represents the probability of "success" (i.e., daughter directing gaze to mother's face).

To measure the lagged impact of maternal negative and positive affect, compared to neutral, on daughters' attention toward the mother 10 measurement points later, we used the following Level 1 model:

$$\eta_{\mathrm{ji}} = \pi_{0j} + \pi_{1j}\left(\mathrm{Maternal\,Negative\,Affect}_{tji-10}\right) + \pi_{2j}\left(\mathrm{Maternal\,Positive\,Affect}_{tji-10}\right)$$

where η_{ji} represents the log of the odds of success for participant *j* at measurement point *i*, π_{0j} is the intercept (reflecting the odds of the daughter attending to her mother's face during neutral maternal affect), π_{1j} is the slope of the relation between maternal negative affect, compared to neutral, at measurement point *i-10* and the probability of success at measurement point *i* for participant *j*, and π_{2j} is the slope of the relation between maternal positive affect, compared to neutral, at measurement point *i-10* and the probability of success at measurement point *i* for participant *j*.

The Level 2 model was:

$$\pi_{0j} = \beta_{00} + r_{0j}$$

$$\pi_{1j} = \beta_{10} + r_{1j}$$

$$\pi_{2j} = \beta_{20} + r_{2j}$$

where β_{00}, β_{10}, and β_{20} are the intercept terms for each of their respective equations and r_{0j}, r_{1j}, and r_{2j} are the error terms.

In sum, this non-linear HLM model with the logit link function utilized up to 9,000 time points per dyad to test the binary probability (yes, no) of whether the adolescent would be gazing away from the mother's face at any given time point, dependent on the mother's display of affect (neutral, negative, or positive) at a preceding time point. The model utilized logit transformation by transforming probability estimates (ϕ_{ij}), ranging between 0 to 1, to log odds $\left[\log\left(\frac{\phi ij}{1-\phi ij}\right)\right]$. Coefficients from these models represent the estimated log odds of "success" (i.e., attending to the mother's face). Therefore, a positive coefficient implies higher probability of success (estimated across measurements) whereas a negative coefficient implies lower probability of success. Because positive and negative affect were included as separate predictors, neutral affect becomes the reference and is represented at the intercept. Therefore, the coefficient of the intercept represents the log odds for "success" during neutral maternal affect; a negative coefficient would demonstrate that there is a lower probability of attending to neutral affect (compared to attending away). The coefficient for negative maternal affect represents the log of the odds ratio between negative and neutral affect (i.e., the odds of attending to negative maternal affect over the odds of attending to neutral maternal affect). The same is true for positive affect. Therefore, a negative coefficient would demonstrate that the odds of attending to negative or positive maternal affect are lower than the odds of attending to neutral affect.

To determine effect sizes from this model, we used odds ratios (OR) and interpreted effect sizes based on Cohen's "Rules-of-Thumb" for interpreting effect sizes using ORs (i.e., small = 1.50, medium = 2.50, and large = 4.30; Cohen, 1988). Of note, we inverted OR and confidence interval (CI) values generated by the HLM model to reflect the probability that daughters would be looking away (rather than looking toward) mothers' faces to facilitate comparisons with established norms and inclusion in future meta-analyses.

Results

During the conflict discussion task, mothers displayed neutral affect (83%) at a higher proportion than negative (5%) or positive (12%) affect. Daughters spent a greater proportion of time looking away from their mothers' faces (70%) compared to directing their gaze toward their mothers' faces (30%).

Using the HLM model described in the analytic plan, we first examined whether daughters were more likely to attend either toward or away from their mothers' faces 200–240 ms following predominately neutral maternal affect. Consistent with the descriptive statistics, results showed that daughters were more likely to be looking away from their mother's face following displays of neutral affect, $t(27) = -3.33$, $p = .002$ (see also Table 3). The size of this effect was large, as daughters were 4.31 times more likely to be looking away than looking toward their mothers when she displayed neutral affect.

