Developmental Cognitive Neuroscience xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Developmental Cognitive Neuroscience

journal homepage: www.elsevier.com/locate/dcn

Young children's behavioral and neural responses to peer feedback relate to internalizing problems

Santiago Morales[a,b,*,1], Alicia Vallorani[b,1], Koraly Pérez-Edgar[b]

[a] University of Maryland, College Park, MD, 20742, United States
[b] The Pennsylvania State University, University Park, PA, 16802, United States

ARTICLE INFO

Keywords:
Peer feedback
Internalizing problems
EEG theta power
Social rejection
Attention bias to threat

ABSTRACT

Despite the importance of peer experiences during early childhood for socioemotional development, few studies have examined how young children process and respond to peer feedback. The current study used an ecologically valid experimental paradigm to study young children's processing of peer social acceptance or rejection. In this paradigm, 118 children (50% boys; M_{age} = 72.92 months; *SD* = 9.30; $Range_{age}$ = 53.19–98.86 months) sorted pictures of unknown, similar-aged peers into those with whom they wished or did not wish to play. They were later told how these peers sorted them, such that in half of the cases the presumed peer accepted or rejected the participant. When rejected children reported more distress (sadness), they were slower to rate their affective response, and exhibited increased mid-frontal EEG theta power, compared to when accepted. Moreover, we found that children's affective responses and EEG theta power for rejection predicted internalizing problems, especially if they displayed an attention bias to social threat. Our results further validate and illustrate the utility of this paradigm for studying how young children process and respond to peer feedback.

1. Introduction

Children's interpretations and responses to peer feedback contribute to social competence and may predict later psychological adjustment (Parker and Asher, 1987; Parker et al., 2006), making it important to understand how children process experiences with peers. However, studies using ecologically valid experimental paradigms to investigate how young children process and respond to peer feedback are rare (Howarth et al., 2013; Walker et al., 2014). In the current study, we employ a novel and ecologically valid experimental paradigm to examine processing of peer feedback during early childhood, in and around the transition to schooling. This developmental period is marked by peer interactions that become more frequent, salient, and important for socioemotional development (Parker et al., 2006; Rimm-Kaufman and Pianta, 2000). Furthermore, evidence suggests that attention to social threat is related to both greater sensitivity to negative feedback (MacLeod et al., 2002) and internalizing problems (Bar-Haim et al., 2007). A bias for socially threatening information may potentially color how children interpret social cues, potentiating risk for internalizing problems. We examine if young children's processing of peer feedback, using affective, behavioral, and neural measures, is related to internalizing problems and whether this relation is exacerbated in children exhibiting greater attention to social threat.

Studies tend to focus on adolescence as a developmental stage in which peers are highly salient (Guyer and Jarcho, 2018). However, peer interactions during early childhood may set the developmental course for later peer relationships. Indeed, experiences with peers are a significant early catalyst for socioemotional development (Parker and Asher, 1987; Parker et al., 2006). For example, children who experience positive peer interactions during their preschool years, compared to children experiencing more negative interactions, exhibit more social skills and have more friends in third grade (National Institute of Child Health and Human Development Early Child Care Research Network, 2008). Additionally, rejection from peers is concurrently and longitudinally associated across childhood with increased internalizing problems, including anxiety, depression, and loneliness (Gazelle and Ladd, 2003; Gazelle and Rudolph, 2004; Kraatz-Keiley et al., 2000; Ladd and Troop-Gordon, 2003). As such, examining peer experiences during early childhood may provide foundational information needed to understand different trajectories of socioemotional development, including the path between peer rejection and internalizing problems.

Traditional approaches for evaluating children's responses to peer feedback often require large sample sizes and complex procedures, such as sociometric ratings, reports from teachers and parents, or thorough

* Corresponding author at: Department of Human Development and Quantitative Methodology, University of Maryland, College Park, MD, 20742, United States.
E-mail address: moraless@umd.edu (S. Morales).

[1] Both authors contributed equally to this work.

https://doi.org/10.1016/j.dcn.2018.12.008
Received 1 June 2018; Received in revised form 8 December 2018; Accepted 12 December 2018
1878-9293/

coding of children's behavior in school or laboratory settings (Burgess et al., 2006; Gazelle and Druhen, 2009; Ladd and Troop-Gordon, 2003). Although these approaches are fruitful and have high ecological validity, their lack of experimental control leads to important limitations. First, determining how each child interprets and responds to multiple types of peer feedback is often difficult. This is because peer interactions are often embedded in a complex and idiosyncratic transactional process that leads some children to experience more rejection than others (Parker et al., 2006). Second, while these approaches identify rejected children and their behavioral responses to rejection, they do not examine how children process rejection. Paradigms that allow for concurrent electrophysiological measures may elucidate how children process peer feedback. Through ecologically valid experimental paradigms, investigators can collect converging evidence to reveal relations between the processing of, and responses to, peer feedback as well as how these relations may identify children with internalizing problems.

Currently available ecologically valid experimental approaches allow participants to engage in ostensibly real computer-based games and social interactions that are in reality experimenter-controlled. For example, the chat-room task (Guyer et al., 2012) investigates reactions to positive and negative peer feedback from peers with whom the participant either did or did not wish to communicate. This task allows researchers to investigate how personal investment in a given social interaction relates to behavioral and neural responses to peer feedback and has been associated with early temperament (Guyer et al., 2014).

Recently, we adapted the chat-room task to examine young children's responses to and processing of peer feedback (Howarth et al., 2013). In this paradigm—the playdate task—young children sort pictures of unknown, similar-aged children into those with whom they do or do not wish to play. Children then receive feedback about whether or not the pictured children wanted to play with them. In this way we can directly contrast the child's subjective view (Interest vs. No Interest) with the putative peer's response to the social bid (Accept vs. Reject).

Importantly, most of the prior work examining experimentally-controlled peer feedback has been limited to samples of older children, adolescents, and adults (Achterberg et al., 2016; Crowley et al., 2014; Gunther Moor et al., 2010; Guyer et al., 2008; Jarcho et al., 2016; Kujawa et al., 2014; Tang et al., 2018; van Noordt et al., 2015), due to the complexity of the task or the use of neuroimaging techniques, limiting our understanding of how young children experience peer feedback.

We selected the playdate task over other viable paradigms, such as Cyberball (Walker et al., 2014), as it would allow us to examine how individual preferences relate to processing of peer feedback. Additionally, unlike the virtual-school task (Jarcho et al., 2013), which provides children with feedback from virtual peers but requires them to retain information throughout the task, the playdate paradigm reminds children of their previous choices, making it easier for young children to complete.

