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Relations between social attention, expressed positive affect and behavioral inhibition during play

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Abstract

Flexible social attention, including visually attending to social interaction partners, coupled with positive affect may facilitate adaptive social functioning. However, most research assessing social attention relies on static computer-based paradigms, overlooking the dynamics of social interactions and limiting understanding of individual differences in the deployment of naturalistic attention. The current study used mobile eye-tracking to examine relations between social attention, expressed affect and behavioral inhibition during naturalistic play in young children. Children (N = 28, M_{age} = 6.12, 46.4% girls, 92.9% White) participated in a 5-minute free play with a novel age- and sex-matched peer while mobile eye-tracking data were collected. Interactions were coded for social attention and expressed affect and modeled second-by-second, generating 4,399 observations. Children spent more time dwelling on toys than on peers or anywhere else in the room. Further analyses demonstrated children were almost twice as likely to gaze at their peer when simultaneously self-expressing positive affect. Additionally, children were more than twice as likely and more than three times as likely to self-express positive affect when dwelling on peer or in the presence of peer-expressed positive affect, respectively. Behavioral inhibition was not significantly related to social attention. However, children higher in behavioral inhibition were less likely to self-express positive affect in the presence of peer-expressed positive affect. The current results provide a snapshot of relations between social attention, expressed affect and individual differences during play and provide guidance for future work assessing the roles of social attention and positive affect in facilitating positive social interactions.

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Keywords

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Social relationships foster physical and mental well-being (Umberson & Karas Montez, 2010) and are critical for social learning (Legare et al., 2017) and social development (Carpendale & Lewis, 2004). The ability to form, maintain, and learn from social relationships relies on social engagement, or the propensity to interact with both familiar and unfamiliar others. One of the most basic and well-studied processes underlying social engagement is social attention, often measured as visual attention to, or neural processing of, socioemotional stimuli, such as faces. Indeed, humans are biased to attend to faces from the first days of life (Farroni et al., 2013) and young children may exhibit preferential processing of happy faces (Todd et al., 2011). Preferentially processing positive affect may facilitate the development of the social competencies necessary for general social learning and maintenance of social relationships.

The broaden-and-build theory of positive emotions (Fredrickson, 1998, 2001) suggests that positive affect broadens the spectrum of actions in an individual's behavioral toolbox, enabling the accumulation of social resources. This is in contrast to negative affect, which often narrows the scope of actions an individual will take (daSilva et al., 2021). Expressed positive affect, the externalization of positive emotion, may increase engagement during short-term social interactions. For example, in the presence of expressed positive affect, individuals may be more inclined to look at an interaction partner, potentially indicating a bid for shared attention (Redcay et al., 2012) or emotionality (Beltz et al., 2013). In turn, processes supporting short-term positive social interactions may lead to more adaptive social interactions long-term. Indeed, recent work suggests that expressed positive affect and both peer- and parent-relationship quality are mutually reinforcing throughout late childhood and into middle adolescence (Griffith et al., 2021), highlighting the importance of positive affect in strengthening social bonds. Although social attention is believed to be critical for socialization, the role of social attention during social interactions and relations between social attention and expressed positive affect are unclear.

Previous work has investigated "anticipatory smiling," or smiling while gazing at something pleasing prior to smiling at a social partner. Anticipatory smiling emerges during infancy (Venezia et al., 2004) and is related to social competencies during toddlerhood (Parlade et al., 2009). Patterns of anticipatory smiling during social interactions may be folded into bids for joint attention (Gangi et al., 2014), particularly as a form of nonverbal communication. Research suggests that verbal requests for joint attention are more common in parent-child social interactions than child-child social interactions (Ninio, 2016). Expressions of positive affect, including smiling, laughing and positive vocal tone, could be tools young children employ during interactions with their peers to facilitate engagement. Indeed, dyadic expressions of positive affect in preschool-aged children are related to greater peer acceptance, higher levels of classroom adjustment and more visual attention from peers outside of the interaction context (Shin et al., 2011). Primary school-aged children (5 – 7) are continuing to develop their social repertoire by learning how to engage with peers across multiple contexts. Examining how social attention and expressions of positive affect coordinate during novel peer interactions in young children may help identify early emerging components of positive social interactions that may be key to the development of the skills necessary to navigate social interactions later in life, which become increasingly complex during adolescence and adulthood.

Most research investigating social attention has relied on static computer paradigms to assess how individuals attend to and process socioemotional stimuli (Bar-Haim et al., 2007; Sabatinelli et al., 2011). These paradigms provide a foundation for understanding individual differences in social attention, but they cannot provide insight into the dynamic nature of social interactions that rely on contingent responses between interaction partners. Even paradigms that employ dynamic stimuli (Sato et al., 2004) do not account for the fluid timing- and situation-dependent emotional variation natural social interactions entail. Computer paradigms that attempt to emulate real-world social interactions, such as Cyberball (Eisenberger & Lieberman, 2004), chatroom tasks (Alkire et al., 2018; Guyer et al., 2008) and the virtual school task (Jarcho et al., 2016), capture real-time fluctuations in socioemotional experience. However, they cannot capture how attention is deployed throughout a face-to-face experience. This is a threat to generalizability and ecological validity given emerging data indicating that individuals attend to computerized stimuli differently from how they attend to, and engage with, their experienced environment (Fu et al., 2019; Isaacowitz et al., 2015; Risko et al., 2016). Thus, examining how individuals deploy social attention in real-life social interactions is imperative for understanding attention-affect relations that may support both concurrent and long-term socioemotional functioning (Pérez-Edgar et al., 2020).

Mobile eye-tracking (MET) enables researchers to examine visual attention during naturalistic social interactions. For example, recent MET studies have captured individual differences in eye-contact during naturalistic conversation (Rogers et al., 2018), relations between attentional patterns to a stranger and individual differences in young children (Gunther, Brown, et al., 2021; Gunther, Fu, et al., 2021), the role of gaze in emotion regulation during conflict (Woody et al., 2020) and the impact of coordinated gaze during a collaborative task (Andrist et al., 2015). Collecting MET data from one or more social interaction partners enables researchers to ask how attention functions as a real-time mechanism driving social engagement and social learning. Interestingly, although computer-based paradigms for measuring social attention typically rely on measuring attention to faces, MET work suggests that people may not gaze at each other during naturalistic social interactions as much as researchers intuit (Franchak et al., 2018; MacNeill et al., 2021). However, individual differences, such as behavioral inhibition, may influence the likelihood of an individual exhibiting social attention or expressing positive affect during a social interaction.