To determine whether emotional versus neutral maternal affect would moderate daughters' attention toward the mother, we examined the effect of both negative and positive maternal affect, compared to neutral, on daughters' attention toward their mothers' faces 200–240 ms later. Results of these analyses are presented in Table 3. When comparing the impact of negative maternal affect, we found that daughters were more likely to be looking away from their mothers' faces following displays of negative compared to neutral affect, $t(27) = -2.55$, $p = .017$. The size of this effect was large, as daughters were 9.20 times more likely to be looking away from negative maternal affect compared to neutral maternal affect. Similarly, daughters were more likely to be looking away from their mothers' faces following displays of positive compared to neutral affect, $t(27) = -2.79$, $p = .010$. The size of this effect was medium as daughters were 2.68 times more likely to be looking away from positive maternal affect compared to neutral maternal affect.

Discussion

This pilot study examined whether maternal affect would impact adolescent offspring's attention toward the mother during a mother-daughter conflict discussion. More specifically, we sought to determine if in vivo displays of maternal affect and subsequent adolescent attention allocation to the mother's face were related, moment-to-moment. If supported, the association between maternal affect and adolescent attention would suggest that adolescent affect-biased attention can be captured by mobile eye tracking during parent-child interaction. Our hypotheses were partially supported, with results suggesting that both negative *and* positive maternal emotional expressions, compared to neutral, were followed by more offspring attentional avoidance of the mother during conflict discussion. Thus, this study is one of the first to translate typically computer-based laboratory measures (i.e., eye tracking and facial affect coding) to in vivo social interaction using previously validated, state-of-the-science wearable technology, which provided a novel and temporally-sensitive view of the dynamic patterns of adolescent affect-biased attention during mother-offspring conflict discussion. This approach represents a leap in measuring and understanding how maternal affect influences offspring attention from millisecond to millisecond.

Our findings are consistent with models of emotion regulation and evolutionary psychology. Specifically, avoidant patterns of offspring behavior in response to emotional affect are well supported by developmental models of emotion regulation. In youth, a common emotion regulation technique is to look away from emotionally-intense information in an effort to reduce affective reactivity (Gross & Jazaieri, 2014). Similarly, cross-species evidence suggests that gaze aversion is a common strategy to show deference toward a dominant social partner and/or to socially withdraw from conflict (Gómez, 1996; Kidwell, 2015). Notably, we found that adolescent gaze aversion predominated the mother-daughter conflict discussion, even during displays of neutral maternal affect, and this strategy was used even more frequently in the presence of both negative and positive maternal affect, relative to neutral. Conflict discussion can often be an anxiety-provoking or distressing task, even when it results in a positive outcome. Previous research has shown that higher levels of anxiety can be associated with gaze aversion to both negative and positive stimuli (Heuer, Rinck, & Becker, 2007), which may serve to reduce arousal (at least temporarily) via avoidance (Mogg & Bradley, 1998, 2016). However, if overly relied on, attentional avoidance of either positive or negative socio-emotional stimuli can have maladaptive consequences for youth. Given that attention is reciprocally linked with learning and memory, in part because looking facilitates remembering and skills acquisition (Meister & Buffalo, 2016), offspring attentional avoidance of the mother during mother-child interaction could impede offspring's acquisition of adaptive conflict resolution skills; this impedance could perhaps explain why offspring's levels of avoidant behavior during parent-offspring conflict is linked to later risk for internalizing and externalizing problems (Branje, van Doorn, van der Valk, & Meeus, 2009). Alternatively, higher levels of offspring psychopathology may be linked to increases in attentional avoidance during mother-offspring conflict discussion, thus leading to greater functional impairment. Building on the current, foundational work to develop an ecologically valid procedure that successfully captures affect-biased attention with temporal precision, future studies can be designed to better understand the potential correlates and consequences of offspring attentional avoidance during mother-offspring interaction. Mobile eye tracking technology and facial affect coding will be essential in elucidating these associations.