Results from a previous study (Howarth et al., 2013) using this paradigm show that young children (4–7 years) rate their affective responses to feedback in the expected pattern, such that they report being happier when accepted and sadder when rejected. Moreover, these responses are accentuated when children expressed interest in playing with the peers providing feedback. In the current study, we look to further demonstrate the validity of this paradigm by not only examining affective responses to peer feedback, but also behavioral and neural responses during peer feedback. Furthermore, we examine if responses to peer feedback relate to internalizing problems, particularly in children who exhibit greater attention to social threat.

Studies using computer-based tasks with older children, adolescents, and adults suggest that social rejection is distressing and perceived as a threat (Eisenberger and Lieberman, 2004; Harrewijn et al., 2018; van Noordt et al., 2015). Moreover, neuroimaging studies demonstrate that social rejection is processed quickly by regions broadly involved in conflict detection (Eisenberger and Lieberman, 2004; Shackman et al., 2011), including the anterior cingulate cortex (ACC) and anterior insula (AI), potentially via electroencephalogram (EEG) oscillations in the theta band (Cristofori et al., 2012; Eisenberger, 2012; Van der Molen et al., 2017). For example, children 8–12 years old exhibit greater mid-frontal theta power when rejected. Children exhibiting the greatest theta power when rejected also report higher levels of distress to rejection (van Noordt et al., 2015). Moreover, emerging evidence suggests that mid-frontal theta is stronger when rejection is unexpected and that it is further enhanced for both children and adults with an anxiety disorder (Harrewijn et al., 2018).

Importantly, children's responses to peer feedback may be influenced by other individual characteristics that enhance or buffer the impact of social rejection. For instance, individual differences in how children process social information may influence how they make sense of their social interactions with peers (Crick and Dodge, 1994; Lemerise and Arsenio, 2000; Rubin and Krasnor, 1986). Although most empirical research studying social rejection has focused on children's interpretations of social interactions (e.g., Burgess et al., 2006; Wichmann et al., 2004), work in internalizing disorders has highlighted the role of attention bias to social threat in the development and maintenance of anxiety (Bar-Haim et al., 2007). Generally, this corpus of research indicates that children higher in internalizing problems or at increased risk for internalizing problems (e.g., high levels of fearful temperament and/or social withdrawal) display a heightened attention bias to threat (Abend et al., 2018; Morales et al., 2016; Pérez-Edgar et al., 2010, 2011; Salum et al., 2013; Tang et al., 2017). Furthermore, experimental work has shown that individuals induced to attend to threating information (angry faces) experience greater distress when given negative feedback (MacLeod et al., 2002). Heightened awareness of threat in the environment may color how individuals respond to and rationalize social feedback. As such, it is possible that children who display greater attention to socially threatening information may exhibit heightened sensitivity to rejection and greater levels of internalizing problems. However, to our knowledge no study has examined these relations in young children.

1.1. Current study

The first aim of the current study was to examine young children's processing of peer feedback using affective (self-report ratings of response to feedback), behavioral (reaction times, RTs, for feedback ratings), and neural (theta power during feedback) markers of sensitivity to peer feedback. Building on the previous study using this paradigm (Howarth et al., 2013), we expected children to feel happier when accepted and sadder when rejected by presumed peers. Additionally, we anticipated these responses would be especially salient when children were interested in playing with the peer providing the feedback. We also evaluated children's RTs when providing their affective response to social feedback. Although no previous study has used this specific measure of social feedback, RTs are often considered a measure of cognitive processing and are often delayed by conflict detection (e.g., incongruent stimuli and errors). We expected that children would take longer to respond after rejection trials as well as trials in which peer feedback did not match the participant's interest. This would provide further support that children use not only peer feedback, but also their initial interest when considering their affective responses to feedback. Finally, for the first time, we examine young children's mid-frontal theta power during peer feedback. In line with previous studies (Van der Molen et al., 2017; van Noordt et al., 2015), we expected increased theta power to rejection and even stronger theta power if the child was interested in playing with that peer.

A second aim of the current study was to examine if participants' responses to peer feedback were related to internalizing problems. Based on previous studies, we expected children who reported more distress (sadness) when rejected by peers would exhibit more internalizing problems than children who reported less distress. Similarly, we expected children who displayed heightened processing of rejection (as indexed by greater RTs and theta power) would exhibit more internalizing problems. Finally, given that social rejection is often interpreted as a social threat (Cristofori et al., 2012; Harrewijn et al., 2018; van Noordt et al., 2015), we evaluated if the relations between internalizing problems and each measure of social rejection processing were stronger for children with an attention bias to social threat.

2. Method

2.1. Participants

The sample consisted of 118 children (50% boys; M_{age} = 72.92 months; Mdn_{age} = 72.05 months; SD = 9.30; $Range_{age}$ = 53.19–98.86 months). Families were recruited through a university database of families interested in participating in research studies, community outreach, and word-of-mouth. Parents provided consent and children provided verbal assent prior to participation. The Institutional Review Board approved this study.

2.2. Procedure

Children were introduced to the playdate task and then to our EEG system (both described below). Children completed the playdate task while providing EEG to measure affective, behavioral, and neural responses to peer feedback. Children then provided behavioral data from the dot-probe task to measure their affect-biased attention. Parents rated their children's levels of internalizing problems using the Child Behavior Checklist.

2.3. Measures

2.3.1. Playdate task

Behavioral and neural responses to acceptance and rejection were measured using a version of the playdate task[2] (Howarth et al., 2013). Children were told that they would see pictures of other children that they could select to play with now or later. They were also told that they needed to provide their own picture because other children were also participating in the study and selecting potential playmates. The experimenters took pictures of the participating children and told them that their pictures would be uploaded for other children to see. In reality, the researcher deleted participant pictures immediately after they were taken.

Children were seated in front of a computer monitor (20 in. and were shown a single display of 60 photographs (3 cm × 4 cm) of similar-age racially and ethnically diverse children (50% male) displaying happy facial expressions. All pictures were obtained from the Child Affective Facial Expression (CAFE) set (LoBue and Thrasher, 2015). Participants selected 30 children "they wanted to play with now" and 30 children "they wanted to play with later" by clicking on the pictures with a mouse, which sorted them into one of two boxes on the screen. The task design required an even split of potential peers into the two categories in order to ensure equal trial distribution per condition. This process took approximately 10 to 20 min.

Following the peer selection procedure, children were taken to a separate room where they were introduced to the EEG net. After placement of the EEG net (~25 min), children were again seated approximately 60 cm away from the computer monitor. Participants were told they would "find out if the children you saw earlier wanted to play with you." The experimenter explained to the participants that the children they saw pictured had also made their playdate choices and that the computer would show whether each pictured child had selected the participant. Participants were also then taught to use a 4-point scale to rate their feelings (described below).