Behavioral inhibition is a temperament profile characterized by a fear of novelty (Fox et al., 2001; Garcia-Coll et al., 1984), wariness during social interactions (Degnan et al., 2014), greater negative affect (Kagan & Snidman, 1991) and potential rigidity in social attention (Fu et al., 2019; Morales et al., 2017). Although, on average, individuals might find social interactions rewarding (Krach et al., 2010), individuals high in behavioral inhibition may be less rewarded by social interactions. For example, research suggests young boys high in behavioral inhibition may be more upset when someone wants to play with them if they do not want to play with that individual (Howarth et al., 2013). The uncertainty of such interactions may drive social reticence patterns in children high in behavioral inhibition (Jarcho et al., 2016). Experiencing the uncertainty inherent to novel social interactions may also reduce social attention or restrict opportunities for shared emotionality for children high in behavioral inhibition. Overtime, reductions in social attention or shared emotionality may cause difficulty in forming or maintaining social relationships as children high in behavioral inhibition lose opportunities to learn about their social world (Jarcho & Guyer, 2018).

The current study was designed to assess relations between social attention, expressed affect and behavioral inhibition during naturalistic, dyadic play in young children. We had three main goals. First, we sought to describe the commonality of social attention during naturalistic play between novel peers. Although most social attention paradigms rely on static faces (Bar-Haim et al., 2007), MET work suggests that individuals may attend more to stimuli in the immediate environment rather than social interaction partners (Franchak et al., 2018; MacNeill et al., 2021). Indeed, social interactions during childhood are primarily driven by play and play is often toy-based, as children use external objects, such as toys, to help structure and scaffold social engagement (Rubin & Howe, 1985). Examining the frequency of social attention during a naturalistic paradigm may better elucidate the role of individual differences in social attention. We anticipated that children overall would spend more time gazing at toys than peers (social attention).

Second, we examined the relations of behavioral inhibition, self-expressed affect (an individual's externalized positive affect) and peer-expressed affect (an individual's interaction partner's externalized positive affect) with the likelihood of exhibiting social attention. We anticipated that while positive affect might relate to higher odds of simultaneously exhibiting social attention, higher levels of behavioral inhibition might relate to lower odds of exhibiting social attention. Third, we examined the relations of behavioral inhibition, social attention, and peer-expressed affect with the likelihood of self-expressing positive affect. We anticipated that while social attention and peer-expressed positive affect might relate to higher odds of self-expressed positive affect, behavioral inhibition might relate to lower odds of self-expressing positive affect. By examining these relations, our study provides a snapshot of naturalistic social interactions in young children as well as highlights contextual and individual difference factors that may influence the course of social interactions.

Method

Study Overview

We recruited children between the ages of 5 and 7 years for a larger study using mobile eye-tracking (MET) to assess relations between temperament, naturalistic social attention, and social behavior. Recruitment oversampled for behavioral inhibition (see S1). Once recruited into the study, children participated in multiple laboratory episodes designed to assess social behavior and naturalistic social attention. For the current analyses, we focused on the Free Play episode during which two sex- and age-matched children were left in a room with toys to play together for 5 minutes. During the episode, MET data (see Mobile Eye-Tracking) and affective data (see Dyadic Free Play Episode) were collected. Data are accessible through Databrary (Pérez-Edgar & Fu, 2017) for those participants who consented to data sharing. The study was not preregistered.

Participants

The final sample consisted of 28 children (9 complete dyads and 10 children from dyads where one child was missing MET; 13 girls; 26 children were White, 1 was Black and 1 was Asian (M_{age} = 6.12, SD_{age} = 0.62) drawn from the 42 children (21 dyads) that completed the free play episode (see below for explanation of missing MET data). Children were paired with novel peers also enrolled in the study. All children who provided any MET data were included in our analyses as our models did not change based on the amount of tracked data. The sample size is in line with theoretical work showing the utility of small-N design for examining within-person processes (Smith & Little, 2018), and previous mobile eye-tracking work investigating relations between naturalistic social attention and expressed affect during social interactions (Woody et al., 2020). Based on the most similar prior work (Woody et al., 2020), we expected the ability to detect medium effect sizes (Cohen, 1988).

We recruited families into the larger study via community outreach and word-of-mouth. Participants were excluded from the larger study if they were non-English speakers, had gross developmental delays, or had severe neurological or medical illnesses. We recruited from a convenience sample to focus our efforts on piloting novel methods in young children. All study procedures were approved by The Pennsylvania State University Institutional Review Board (iTRAC; STUDY00004687). Parents and children completed written consent/assent and received monetary compensation for their participation. Parents provided consent for the use of their children's images in the current manuscript.

Missing MET Data.—Of the 42 children who participated in the dyad portion of the study, 28 provided some usable MET data. Of the 14 without MET data, 1 child removed the MET system prior to the free play episode, 5 children were not calibrated reliably, and 8 children were lost to technical malfunctions. For the 28 children that did provide some usable MET data, missing data existed due to challenges surrounding eye-tracking during movement, as children were free to walk around the entire space and engage with any toys they chose. For example, if a child moved their head too quickly, it could take a moment for the MET tracker to adjust. Additionally, in some circumstances the eyelids occluded the pupil during downward gaze, leading to data loss if a child spent a good deal of time looking at something below them (e.g., a board game or drawing). Finally, children sometimes touched their faces or the tracker disrupting positioning of the tracker, which led to missing data.

Mobile eye-tracking allows for increasingly complex paradigms with high ecological validity, but with this complexity comes data loss. However, it is important to note that this cost-benefit calculus is necessary even in the most well-established of biological data collection paradigms. For example, in EEG/ERP studies with children it is not unusual to lose as much as 36% of the sample in artifact rejection and as much as 50% due to poor performance on the task at hand (Brooker et al., 2020). As expected, data loss is also diminished when mobile eye-tracking is used with older children and as a function of task. For example, in a sample of 14-year-old adolescent girls, researchers discarded 4 of 32 (12.5%) participants when the task had them sitting (Woody et al., 2020) and 6 of 32 (18.75%) when standing to give a stress-inducing speech (Woody et al., 2019).

Analyses of children who provided some MET data compared to children who provided no MET data suggested there were no differences between groups on behavioral inhibition score ($t = -0.86$, $p = .400$), age ($t = 1.10$, $p = .281$) or sex ($X^2 = 0.12$, p = .741).

Behavioral Inhibition Questionnaire

Parents completed the 30-item Behavioral Inhibition Questionnaire (BIQ; Bishop et al., 2003) to rate child behavioral inhibition. Example items include: “My child is shy when first meeting new children” and “My child is nervous or uncomfortable in new situations.” Parent-report on the BIQ has been correlated with laboratory observations of BI (Dyson et al., 2011). Items are rated on a scale from 1 = hardly ever to 7 = almost always. The BIQ demonstrated excellent internal consistency in our sample (α = .95) and scores were normally distributed.

Dyadic Free Play Episode

A researcher led the dyads into a room with multiple toys stationed throughout. The researcher told the children they should “play however you like” and left the room. Toys in the room included coloring supplies, dinosaurs, dolls, puzzles, books and the games Jenga and Candyland (see Figure S1 for diagram of room setup). We noted the predominant activity for the 19 included dyads: 6 played Candyland, 4 played with dolls and/or dinosaurs together, 4 played Jenga, 2 colored together, 1 used the Jenga game as blocks together, 1 did a puzzle together and 1 dyad evenly split their time between playing Jenga and Candyland. The researcher returned after 5 minutes to end the episode. Videos from cameras stationed behind a 2-way mirror were used to capture behavior for affect coding.