Results from the current study also highlight future avenues to extend past research examining affect-biased attention, particularly in internalizing disorders. While depressive and anxiety disorders are typically associated with biases in eye gaze toward negatively-valenced stimuli (i.e., faces, images, and words) during computerized tasks (Armstrong & Olatunji, 2012; Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007), the advent of mobile eye tracking technology offers opportunities to directly examine how affect-biased attention exists in dynamic social environments and may communicate approach/avoidance signals to others. For example, the “Hot Topics” and other parent-child interaction paradigms could be used with mobile eye tracking to study attention biases among offspring of depressed mothers, as research shows that these high-risk offspring are often more likely to avoid looking at sad facial expressions (as assessed by static, standardized images during computerized tasks) (Gibb, Benas, Grassia, & McGeary, 2009; Gibb, Pollak, Hajcak, & Owens, 2016). Theorists have suggested that offspring of depressed mothers may use attentional avoidance as an emotion regulation strategy to withdraw from mothers during bouts of maternal depression, which can paradoxically increase the offspring’s risk for later depression (Gibb, McGeary, & Beevers, 2016). In combination with facial affect coding, mobile eye tracking paradigms could extend this research to confirm whether offspring of depressed mothers, compared to never-depressed mothers, are more likely to exhibit attentional avoidance of their mother’s faces following displays of real-life expressions of maternal sadness.

Although facial expressions are often considered an index of affect (Buck, Savin, Miller, & Caul, 1972), they also serve a pragmatic communicative function when used during social interaction (Dols, 2017). During mother-child conflict discussions, mothers can regulate their own facial affect as a tool to socialize emotional responses in their children (Morris, Criss, Silk, & Houltberg, 2017). Thus, in the current study, mothers may have chosen to display predominantly neutral affect in order to convey a sense of calm to their daughter during a difficult conversation. In contrast, by displaying either positive or negative affect, mothers might have signaled (intentionally or not) that the conversation was becoming more affectively-charged, thereby influencing adolescent gaze behavior. Critical for future research, it is important to note that maternal affect is conveyed multi-modally through facial expression, body language, tone of voice, content of speech, etc. Because these additional variables were not measured in the current study, we cannot rule out that these other markers of maternal affect also exhibited a strong effect on daughters’ affect-biased attention toward their mothers. Thus, future research should continue to build on the promise of “wearables” by developing multi-modal assessments of affect. Of note, these multi-modal assessments may have tremendous clinical value as they could provide moment-to-moment feedback regarding the quality of social interaction to facilitate social-affective learning among children with social deficits (e.g., children with autism) (Daniels et al., 2018). Nevertheless, the medium-to-large effect sizes observed in the present analyses (e.g., odds ratio greater than 9 in the case of negative maternal affect) suggest that facial expression alone is a potent predictor of subsequent attention.

Although the current study displayed several strengths, such as examining adolescent affect-biased attention with greater ecological validity and temporal precision, there were also limitations that highlight areas for future research. First, the study consisted of only 28 mother-offspring dyads, which may have resulted in reduced statistical power. However, data from these 28 dyads were intensively measured and provided up to 9,000 within-dyad samples across the conflict discussion, which dramatically increases the statistical power to detect meaningful and reliable effects (Guo, Logan, Glueck, & Muller, 2013). Specifically, even for less common events such as displays of emotional maternal affect (~17% across time points), the large number of data points meant that we were able to assess the probability of an adolescent gazing away from maternal emotional affect around 1,500 times for the average dyad. Case in point, effect sizes ranged from medium to large, suggesting that the findings are robust and meaningful. Nevertheless, future research would benefit from larger sample sizes, which would also lend itself toward testing more complex dyadic models. Second, therefore, future studies should probe bidirectional effects within the dyad using the actor-partner interdependence framework (Cook & Kenny, 2005). For example, the study only examined the unidirectional effect of maternal affect on offspring attention toward the mother, and future studies would benefit from an examination of transactional mother-daughter affective and attentional processes. Third, participants in the current study displayed relatively lower proportions of negative (5%) and positive (12%) maternal affect during the task compared to neutral (83%). The laboratory environment may have suppressed the expression of emotional affect due to social desirability demands. Future studies will benefit from measuring maternal affect in participants' real-life environments, which may reduce bias related to the laboratory environment. Finally, participants in the current study were comprised of a relatively small and homogeneous group of urban and suburban mother-daughter dyads from the northeastern United States. This is important as there is considerable evidence that the expression of and reaction to emotion differs based on culture (Kitayama & Markus, 1994) and gender (Chaplin & Aldao, 2013). Therefore, we see the current study as only the first step in characterizing the effect of maternal affect on offspring attention and validating the real-world relevance of laboratory measurement paradigms using cutting-edge technology. Future work examining these effects across culture, gender, and development will be necessary to further our understanding of the complex relations between maternal affect and offspring behavior.