Trials began with a fixation cross at the center of the screen. The experimenter advanced the trial by a keyboard press once the child was focused on the screen. Each fixation was followed by a 15 cm by 20 cm picture of a previously sorted (play now vs. play later) child for 2000 ms. The participant's sorting decision was noted by the border color of the pictured child: if the participant wanted to play with the pictured child, the border was green, and if the participant did not want to play with the child, it was red. The research assistant also verbally reminded the participant of their choices, saying "You did want (or did not want) to play with this child."

The background color then reflected the peer's "choice" for 2000 ms. If the pictured child accepted the participant, the background was green. If the pictured child rejected the participant, the background was red. The research assistant also told the participant of the pictured child's decision with the statement "This child did (or did not) want to play with you." Verbal reminders for participant's choices and pictured children's choices were provided due to the young age of our participants.

The task was programmed to counterbalance the participant's sorting of the pictures with the simulated social feedback to ensure equal numbers of trials within each of four conditions: acceptance from children with whom participants wished to play (interested/accepted; marked as green/green), rejection from children with whom they wished to play (interested/rejected; green/red), acceptance from children with whom they did not wish to play (not interested/accepted; red/green), and rejection from children with whom they did not wish to play (not interested/rejected; red/red). Trials were presented in four blocks of 15 trials. Each block contained 12 trials of one condition (e.g., not interested/rejected) and one trial from each of the other conditions. Blocks were weighted toward one condition because we were also interested in inducing changes in physiological systems that are commonly measured using longer time periods (i.e., sympathetic and parasympathetic cardiac measures) (McLaughlin et al., 2015). Results using these measures will be reported elsewhere. Blocks were presented in pseudorandom order such that blocks with the same feedback were never presented consecutively.

After receiving feedback, participants were asked to answer the question 'How do you feel?' on a 4-point scale using a four-button response box: (1) sad, (2) a little sad, (3) a little happy, (4) happy. Above each picture there were schematic drawings of facial expressions illustrating each possible response. The fixation cross reappeared once the participant made a rating. Participants were given an indefinite amount of time to make their ratings. The peer evaluation phase of the playdate task lasted approximately 20 min. At the end of the visit, researchers told the participants they had discovered that the computer collecting the selections was broken and that all the peers had evaluated them positively. None of the children reported distress in response to this disclosure. The peer selection and peer feedback were presented with E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA). The data of interest from this task involved children's rated affective responses to peers' feedback, the RTs to provide their affective responses, and their neural responses captured by theta power to feedback.

2.3.2. Behavioral data

To assess children's affective responses to peers' feedback, their emotion ratings when asked 'How do you feel?' were averaged for each of the four conditions separately. To evaluate their processing of social feedback we evaluated their RTs to provide their affective ratings. Before averaging the RTs for each condition, trials with RT of less 150 ms and trials with RTs +/- 2 SDs of each condition from the individual's mean were removed.

[2] This version was completely done on the computer, whereas the original version of the playdate task children used laminated cards to sort children. In addition, as outlined below, this version of the playdate task presented the feedback in blocks weighted toward one condition.

2.3.3. EEG data

EEG activity was continuously recorded during the playdate task using a 128-channel geodesic sensor net (Electrical Geodesics Inc., Eugene, Oregon). Data from each channel was digitized at a 250 Hz sampling rate. EEG channels were collected with reference to Cz and, re-referenced offline to the average of the mastoids. Vertical eye movements were recorded from electrodes placed approximately 1 cm above and below each eye. Horizontal eye movements were monitored with electrodes placed approximately 1 cm at the outer canthi of each eye. Impedances were kept below 50 kΩ.

Offline, all data preparation and processing were conducted using Brain Vision Analyzer (Brain Products GmbH, Germany). Data were filtered with a high-pass frequency of 0.1 Hz, a low-pass frequency of 40 Hz, and a 60 Hz notch filter. Ocular artifacts from eye blinks and horizontal eye movements were corrected using the method developed by Gratton (Gratton et al., 1983). Before artifact rejection, we selected the electrodes of interest in frontal and central sites (3, 4, 5, 7, 9/Fp2, 10, 11/Fz, 12, 16, 18, 19, 20, 22/Fp1, 23, 24/F3, 27, 28, 31, 32, 33, 55, 80, 106, 117, 118, 122, 123, 124/F4, and 129/Cz). We used the specified electrode configuration in order to minimize the number of trials and participants deleted due to artifacts. Namely, we did not wish to delete segments that only had artifacts on channels that were not included in our designated analyses. Data were time-locked to the feedback and segmented into epochs from 200 ms before to 1000 ms after stimulus presentation (i.e., the pictured child's feedback). Epochs exceeding ± 120 μV, a voltage step of more than 75 μV between sample points, or a maximum voltage difference of less than .50 μV within any 100-ms interval were marked as artifacts and removed. Data were also visually inspected for any remaining artifacts.

Based on previous studies (Harrewijn et al., 2018; van Noordt et al., 2015), we focused on a frontocentral electrode cluster along the midline (4, 5, 10, 11/Fz, 12, 16, 18, and 19). ERP averages were then created separately for each condition of interest (Interest-Accept, Interest-Reject, No Interest-Accept, No Interest-Reject) and were baseline corrected by subtracting from each trial the average activity in a window -200 to the presentation of the feedback. We then performed time-frequency analysis by convoluting the ERP average waveform of each condition with complex Morlet wavelets. The Morlet wavelets increased from 1 to 30 Hz in 30 logarithmically spaced steps, using a Morlet parameter of 5 and the unit energy normalization method. When collapsing across the four conditions, we observed increased theta power 100–400 ms after feedback. We extracted the evoked power corresponding to the theta band (4–8 Hz) during this time-window for each condition separately. We focus here in mid-frontal theta power based on the social rejection literature with older children, adolescents, and adults (Van der Molen et al., 2017; van Noordt et al., 2015), as well as work from other literatures showing its conceptual and methodological benefits over ERPs (Cavanagh and Shackman, 2015; DuPuis et al., 2015). We present the grand average waveforms and the time-frequency plots for each condition in the supplement.