Affect Coding.—Free play episodes were videotaped and coded offline by trained and reliable graduate student coders. Affect was coded second-by-second across the entire interaction for positive, neutral, and negative affect. Positive affect was defined as any positive facial affect or positive vocalizations including expressions such as smiles, laughter, and clapping out of excitement. Negative affect was defined as any negative facial affect or negative vocalizations. These included expressions of anger/frustration, annoyance, or sadness. Neutral affect was defined as any neutral facial affect or neutral vocalizations, this included when children were not expressing clear positive or negative affect. All 21 dyads that completed the free play episode were coded for affect, with 20% of videos double-coded for reliability. Affect was coded on a continuous, second-by-second time scale. All coders were trained until they reached at least 70% agreement in content, duration, and timing. Reliability estimates were based on 20% of the total number of videos coded and were calculated for content, timing, and duration of behavior across the entire task using a 1-second buffer window. Percent agreement between coders was 92.4%.

Mobile Eye-Tracking

Data Collection.—We collected MET data via a head-mounted (mobile) eye-tracker (PUPIL; Kassner et al., 2014; Figure 1). Data were recorded either with Pupil Capture v.0.9.6 (Pupil Labs) installed on a Microsoft Surface Pro 3 tablet with Windows 10 used in an earlier phase of the larger study (n = 7 in final sample) or with Pupil Capture v.0.9.12 (Pupil Labs) installed on a MSI VR One Backpack PC also running Windows 10 (n = 21 in final sample). The eye-tracker had two infrared eye cameras that recorded binocular pupil and corneal reflections from the images of both eyes at a resolution of 640×480 pixels. The eye-tracker also had a worldview camera that captured a first-person, 90° diagonal field of view at a resolution of 1280×720 pixels. The eye-tracking system's average gaze estimate accuracy was 0.6° of visual angle (0.08° precision; Kassner et al., 2014). Together, the backpack and eye-tracker were light enough to allow the children to move freely throughout the visit. At the beginning of the laboratory visit, the eye-tracker was placed on each child's head and the eye cameras were adjusted to ensure the eyes were captured by the eye cameras. Following this, a 5-point calibration procedure was conducted using an overhead projector to capture the scope of a room (for more detail see Pérez-Edgar et al., 2019). Prior to beginning the episode, a validation procedure was conducted (for more detail see Pérez-Edgar et al., 2019) to enable offline gaze correction procedures. Calibration and validation procedures are essential for documenting accurate and reliable data, particularly when dealing with dynamic behaviors that shift across space and distance in relation to the fixation point of interest (Franchak, 2017).

Data Pre-Processing.—The eye camera videos were overlaid on the worldview video after each visit to create a single eye-tracking video for coding. Additionally, three concentric circles were added to indicate point of gaze. The radius of each circle was proportional to the screen resolution (red: 2%; yellow: 5%; green: 8%). Videos were prepared for coding using Pupil Player v.0.9.12 (Pupil Labs) and Final Cut Pro (see S2 for details).

Coding.—Trained RAs coded child eye gaze using Datavyu 1.3.4 (Franchak & Adolph, 2010; Fu et al., 2019). Eye gaze data were coded frame-by-frame at a frame rate of 30 frames per second, coded continuously (Franchak & Adolph, 2010). Coders used the red circle to determine looking behavior for the following AOIs: peer (looking at the peer's body or face), toy (looking at any toy in the space), and other (looking anywhere that was not the peer or a toy). Additionally, we coded when a frame was determined to be un-codable (the red circle was not on the screen or multiple red circles appeared on the screen). Un-codable frames were labeled as missing data. To achieve inter-rater reliability, the master coder coded 20% of each video. All coders were trained until they reached at least 90% agreement at the frame-by-frame level. Reliability estimates were based on the 20% double coding of each video at absolute agreement. Average percent agreement between coders for the included participants was 97.0%.

Data Reduction.—MET data were coded at 30 frames-per-second. However, for the purposes of data analysis, we selected the AOI with the greatest number of frames in a given second as the dominant AOI for that second in time. That is, if in a one-second time frame

20 frames were 'peer', 5 frames were 'toy', and 5 frames were 'un-codable', that second was labeled as 'peer.' If the majority of frames were 'un-codable' the second was considered missing data. Thus, our metric captures dwell to an AOI as our measure of social attention. Using second-by-second MET data allowed alignment with our behavioral data, which was also coded at the second-by-second timescale.

Data Analysis

Figure 2 displays the raw MET and expressed affect data. Given the low presence of negative affect in the study (only 2 children expressed any negative affect), we removed seconds where negative affect was expressed prior to analyses. Figures S2 – S4 display dwell, self-expressed and peer-expressed affect over the course of the free play episode for each child. All data analysis code and results are available on Open Science Framework (Pérez-Edgar et al., 2019).

Our analyses were designed to assess three main questions. First, what do children spend most of their time dwelling on during a social interaction with a novel peer? Second, are behavioral inhibition, self-expressed affect and peer-expressed affect related to the odds of dwelling to a peer compared to anywhere else in the room during a social interaction with a novel peer? Third, are behavioral inhibition, peer-expressed affect and dwell related to the odds of self-expressing positive compared to neutral affect? We conducted three multilevel regressions, and appropriate model comparisons, to assess our questions. All analyses were conducted in R using the lme4 package (Bates et al., 2015). In each model, we controlled for age and percent tracked seconds of MET data. Continuous variables (age, percent tracked seconds and behavioral inhibition) were scaled (converted to z-scores) prior to inclusion. As the task was unstructured, we did not have expectations that behaviors would vary systematically with time across individuals. However, due to potential time effects on behavior and affect as children grew more familiar with one another, we included time as a fixed and random effect in Models 2 and 3 (see below). Models including time fit best when the random slopes and intercepts were left uncorrelated. Time in seconds was divided by 100 prior to inclusion in the models.