In conclusion, by capitalizing on advances in wearable technology, this pilot study validated a mobile eye tracking procedure to examine the moment-to-moment influence of maternal affect on adolescent affect-biased attention. Findings demonstrated that maternal affect was a significant moderator of adolescent attention such that adolescents exhibited more gaze aversion of their mothers when faced with either negative *or* positive maternal affect, compared to neutral. Our findings are consistent with cross-species approach-avoidance models suggesting that offspring respond to emotional maternal facial expressions (relative to neutral) with avoidance or deference during times of anxiety or conflict. This study promotes a novel mobile eye tracking approach for studying affect-biased attention using highly salient and idiographic real-world stimuli. It is clear that maternal affect influences offspring behavior and outcomes across development, which can be seen at the micro-level within the current study and broadly at the level of the intergenerational transmission of mood disorders (Goodman, 2007). If findings are replicated and extended, this novel methodological approach has the potential to inform and transform future research examining the role of maternal affect in offspring development.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Mock subjects during Hot Topics Discussion.

Table 1.

Descriptive statistics and correlations among study variables.

	Average	1	2	3	4	5	6	7
1. Offspring Age	14.28 (1.63)	-						
2. Offspring Race (% Caucasian)	75%	−0.21	-					
3. Family Income	$70,001–80,000	0.20	0.45*	-				
4. Maternal Neutral Affect	83% (19%)	−0.25	−0.26	−0.23	-			
5. Maternal Negative Affect	5% (9%)	0.13	−0.01	0.05	−0.32	-		
6. Maternal Positive Affect	12% (18%)	0.20	0.27	0.21	−0.89**	−0.15	-	
7. Directed Eye Gaze toward Mother	30% (19%)	−0.16	0.10	0.09	0.09	0.01	−0.10	-

Note. Average values represent the mean except for a median value for Family Income. Values contained within parentheses represent *SD*.

* $p < .05$

** $p < .01$

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Table 2.

Average Intensity of Maternal Affect By Dominant Affect Type

	Neutral Dominant	Negative Dominant	Positive Dominant
Neutral Intensity	**0.65**	0.37	0.23
Negative Intensity	0.05	**0.63**	0.10
Positive Intensity	0.24	0.02	**0.66**

Table 3.

Results of Hierarchical Linear Model.

Fixed Effect	**Coefficient**	**OR**	**CI (95%)**	***t***	***df***	***p***
Maternal Neutral Affect Intercept, π_{0j}	−1.46	4.31	(1.75, 10.64)	−3.33	27	0.002
Maternal Negative Affect Slope, π_{1j}	−2.22	9.20	(1.54, 55.55)	−2.55	27	0.017
Maternal Positive Affect Slope, π_{2j}	−0.98	2.68	(1.30, 5.52)	−2.79	27	0.010

Note. OR and CI values were inverted to reflect the probability that daughters would be looking away (rather than looking toward) mothers' faces to facilitate comparisons with established norms and inclusion in future meta-analyses.