2.3.4. Dot-probe task

Affect-biased attention was measured by the dot-probe task (Bar-Haim et al., 2007; MacLeod et al., 1986). The task consisted of 8 practice trials and 100 experimental trials randomly presented in four blocks of 25 trials. Each trial began with the presentation of a central fixation cross for 500 ms followed by a pair of faces presented side-by-side for 500 ms. Both faces were then removed and an asterisk appeared in one of the prior face locations for 2500 ms. Using a computer mouse, children were asked to indicate, as quickly and accurately as possible, the location of the asterisk. The inter-trial interval was 1800 ms. Children were seated approximately 60 cm from a 20 in LCD color monitor. Stimuli were presented with E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA).

Three combinations of faces were presented: Angry-Neutral (40 trials), Happy-Neutral (40 trials), and Neutral-Neutral (20 trials). Ten different actors (5 male) were used from the NimStim face stimulus set (Tottenham et al., 2009). Each face was presented ten times. On congruent trials, the probe replaced the affective face (i.e., angry or happy). On incongruent trials, the probe replaced the neutral face. Response accuracy and reaction times were recorded for each trial.

Incorrect dot-probe trials or trials with RTs of less 150 ms or more than 2000 ms were removed before analyses. In addition, trials that have responses with RTs +/- 2 SDs from an individual's mean were removed. Typically (Bar-Haim et al., 2007), difference scores across congruent and incongruent trials are calculated to capture attention bias patterns. However, difference scores lead to data loss and do not allow the researcher to determine if congruent or incongruent trials drive an effect (van Rooijen et al., 2017). As a result, we chose to include both congruent and incongruent trials in our models.

2.3.5. Internalizing problems

The Internalizing scale from the school-age version of the Child Behavior Checklist (CBCL) was used to measure internalizing problems (Achenbach and Rescorla, 2001). The CBCL is a well-validated parent report questionnaire used to assess the socioemotional functioning of young children (Achenbach, 1991). Parents rated children's behavior in the last two months on a 3-point scale from 0 (not true) to 2 (very true or often true). The levels of internalizing problems were determined by the total sum of the 32 items describing fearful, anxious, and depressed behaviors (α = .81). The items include statements like "fears going to school" or "nervous, high strung, or tense."

2.4. Statistical analyses

Analyses were conducted in R (R Core Team, 2017) and SPSS (version 24). The current study had two goals. The first was to evaluate children's affective, behavioral, and neural responses to feedback during the playdate task. A two-factor repeated measures ANOVA was used to evaluate differences between conditions based on children's Interest (Interest, No Interest) and the Feedback from peers (Accept, Reject) on each of the measures of interest (i.e., affective ratings, RTs, and theta power). Given that we hypothesized that children, across all measures, would display differences based on feedback and that these differences would be further qualified by children's interest in the peer providing the feedback, the effect of interest was an interaction between Interest and Feedback.

The second goal was to examine if children's responses to rejection were related to internalizing problems and if these relations were further moderated by attention bias to threat. In order to examine this question, we ran Poisson models for each of the task measures (i.e., affective ratings, RTs, and theta power) predicting internalizing problems. We used Poisson models to account for the non-normal distribution ($M_{internalizing}$ = 4.18, $SD_{internalizing}$ = 4.24, $Mdn_{internalizing}$ = 2.00, $Range_{internalizing}$ = 0–19, skew = 1.21) of the internalizing scores due to the large number of children with low internalizing scores (< 2; n = 52). Poisson models examined the direct relations between task measures and internalizing problems as well as the potential moderation by threat bias. All three models controlled for the effects of sex and age. To statistically isolate the effect of RTs to incongruent trials of the dot-probe task as well as the effects of responses to rejection feedback, we also controlled for the effects of RTs to congruent trials and responses to acceptance feedback. Significant interactions were probed using the Johnson-Neyman technique in jtools (Long, 2017).

Of the full sample of 118 children, 115 attempted the playdate task and 104 completed the task successfully. Reasons for not completing the task were refusing to complete the full task (n = 3), and not understanding or engaging with the task (n = 8). Children who refused to perform the playdate task or could not perform it correctly did not significantly differ from other children on any of the study measures (*p*'s > .13). Of these 104 children, 94 completed the task with EEG (i.e., 10 children refused to wear the EEG cap). In addition, 21 children were excluded from at least one condition if they did not have a minimum of 7 artifact-free trials in that condition to compute an average waveform – 9 children for Interest-Accept, 9 Interest-Reject, 9 No Interest-Accept, 12 No Interest-Reject. Each condition had on average 12.41 trials (see Table S1 in the online supplement for a breakdown for each condition). Children with missing EEG data or who had a condition with less than 7 artifact-free trials did not differ from other children on any of the study measures (p's > .20).

Of the full sample of 118 children, 108 performed the dot probe task. Four of these children were excluded due to poor accuracy (< 75% accuracy). Children with missing data on the dot probe task did not differ from other children on any of the study variables (p's > .49).

Finally, of the full sample of 118 children, 16 children did not have data on their internalizing problems. Children with missing data on parent reports of internalizing problems did not differ from other children on any of the study variables, with the exception of race – two out of the three Asian children did not report internalizing problems, $\chi^2(4) = 13.13$, $p = .01$. For the analysis with the least participants (n = 62; Poisson model involving neural responses) included children did not differ from the rest of the children in the sample on any of the study variables, including age and gender (p's > .32).

Before analyses, all behavioral and EEG variables were checked for normality and inspected for outliers. Values greater than 2.5 SDs from the mean were removed.

3. Results

Table 1 displays descriptive statistics and Spearman's correlations for the measures of interest (Pearson's correlations are presented in the supplement; Table S2). Children who reported feeling sadder after rejection reported more happiness after acceptance, $r = -.35$, $p < .001$. Additionally, children who expressed more sadness after being rejected exhibited longer RTs to both angry congruent, $r = -.25$, $p = .017$, and angry incongruent, $r = -.27$, $p = .012$, trials during the dot-probe task. Finally, children exhibiting greater neural response to rejection, but not greater neural response to acceptance, were rated as having higher levels of Internalizing Problems, $r = .30$, $p = .011$ vs. $r = .04$, $p = .738$.

3.1. Aim 1: Effects of the task

Aim 1 of the study was to examine how children's affective, behavioral, and neural responses to peer feedback differed across the playdate task conditions.

3.1.1. Affective responses

When examining the behavioral responses, we found a significant effect of Feedback, $F(1,98) = 371.81$, $p < .001$, $\eta_p^2 = 0.79$, such that children reported feeling less happy when rejected than when accepted, $t(103) = 15.80$, $p < .001$, $d = 1.55$. Importantly, as expected, this effect was qualified by a significant interaction of Interest by Feedback, $F(1,98) = 62.64$, $p < .001$, $\eta_p^2 = 0.39$, indicating that when children rated their feelings they took into consideration not only the feedback, but also their initial interest. Specifically, as shown in Fig. 1A & B, children rated feeling the happiest when accepted by children with whom they were interested in playing (Interest-Accept, $M = 3.84$; $SD = 0.24$). In contrast children felt the least happy (sad) when rejected by children with whom they wished to play (Interest-Reject; $M = 1.49$; $SD = 0.51$). However, when children were not interested in playing with the other child, the affective responses to acceptance and rejection were relatively reduced (Not Interested-Accept, $M = 3.15$; $SD = 0.89$; and Not Interested-Reject, $M = 2.15$; $SD = 1.02$).