Model 1 (81 observations nested in 28 individuals/19 dyads) assessed where children dwelled most during play with count of seconds for each AOI (toy, peer other) as a continuous outcome variable and AOI as a categorical predictor (toy as reference). For models 2 and 3 (4399 observations nested in 28 individuals/19 dyads) we collapsed across the toy and other AOIs to assess social attention compared to visual attention to anywhere else in the room during the social interaction. Model comparisons with random intercepts (individual/dyad, individual alone and dyad alone) and without random intercepts were conducted for Model 1 (Table S1). The best fitting model did not retain random intercepts. Model 2 used logistic regression to assess the likelihood of a child dwelling to the peer compared to anywhere else in the room with AOI as a categorical outcome (0 = not peer, 1 = peer). Behavioral inhibition was included as a continuous predictor and self- and peer-expressed affect were included as categorical predictors (0 = neutral, 1 = positive). Model comparisons assessing interaction terms and random slopes for self- and peer-expressed affect were conducted for Model 2 (Table S2). The final model retained random intercepts for individual and dyad. Model 3 used logistic regression to assess the likelihood of self-expressed positive compared to neutral affect with self-expressed affect as a categorical outcome (0 = neutral, 1 = positive). Behavioral inhibition was included as a continuous predictor, AOI (0 = not peer, 1 = peer) and peer-expressed affect (0 = neutral, 1 = positive) were included as categorical predictors. Model comparisons assessing interaction terms, random slopes for AOI and peer-expressed affect and random intercepts for individual and dyad were conducted for Model 3 (Table S3). The final Model 3 retained the random intercept for individual.

We completed additional sensitivity analyses given the complexity of our data (see data analysis code). First, we re-ran our analyses removing children who provided less than 1 minute of MET data. Second, we re-ran our analyses removing the dyad where one of the children in the dyad spent much more time dwelling on their peer compared to all other children in the sample (+4 SD). In both cases, the results we report in the main text held consistent.

We also completed additional exploratory analyses to test 1) the effect of lagged and leading self- and peer-expressed affect in Model 2 and 2) the effect of dyadic behavioral inhibition in Models 2 and 3 (S3).

Results

Table 1 displays zero-order correlations and descriptive statistics for the sample. Behavioral inhibition and age were not significantly related to the percent tracked seconds of MET data. Girls in the sample tended to be younger than boys in the sample. However, the dyads were age- and sex- matched so this was unlikely to impact the course of individual social interactions. On average, the correlations between affect and gaze within dyad were small (peer-expressed affect: $r = .01$; self-expressed affect was $r = .04$). There was substantial variability between dyads in these correlations as displayed in Figure S5. However, even at the extreme of the distribution, these variables are not highly correlated. As such, they are distinguishable within the following models.

Figure 3 and Table 2 display the results of Model 1 assessing where children dwell most during play with a novel peer (81 observations across 28 individuals/19 dyads). We found that children spent more time dwelling on toys than on their peer ($b = -81.50$, $p < .001$) or anywhere else in the room (other AOI; $b = -76.39$, $p < .001$). The peer and other AOIs did not differ from each other ($b = 5.11$, $p = .664$). Results were not dependent on nesting by dyad or individual, suggesting that regardless of individual social interaction context, children were more likely to look at toys than anywhere else during the social interaction (Pérez-Edgar et al., 2019).

In our following analyses, we were most interested in if social attention (peer AOI) differed from non-social attention (toy and other AOIs) and so collapsed across toy and other. Figure 4 and Table 3 display the results of Model 2 assessing the effects of behavioral inhibition, self-expressed and peer-expressed affect on likelihood of dwelling to the peer (4,399 observations across 28 individuals/19 dyads). Model comparisons indicated that a model including only main effects and no random slopes with nesting by both individual and dyad provided the best fit (see data analysis code). Results suggested a main effect of self-expressed affect such that when self-expressing positive affect, children were approximately twice as likely (odds ratio estimate: 2.02) to dwell on their peer versus anywhere else in the room ($b = .70$, $p < .001$). There was also a main effect of time such that children decreased their attention to the peer over the course of the social interaction ($b = −0.28$, $p = .007$).

Exploratory Analysis.

Retaining the final model structure selected for Model 2 with time removed as a fixed and random effect, we assessed 1-second lagged and leading self-expressed and peer-expressed positive affect on likelihood of dwelling to the peer (4343 observations across 27 individuals/18 dyads). We found (Table 4) that leading self-expressed positive affect was related to greater looking at the peer versus anywhere else in the room ($b = 0.60$, $p = .003$).

Figure 5A and Table 5 display the results of Model 3 assessing the effects of behavioral inhibition, peer-expressed affect and dwell on likelihood of self-expressing positive affect (4,399 observations across 28 individuals). Model comparisons indicated that a model including potential two-way interactions and no random slopes with nesting by individual provided the best fit (Pérez-Edgar et al., 2019). Results suggested a main effect of dwell such that when dwelling on the peer, children were more than twice as likely (odds ratio estimate: 2.60) to self-express positive affect ($b = 0.95$, $p < .001$). There was also a main effect of peer-expressed affect such that when a peer expressed positive affect, children were more than three times as likely (odds ratio estimate: 3.21) to self-express positive affect ($b = 1.17$, $p < .001$). We observed a two-way interaction between behavioral inhibition and peer-expressed affect (Figure 5B), such that individuals higher in behavioral inhibition were less likely to self-express positive affect in the context of peer-expressed positive affect (odds ratio estimate: 0.68, $b = −0.38$, $p = .045$). Finally, we observed a two-way interaction between AOI peer and peer-expressed affect, such that in the presence of peer-expressed neutral affect, children were more likely to express positive affect when looking at the peer (odds ratio estimate: 0.33, $b = −1.12$, $p = .030$).

Discussion

The current study was designed to assess relations between social attention, expressed affect and behavioral inhibition during dyadic, naturalistic play in young children. We used naturalistic measures, including mobile eye-tracking, to assess our constructs of interest, which enabled us to increase the ecological validity of our assessments. In line with previous mobile eye-tracking work (Franchak et al., 2018; MacNeill et al., 2021), we found that children spent more time dwelling on toys than at social interaction partners. However, children were approximately twice as likely to gaze at their peer, compared to anywhere else in the room, during self-expressed positive, rather than neutral, affect. Our exploratory analyses suggested there might be a temporal effect such that self-expressed positive affect precedes gazing at an interaction partner, in keeping with previous work on anticipatory smiling (Gangi et al., 2014; Parlade et al., 2009; Venezia et al., 2004). Positive expressions may indicate to interaction partners that children are in an affective state conducive to social engagement. However, these results should be replicated in future work with confirmatory analyses.

We also found that children were more than twice as likely and more than three times as likely to self-express positive affect when dwelling on their peer or in the presence of peer-expressed positive affect, respectively. Children higher in behavioral inhibition did not differ in social attention. However, children higher in behavioral inhibition were less likely to self-express positive affect in the presence of peer-expressed positive affect. This initial study also provides an example of how researchers may incorporate novel MET technology in larger samples to capture dynamic patterns of visual attention in the moment. Together, our results characterize the complexity of social attention-affect-individual differences relations when measured in a naturalistic context.

Most research assessing social attention relies on static faces. However, recent mobile eye-tracking work (Franchak et al., 2018; MacNeill et al., 2021; Woody et al., 2020) suggests that individuals do not look at social interaction partners with the frequency that paradigms relying on static facial expressions anticipate. Our results indicating that children on average spend the majority of their time dwelling on toys adds to this growing literature. We additionally found that over the course of the social interaction, children spent less time gazing at their peer. Potentially, as children settled into play, they were overall more focused on the toys they were using to engage with their peer. As more studies show the infrequency with which individuals actually dwell on interaction partners, it becomes more important to contextualize what paradigms relying on static faces represent in terms of real-world experience.

For example, there is conflicting evidence regarding if children high in behavioral inhibition are more likely to attend to (Nozadi et al., 2016; Pérez-Edgar et al., 2010), avoid (Brown et al., 2013; Grafton et al., 2016; Morales et al., 2015) or exhibit consistent attention patterns (Fu et al., 2019; Morales et al., 2017) to threat. However, recent naturalistic work shows the effect of context. Specifically, in a medium threat context (unfamiliar adult with toy), avoidant social attention was related to elevated internalizing (Gunther, Fu, et al., 2021). Conversely, in a high threat context (unfamiliar adult wearing a ‘scary’ mask), higher levels of behavioral inhibition were related to more attention to threat (Gunther, Brown, et al., 2021). Using naturalistic methods allowed for these context-linked individual differences to emerge. In the current study, the free play was low stakes. Although the peer might be a “threat” to a child higher in behavioral inhibition, they may not be enough of a threat to elicit individual differences in social attention. Indeed, the very low presence of expressed negative affect in the sample suggests that on the whole children were engaged in a neutral to positive social experience. In addition, many children in this age range have growing experience in peer interactions with the transition to formal schooling. Had a higher threat scenario been employed, potentially eliciting more negative affect and uncertainty, clear individual differences in social attention may have emerged as a function of temperament.

Although we did not find associations between behavioral inhibition and social attention, we did observe that children as a whole were approximately twice as likely to dwell on their peer during self-expressed positive, rather than neutral, affect. Additionally, we found that in the presence of peer-expressed neutral affect, children were more likely to express positive affect when looking at the peer. Dwelling on a social partner could be a bid for shared attention (Redcay et al., 2012) or emotionality (Beltz et al., 2013), which may enhance feelings of support and communality, that in turn lead to successful social interactions (Liu et al., 2019). In our young sample we did not find a relation between peer-expressed affect and social attention. However, there is reason to believe the expressed affect of an interaction partner could be related to social attention in older individuals. Indeed, adolescents give more weight to peers than do younger children (Steinberg, 2008) and are more successful at understanding the perspectives of others (Dumontheil et al., 2010). Further, recent MET work shows that maternal affect during a conflict discussion influences how an adolescent child directs their attention throughout the interaction (Woody et al., 2020), suggesting others' expressed affect can influence social attention. Thus, peer-expressed affect might relate to social attention in older individuals in the same way self-expressed affect relates to social attention in our current young sample.

Although peer-expressed affect was unrelated to social attention, we found that children were over three times as likely to self-express positive, rather than neutral, affect in the context of peer-expressed positive, rather than neutral, affect. Additionally, we found that behavioral inhibition moderated this relation, such that children higher in behavioral inhibition were less likely to self-express positive affect in the context of peer-expressed positive affect. This result suggests that children higher in behavioral inhibition were less likely to share positive emotionality with their peer. As positive affect bolsters social interactions (Liu et al., 2019) and relationships (Griffith et al., 2021), missing out on opportunities for shared positive emotionality may decrease social interaction quality or success for children high in behavioral inhibition (Jarcho & Guyer, 2018). Unfortunately, we did not ask children about their experiences during the free play so we are unable to test the possibility in the current paper. Longitudinal work could also assess whether we indeed see a cascading effect of diminishing social bids and opportunities for social engagement.

In total, our results are in keeping with the broaden-and-build theory of positive emotions (Fredrickson, 1998, 2001), which suggests positive affect may broaden an individual's behavioral toolbox and facilitate the accumulation of social resources. Self-expressed positive affect was related to greater odds of dwelling on the peer and peer-expressed positive affect was related to greater odds of self-expressed positive affect. Opportunities for shared intentionality (Redcay et al., 2012) and emotionality (Beltz et al., 2013) in the context of positive affect may strengthen social bonds. Repetition of these processes over the course of multiple social interactions may support the development of lasting social relationships (Griffith et al., 2021). Although the current analyses are not longitudinal, future work should assess repeated social interactions to examine the time course of social attention and expressed affect as building blocks of social relationships. Indeed, while a good deal of the behavioral inhibition literature has focused on behavior with novel peers (Degnan et al., 2014; Smith et al., 2019), we lack data on behavior in long-term relationships experienced by inhibited children and particularly if patterns of social attention and expressed affect may relate to behavior in those long-term relationships (Rubin et al., 2002, 2018).

Although a strength of our work comes from the ecological validity of our data and our ability to speak to what social attention and expressed affect looked like in a naturalistic peer interaction, there are associated weaknesses. First, because we allowed children to play as they wished, our task was unstructured across dyads. While this did yield maximum ecological validity within constraints of the lab environment (Risko et al., 2016), this variability in the form and sequence of behavior meant we could not adequately assess group level temporal effects of our social attention or expressed affect data. Future work may choose to design a social interaction with more structure to have the power to examine temporal effects, building on the exploratory relations noted here. Second, we saw little variation in expressed affect and particularly almost no negative affect. Children in our study were between the ages of 5 and 7, an age at which most children can engage in relatively successful regulation of expressed affect (Carlson & Wang, 2007). Indeed, many of the children had daily practice in regulating affect as part of their experiences in preschool or elementary school. Thus, even if children were experiencing negative affect, the context may not have been stressful enough to elicit overt expressions. Future research should specifically examine relations between social attention, expressed negative affect and behavioral inhibition through tasks designed to elicit negative affect, such as engaging in a difficult conversation (Woody et al., 2020) or completing a challenging task (Anaya et al., 2021). Third, missing data and a small sample size due to the naturalistic data collection could impact the strength of our results. It will be important to replicate findings in larger samples moving forward.

Additionally, future work should consider how other contextual cues may drive attention. For example, a talkative child may elicit more social attention than a quiet child, generally speaking. However, a child higher in behavioral inhibition could find novel partners relatively threatening and might exhibit hypervigilance even to quiet interaction partners (Gunther, Brown, et al., 2021) or avoidance of interaction partners over time (Gunther, Fu, et al., 2021), depending on contextual cues. Similarly, our results cannot speak to how children might have deployed social attention had toys not been present. Although playing with toys is a primary way that children socially engage (Rubin & Howe, 1985), a future line of work could assess differences in social attention when children are engaged in toy-based play compared to pretend-based play without toys. Without the presence of toys, it is possible children would gaze more at peers. Individual differences in which children are naturally drawn to toy-based play versus pretend-based play without toys may also relate to how children socially attend to their environment.