3.1.2. Reaction times

In addition to examining how children rated their feelings, we also evaluated how long they took to make their affective responses. As shown in Fig. 1C & D, a repeated measures ANOVA revealed a significant effects for Interest, $F(1,94) = 21.73$, $p < .001$, $\eta_p^2 = .19$, as well as Feedback, $F(1,94) = 50.10$, $p < .001$, $\eta_p^2 = .35$, such that children were slower to respond when they were not interested versus interested in playing with the child providing the feedback, $t(102) = 4.67$, $p < .001$, $d = 0.46$, and were slower when rejected than accepted, $t(103) = 7.27$, $p < .001$, $d = 0.71$. Crucially, as expected, these effects were subsumed by a significant Interest by Feedback interaction, $F(1,94) = 9.66$, $p = .002$, $\eta_p^2 = .093$, indicating that children's RTs varied according to both feedback and interest.

Specifically, as shown in Fig. 1, children were fastest when accepted by children whom they were interested in playing with (Interest-Accept, $M = 1550.18$; $SD = 502.56$). Children were slower when rejected, compared to when accepted, by children with whom they did not wish to play, $t(99) = 2.92$, $p = .004$, $d = 0.29$ (Not Interested-Reject, $M = 2154.75$; $SD = 778.42$; and Not Interested-Accept, $M = 1951.15$; $SD = 660.95$). However, these conditions (Not Interested-Reject and Not Interested-Accept) did not significantly differ when children were rejected by children with whom they were interested in playing (Interest-Reject, $M = 2066.53$; $SD = 699.93$).

3.1.3. Neural responses

When examining the neural responses to each condition, we only found a main effect of Feedback, $F(1,57) = 6.36$, $p = .015$, $\eta_p^2 = .100$, such that rejection trials had increased theta power compared to acceptance trials, $t(74) = 2.42$, $p = .018$, $d = 0.28$, regardless of the child's interest (Fig. 1E & F). The difference between reject and accept trials is presented as a topoplot in Fig. 2. Given that the topoplot indicated a more pronounced effect of feedback on the central cluster, we performed an additional data-driven analysis to statistically examine the effect of topography. We performed a three-factor repeated measures ANOVA based on cluster (Frontal, Central), children's Interest (Interest, No Interest) and the Feedback from peers (Accept, Reject). The Frontal cluster was the same as defined above and the Central cluster also centered on the midline, but more posterior (129/Cz, 7,

Table 1
Descriptive Statistics and Spearman's Correlations for Measures of Interest.

Variable	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	*M*	*SD*	N
1. Sex	.06	−.12	.11	−.03	.02	−.11	−.13	.20*	.19	−.04			118
2. Age		.11	−.09	−.13	−.14	.15	.06	−.25**	−.29***	−.16	72.92	9.30	118
3. Feelings after Rejection			−.35***	.20*	.06	.01	.13	−.25*	−.27*	.05	1.86	0.71	104
4. Feelings after Acceptance				.08	−.21*	−.01	.02	.17	.10	.04	3.47	0.53	104
5. RT after Rejection					.68***	−.09	−.08	.19	.13	.12	2129.79	644.29	104
6. RT after Acceptance						−.13	−.09	.23*	.22*	.07	1784.99	550.05	104
7. Neural Response to Rejection							.47**	−.23	−.15	.30*	2.17	0.76	79
8. Neural Response to Acceptance								−.18	−.15	.04	1.99	0.61	80
9. Mean RT Angry Congruent									.90***	−.05	756.57	155.32	101
10. Mean RT Angry Incongruent										.00	772.55	168.27	102
11. Internalizing Problems											4.18	4.24	102

Note: *$p < .05$, **$p < .01$, ***$p < .001$. Sex (1 = male, 2 = female). Feelings during playdate task (1 = sad, 2 = a little sad, 3 = a little happy, 4 = happy).