In addition to limitations related to the naturalistic nature of the data collection, we are unable to assess if social attention and expressed affect relations were related to interaction quality as we did not ask children about their experiences. Future work should ask children about their experiences to understand these processes as potential mechanisms underlying successful social interactions. Additionally, the current sample of children were primarily white and drawn from a convenience sample near our university and we did not collect data on family socioeconomic status. Future work must examine these processes in more diverse populations as cultural variation is known to exist in interpretations of expressed affect (Barrett et al., 2019) and potentially the impact of behavioral inhibition on social behavior (Chen et al., 2021; Chronis-Tuscano et al., 2018; Rubin et al., 2006). Additionally, with the inclusion of a more diverse sample, we believe it will be important to assess how cultural variability between participants in social interactions may influence how these processes unfold as children get to know one another. Such work could have important implications for understanding early developing biases that may influence how children interpret and understand socioemotional expressions from members of different cultures. In conclusion, the current study provides an initial snapshot of relations between social attention, expressed affect and behavioral inhibition during a dyadic, naturalistic social interaction between young children. Our results provide evidence that although children spend the majority of their time dwelling on toys, that expressed positive affect is related to greater odds of dwelling on a peer. Additionally, we found that children were more likely to self-express positive affect in the context of peer-expressed positive affect, but that this relation was moderated by behavioral inhibition such that children higher in behavioral inhibition were less likely to share positive emotionality with their peer. Our results provide a foundation for future work assessing relations between social attention, expressed affect and individual differences.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Public Significance Statement

Social attention and positive affect may coordinate during play to support children's social learning and these processes may differ for some children including those exhibiting higher levels of behavioral inhibition, which is related to later emergence of social anxiety. Using naturalistic social interactions and mobile eye-tracking, we found that positive affect was related to social attention and that children, except for children higher in behavioral inhibition, tended to mutually display positive affect. Our results provide a snapshot of processes underlying child social interactions and provide guidance for future work examining how these processes relate to developing positive social relationships.

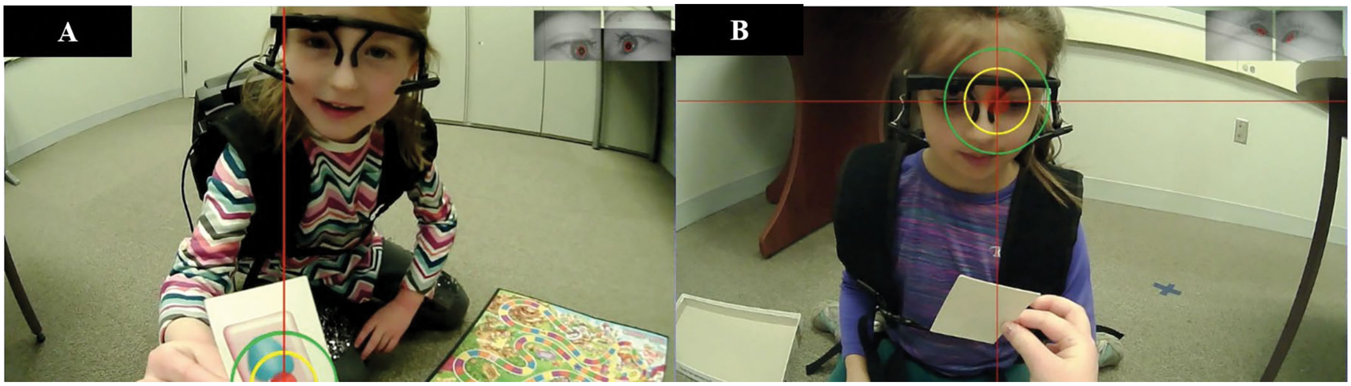

Figure 1.
Example of dyadic mobile eye-tracking data collection. The image illustrates the exact same moment in the interaction from the perspective of each child in the dyad. The red target was used to code gaze patterns. Eye cameras (visualized in upper left-hand corners) were used to confirm successful tracking. The child in **1A** was coded as expressing positive affect (captured in **A**) and gazing at their peer (captured in **B**). The child in **1B** was coded as expressing neutral affect (captured in **B**) and looking at toys (captured in **A**). Parents provided consent for the use of their children's images in academic publications.

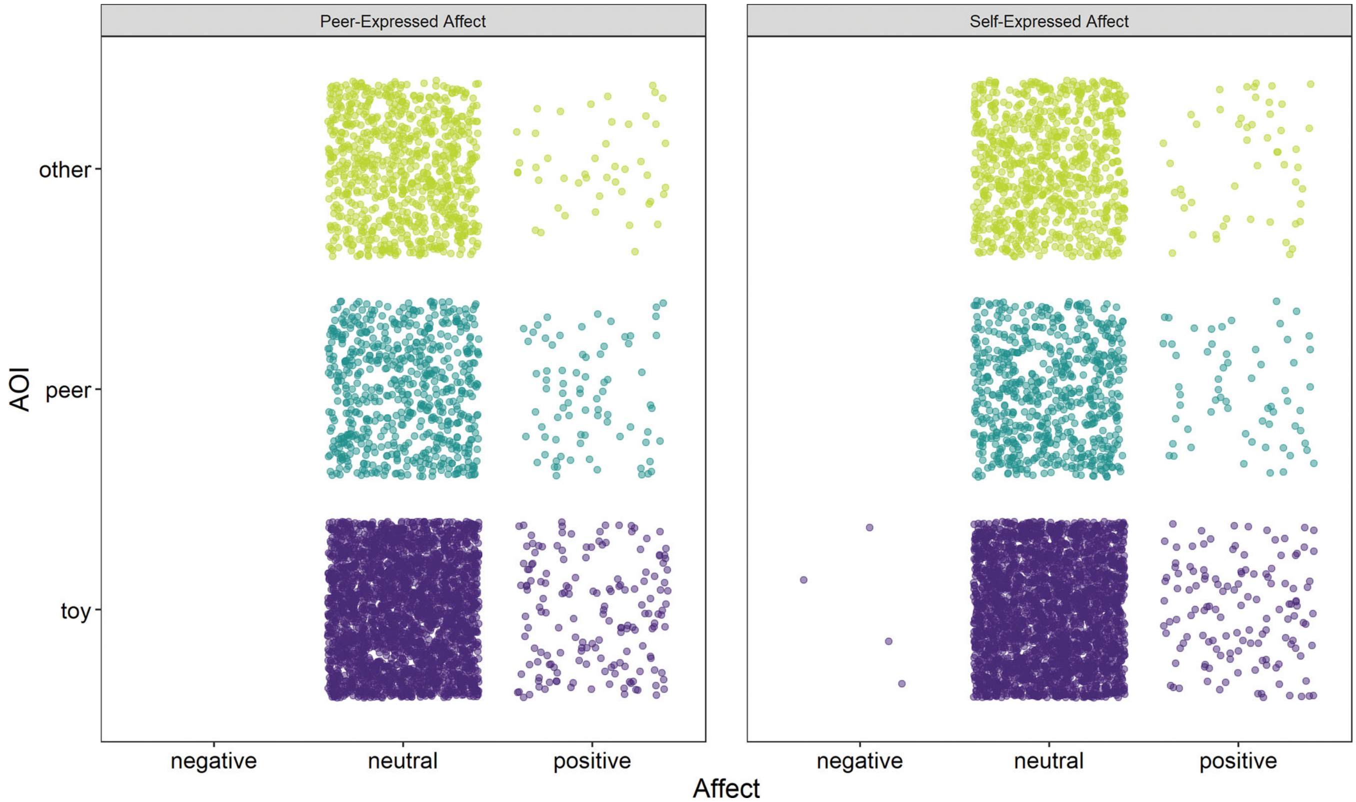

Figure 2.
Raw data visualization of MET and affect data present in the sample. Children spent the majority of their time in neutral affect and displayed almost no negative affect.