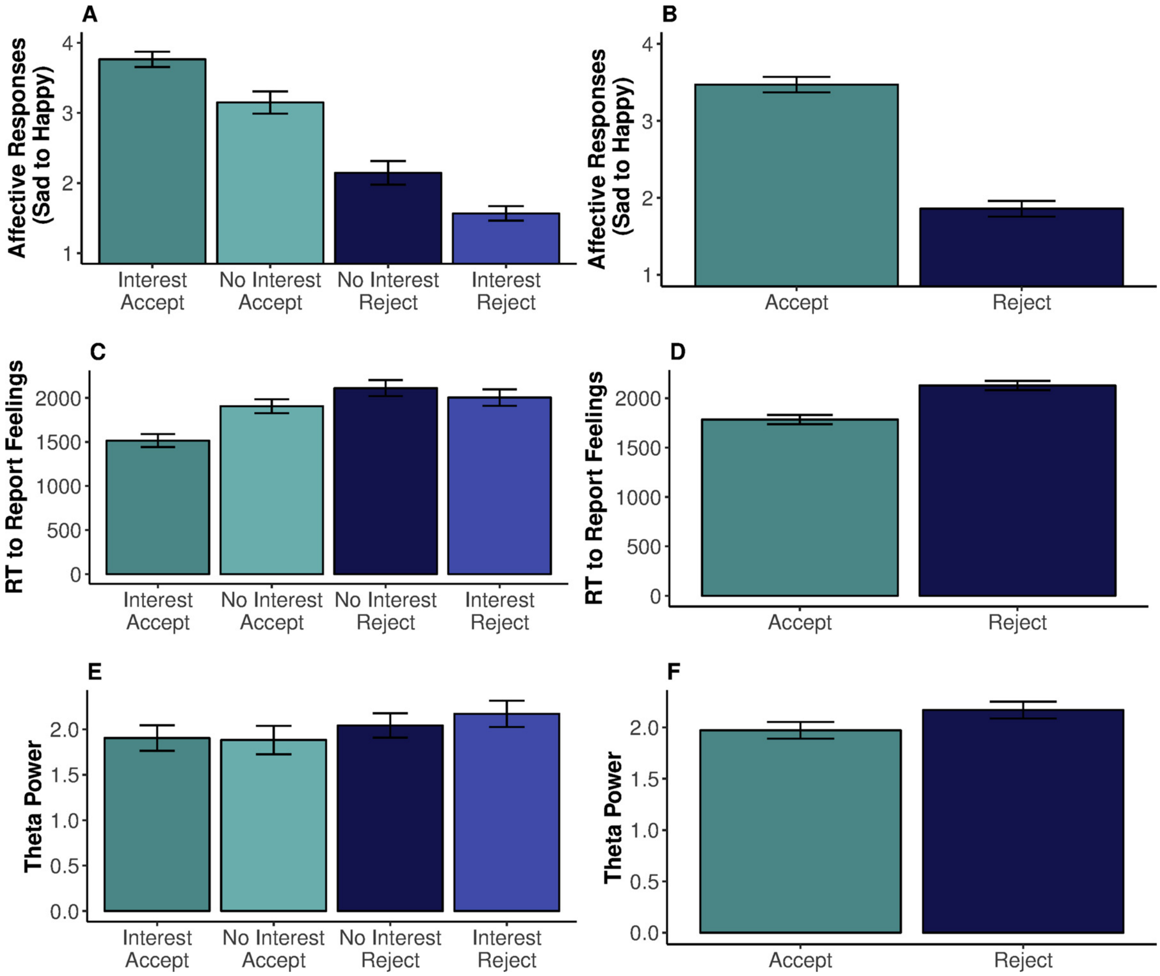

Fig. 1. **(A)** Average affective responses to acceptance and rejection, depending on the child's interest; **(B)** Average affective responses to acceptance and rejection, regardless of child's interest; **(C)** Average RTs to make affective responses to acceptance and rejection, presented separately based on the child's initial interest; **(D)** Average RTs to make affective responses to acceptance and rejection, regardless of the child's initial interest; **(E)** Average theta power to acceptance and rejection, presented separately based on the child's initial interest **(F)** Average theta power to acceptance and rejection, regardless of the child's interest. *Note:* Error bars indicate within-subject 95% confidence intervals (Loftus and Masson, 1994).

106, 31, 80, and 55). This analysis also showed only a main effect of Feedback, $F(1,55) = 7.99$, $p = .007$, $\eta_p^2 = .127$, such that rejection trials had increased theta power compared to acceptance trials, $t(75) = 3.28$, $p = .002$, $d = 0.38$, regardless of cluster and the child's interest.

3.2. Aim 2: Effects of response to rejection and threat Bias on internalizing problems

Aim 2 of the study was to examine if children's ABT moderated the relation between affective, behavioral, and neural responses to rejection during the playdate task and internalizing problems. For these analyzes, we focused on the role of rejection because of its theoretical relations to internalizing problems and because we reliably observed an effect of feedback on all three measures of interest.

3.2.1. Affective responses

Table 2 displays the Poisson regression assessing the moderating effect of ABT on the relation between Affective Response to Rejection and Internalizing Problems. McFadden's pseudo-R^2 for the total model was .08. A significant Affective Response to Rejection X Mean RT to Angry Incongruent trials interaction, $b = 0.160$, $p = .042$, was noted. Fig. 3A illustrates a Johnson-Neyman test of the Affective Response to Rejection by attention bias interaction. Here, the effect of Affective Response to Rejection on Internalizing Problems increased as children exhibited greater affect-biased attention to social threat. Moreover, there was a significant main effect of Affective Response to Rejection after controlling for Affective Response to Acceptance, $b = 0.015$, $p = .007$, suggesting that children who were less sad after being rejected exhibited greater internalizing problems. We also noted unexpected main effects of Age, $b = -0.021$, $p = .004$, and Mean RT to Angry Congruent trials, $b = -0.002$, $p = .014$, suggesting that older children, and children faster to locate probes after angry congruent trials, exhibited lower levels of internalizing problems. There was no significant main effect of Mean RT to Angry Incongruent trials after controlling for Mean RT to Angry Congruent trials.

3.2.2. Behavioral responses

Table 3 displays the Poisson regression assessing the moderating effect of attention bias on the relation between Reaction Time after Rejection and Internalizing Problems. McFadden's pseudo-R^2 for the total model was .07. Contrary to expectations, there was no significant main effect of Reaction Time after Rejection after controlling for RT after Acceptance. Additionally, there was no significant main effect of Mean RT to Angry Incongruent trials after controlling for Mean RT to Angry Congruent trials. Significant main effects of Age, $b = -0.022$, $p = .001$, and Mean RT to Congruent Angry trials, $b = 0.003$, $p = .010$, were consistent with the model assessing affective responses. Finally,

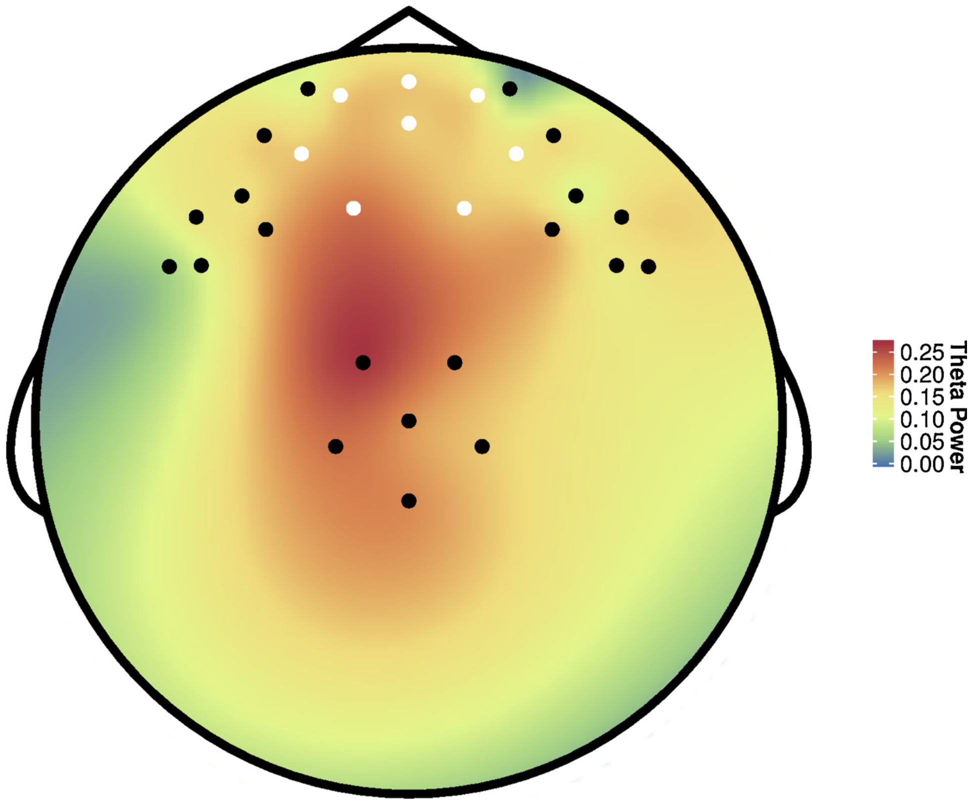

Fig. 2. Difference in theta power between rejection and acceptance trials. Points represent electrodes included in data pre-processing. Points in white represent the frontocentral cluster of electrodes included in the a priori analyses. The eegutils R package was used to create the topoplot (Craddock, 2018).