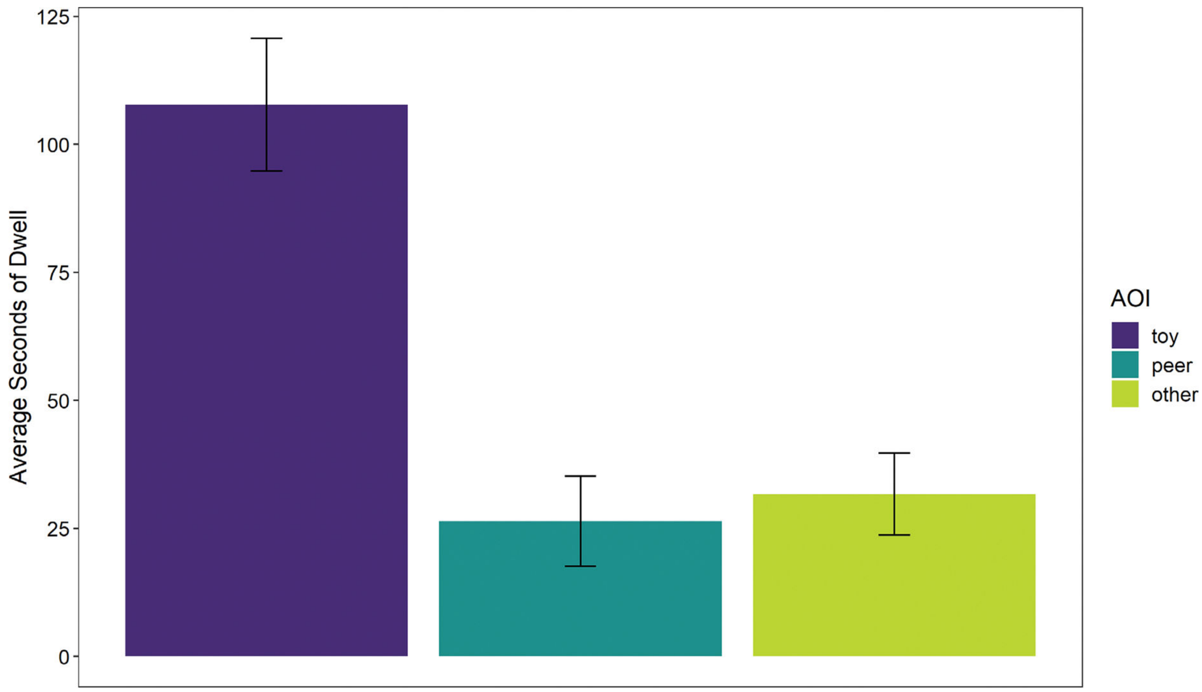

Figure 3.

Average seconds of dwell to AOIs. Model assessed over 81 observations (28 individuals and 19 dyads). Children dwelled to toys more than to the peer or anywhere else in the room. Dwell did not differ between the peer and other AOIs.

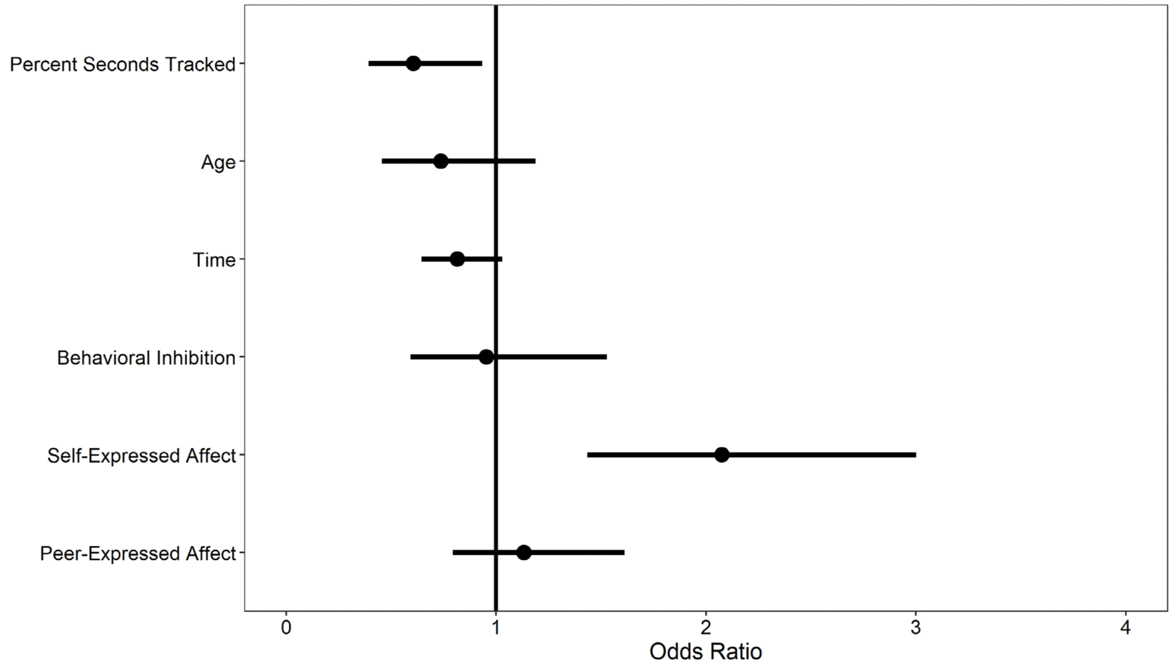

Figure 4.
Forest plot displaying results of model assessing effects of behavioral inhibition, self-expressed affect and peer-expressed affect on likelihood of dwelling to the peer AOI (1) versus anywhere else in the room (toy and other AOIs; 0). Model assessed over 4399 observations (28 individuals and 19 dyads). Children were approximately twice as likely to look at their peer when self-expressing positive affect (1) compared to neutral affect (0).

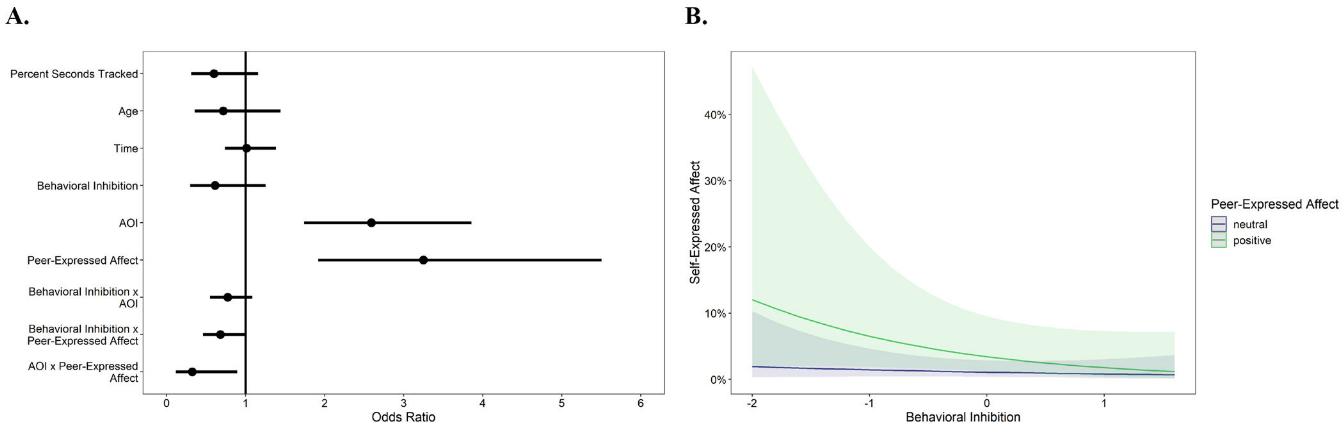

Figure 5.

Results of model assessing effects of behavioral inhibition, dwell and peer-expressed affect on likelihood of self-expressing positive (1) versus neutral (0) affect. Model assessed over 4399 observations (28 individuals). **A.** Forest plot displaying model effects. Children were more than twice as likely and more than three times as likely to self-express positive compared to neutral affect when dwelling on peer (0 = not peer, 1 = peer) or in the presence of peer-expressed positive affect (0 = neutral, 1 = positive), respectively. **B.** Interaction plot displaying moderation of the predicted peer-expressed affect-self-expressed affect relation by behavioral inhibition. Children higher in behavioral inhibition were less likely to self-express positive affect in the presence of peer-expressed positive affect.

Table 1.

Zero-order correlations and descriptive statistics

	2.	**3.**	**4.**	***M***	***SD***
1. Sex	−.38*	−.01	.04		
2. Age		−.19	−.03	6.12	0.62
3. Percent Tracked Seconds			−.22	.51	.46
4. Behavioral Inhibition				99.43	28.65

Note: 28 children provided data on all metrics.

$^{*}p < .05$.

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Table 2.

Model assessing where children dwell most during play with a novel peer

	Estimate	SE	t-value	CI lower	CI upper
Intercept	90.67***	9.26	9.79	72.21	109.12
Percent Tracked Seconds	30.17***	5.94	5.08	18.34	42.01
Age	−0.66	4.47	−0.15	−9.57	8.25
AOI Peer	−81.50***	11.93	−6.83	−105.26	−57.73
AOI Other	−76.39***	11.84	−6.45	−99.97	−52.80

Note: AOI = Area of Interest, SE = Standard Error, CI = Confidence Interval.

*** $p < .001$.

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Table 3.

Model assessing the effects of behavioral inhibition, self-expressed and peer-expressed affect on likelihood of dwelling to the peer

	Estimate	SE	z-value	CI lower	CI upper
Fixed Effects					
Intercept	−1.36***	0.37	−3.69	−2.09	−0.64
Percent Tracked Seconds	−0.56	0.32	−1.79	−1.18	0.06
Age	−0.18	0.28	−0.65	−0.73	0.37
Time	−0.28**	0.11	−2.69	−0.49	−0.08
Behavioral Inhibition	−0.08	0.26	−0.32	−0.59	0.42
Self-Expressed Positive Affect	0.70***	0.19	3.74	0.34	1.07
Peer-Expressed Positive Affect	0.12	0.18	0.67	−0.23	0.47
Random Effects					
Individual:Dyad – Time	0.00 (0.04)				
Individual:Dyad – Intercept	1.19 (1.09)				
Dyad – Time	0.12 (0.34)				
Dyad – Intercept	0.54 (0.73)				

Note: SE = Standard Error, CI = Confidence Interval.

** $p < .05$

*** $p < .001$.

Table 4.

Exploratory model assessing the effects of behavioral inhibition and lagged and leading self-expressed and peer-expressed affect on likelihood of dwelling to the peer

	Estimate	SE	z-value	CI lower	CI upper
Fixed Effects					
Intercept	−1.67***	0.32	−5.18	−2.30	−1.04
Percent Tracked Seconds	−0.65*	0.30	−2.16	−1.24	−0.06
Age	−0.31	0.23	−1.35	−0.76	0.14
Behavioral Inhibition	−0.04	0.23	−0.19	−0.50	0.41
Lagged Self-Expressed Positive Affect	0.18	0.21	0.85	−0.23	0.58
Lagged Peer-Expressed Positive Affect	−0.15	0.20	−0.75	−0.53	0.26
Leading Self-Expressed Positive Affect	0.60**	0.20	2.99	0.21	1.00
Leading Peer-Expressed Positive Affect	0.03	0.20	0.16	−0.35	0.41
Random Effects					
Individual:Dyad – Intercept	1.08 (1.04)				
Dyad – Intercept	0.23 (0.48)				

Note: SE = Standard Error, CI = Confidence Interval.

* $p < .05$

** $p < .01$

*** $p < .001$.

Lags and leads are by 1 second.

Table 5.

Model assessing the effects of behavioral inhibition, self-expressed and peer-expressed affect on likelihood of dwelling to the peer

	Estimate	SE	z-value	CI lower	CI upper
Fixed Effects					
Intercept	−3.76***	0.54	−7.00	−4.82	−2.71
Percent Tracked Seconds	−0.64	0.50	−1.26	−1.62	0.35
Age	−0.56	0.37	−1.49	−1.28	0.18
Time	−0.16	0.18	−0.86	−0.52	0.20
Behavioral Inhibition	−0.29	0.40	−0.72	−1.08	0.50
AOI Peer	0.95***	0.20	4.70	0.56	1.35
Peer-Expressed Positive Affect	1.17***	0.27	4.35	0.64	1.69
Behavioral Inhibition X AOI Peer	−0.26	0.17	−1.57	−0.59	0.07
Behavioral Inhibition X Peer-Expressed Positive Affect	−0.38*	0.19	−2.00	−0.76	−0.01
AOI Peer X Peer-Expressed Positive Affect	−1.12*	0.52	−2.17	−2.14	−0.11
Random Effects					
Individual – Time	0.40 (0.63)				
Individual – Intercept	3.28 (1.81)				

Note: SE = Standard Error, CI = Confidence Interval.

* $p < .05$

*** $p < .001$.