Table 2
Poisson Model Assessing ABT as a Moderator of the Relation between Affective Response to Rejection and Internalizing problems.

Parameter	*Estimate*	*SE*	*z-ratio*
Intercept	3.630***	0.978	3.71
Sex	−0.007	0.117	0.95
Age	−0.019**	0.007	−2.85
Affective Response to Acceptance	0.264	0.138	1.92
Mean RT Angry Congruent	−0.002*	0.001	-2.46
Affective Response to Rejection	0.177**	0.066	2.70
Mean RT Angry Incongruent	0.253	0.150	1.69
Affective Response to Rejection X RT Angry Incongruent	0.160*	0.079	2.03

Note: N = 80. *$p <$ .05, **$p <$ .01, ***$p <$ .001.
McFadden's pseudo-R^2 = .09.

there was no significant interaction between Reaction Time to Rejection X Mean RT to Angry Incongruent trials, suggesting that attention bias is not a significant moderator of the relation between RT to Rejection and Internalizing Problems.

3.2.3. *Neural responses*

Table 4 displays the Poisson regression assessing the moderating effect of ABT on the relation between Neural Response to Rejection and Internalizing Problems. McFadden's pseudo-R^2 for the total model was .18. As expected, a significant Neural Response to Rejection X Mean RT to Angry Incongruent trials interaction, b = 0.167, p = .011, was noted. Fig. 3B illustrates a Johnson-Neyman test of the Neural Response to Rejection by attention bias interaction. Here, the effect of Neural Response to Rejection on Internalizing Problems increased as children exhibited greater affect biased attention to social threat. In addition, there was a significant main effect of Neural Response to Rejection after controlling for Neural Response to Acceptance, b = 0.332, $p <$ .001, suggesting that children who exhibited greater frontal theta power during rejection also exhibited greater internalizing problems. A significant main effect of Age, b = -0.022, p = .006, was consistent with the models assessing affective and behavioral responses. There was no significant main effect of Mean RT to Angry Incongruent trials after controlling for Mean RT to Angry Congruent trials.

4. Discussion

Peer experiences during early childhood are a fundamental aspect of socioemotional development and may set the stage for future relationships (Parker and Asher, 1987; Parker et al., 2006). However, relatively little work has examined how young children process and respond to peer feedback. The current study aimed to fill this gap by using an ecologically valid experimental paradigm (Howarth et al., 2013) that allowed us to examine children's processing of peer feedback using affective, behavioral, and neural markers of sensitivity. Additionally, we investigated if children's responses to peer feedback, specifically rejection, were related to individual differences in internalizing problems and if the relations between rejection processing and internalizing problems were heightened for children exhibiting greater attention bias to social threat.

In line with a previous study using this paradigm (Howarth et al., 2013), young children were engaged in the task and were able to understand it. As expected, the behavioral data revealed that young children reported feeling sadder when rejected and happier when accepted. Moreover, these responses were significantly attenuated when children were not interested in playing with the child providing feedback, suggesting young children were able to rate their feelings after feedback as well as take into consideration their initial preferences. This pattern of results replicates the findings of Howarth et al. (2013) and provides further evidence of the validity and sensitivity of this experimental paradigm in young children.

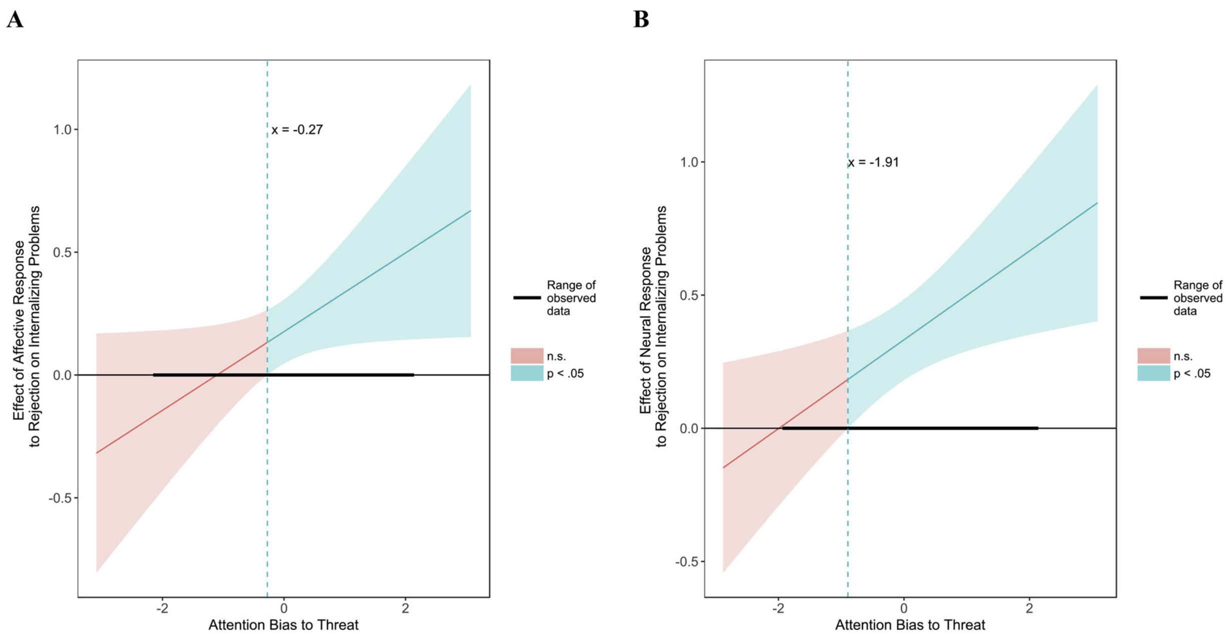

Fig. 3. (A) Attention bias to threat (ABT) as a moderator of the relation between Affective Response to Rejection and Internalizing Problems in young children. The effect of Affective Response to Rejection on Internalizing Problems increases as children exhibit greater ABT, significant with ABT scores greater than -0.27. **(B)** ABT as a moderator of the relation between Neural Response to Rejection and Internalizing Problems in young children. The effect of Neural Sensitivity to Rejection on Internalizing Problems increases as children exhibit greater ABT, significant with ABT scores greater than -1.91.

Table 3
Poisson Model Assessing ABT as a Moderator of the Relation between RT after Rejection and Internalizing problems.

Parameter	*Estimate*	*SE*	*z-ratio*
Intercept	5.281***	0.949	5.71
Sex	−0.005	0.120	−0.04
Age	−0.022***	0.007	−3.44
RT after Acceptance	−0.000	0.000	−1.24
Mean RT Angry Congruent	−0.003**	0.001	−2.73
RT after Rejection	0.143	0.078	1.72
Mean RT Angry Incongruent	0.220	0.158	1.49
RT Rejection X RT Angry Incongruent	−0.009	0.064	−0.12

Note: N = 80. *$p < .05$, **$p < .01$, ***$p < .001$.
McFadden's pseudo-R^2 = .07.

Table 4
Poisson Model Assessing ABT as a Moderator of the Relation between Neural Sensitivity to Rejection and Internalizing problems.

Parameter	*Estimate*	*SE*	*z-ratio*
Intercept	4.910***	1.185	4.15
Sex	−0.208	0.135	−1.55
Age	−0.022**	0.008	−2.72
Neural Response to Acceptance	−0.035	0.131	−0.27
Mean RT Angry Congruent	−0.002	0.001	−1.88
Neural Response to Rejection	0.332***	0.076	4.39
Mean RT Angry Incongruent	0.061	0.193	0.32
Neural Sensitivity Rejection X RT Angry Incongruent	0.167*	0.065	2.55

Note: N = 62. *$p < .05$, **$p < .01$, ***$p < .001$.
McFadden's pseudo-R^2 = .18.

Extending previous findings, we also evaluated children's RTs to rate their feelings as a behavioral measure of feedback processing. As expected, children were slower to report their feelings after being rejected. This is in line with studies that show that RTs are slower after conflict detection. For example, RT slowing is often seen in the presence of broadly defined conflict, such as incongruent stimuli (Eriksen and Eriksen, 1974) or after errors (Rabbitt, 1966) and is believed to index heightened processing of these salient events (Buzzell et al., 2017; Wessel, 2018). As such, it is possible that slowing after rejection may be due to the processing of salient and conflicting information.

In addition, we observed an interaction between interest and feedback. As expected, for acceptance trials, children took longer when the feedback did not match their interest. However, unexpectedly, children's RT did not differ for rejection trials. It may be that social rejection is particularly salient for a young child, as rejection trials elicited overall slower RTs, regardless of the child's initial sorting. In addition, it may be particularly "puzzling" when processing the possibility that you will have to interact with someone who is interested in you (Accept) even though you were not inclined to interact with them (No Interest). This is, in many ways, a quintessentially socially awkward situation.

We also examined mid-frontal theta power to evaluate young children's neural sensitivity to peer feedback. In line with previous studies with older children, adolescents, and adults (Harrewijn et al., 2018; Van der Molen et al., 2017; van Noordt et al., 2015), we found increased mid-frontal theta power during rejection, compared to acceptance, trials. Our data-driven analyses also suggest that central theta power may also reflect processes associated with rejection. However, contrary to recent evidence with a similar paradigm (Harrewijn et al., 2018; Van der Molen et al., 2017) that found stronger theta power for unexpected rejection, we did not find stronger theta power if the child was interested in playing with the child providing the feedback. This may be because the child's interest is not exactly the same as their expectation of whether or not a peer will accept or reject them. In addition, the current study presented the trials in blocks weighed toward one condition and may have caused habituation, potentially dampening the condition-specific effects of rejection on theta power.

Importantly, we found a convergent pattern of results across different markers of sensitivity to peer feedback (i.e., affective, behavioral, and neural). This consistency across measures was especially true for feedback versus the child's initial interest. Namely, as hypothesized, children reported more distress (sadness) were slower to rate their affective response, and exhibited increased mid-frontal EEG theta power, when rejected than when accepted. These findings provide further support to the validity and effectiveness of this experimental paradigm to study young children's responses to feedback.

A second goal of the current study was to examine whether children's responses to peer feedback were associated with internalizing problems and if these relations were stronger for children with an attention bias to threat. For these analyzes, we focused on the role of rejection (regardless of initial interest) because of its theoretical relations to internalizing problems and because we observed an effect of rejection feedback across all task measures. Unexpectedly, when examining the relations between children's affective responses to rejection and internalizing, we found that children that reported feeling less sad when rejected exhibited more internalizing problems and that this relation was heightened for children with an attention bias to threat. Although these findings are in the opposite direction of what we predicted, it is possible that children with higher levels of internalizing problems and a tendency to attend to socially threatening information may feel relieved by not having to play with an unfamiliar child and thus, report feeling less distress (sadness) when rejected. In addition, although we might presume that social rejection is an unexpected event for children, it may reflect ongoing patterns of heightened negative social interactions which lead to (or are a consequence of) internalizing problems (Parker et al., 2006).

We did not find any significant relations when examining relations between RTs to rejection and internalizing problems. Albeit not significant, there was a trend in the expected direction, such that children higher in internalizing problems took more time to rate their feelings. Future studies should evaluate this non-significant trend, as it may provide further convergent evidence that individuals higher in internalizing problems may display slower behavioral responses due to distinct processing of negative information.

Finally, as expected, we found that stronger mid-frontal theta power for rejection was related to higher levels of internalizing problems. This is in line with recent findings with older participants, in which individuals with social anxiety displayed higher theta power in response to rejection, compared to individuals without social anxiety (Harrewijn et al., 2018). Our findings suggest the relation between theta power and internalizing problems is present during early childhood in a community sample. Given these results, it is possible that elevated mid-frontal theta power in the face of rejection is a biomarker of risk for internalizing problems across the lifespan, perhaps with particular risk for social anxiety later in life (Harrewijn et al., 2018). Future work could assess if elevated levels of theta to negative peer feedback in early life relate to later social anxiety to better understand the role of mid-frontal theta power as a predictive biomarker of risk.

In addition to mid-frontal theta power during rejection independently relating to internalizing problems, we also found that this relation was strongest for children with a larger attention bias to threat. This finding supports a common interpretation of theta power to rejection as an index of social threat processing (Harrewijn et al., 2018; van Noordt et al., 2015). Here, we show for the first time that young children who display heightened threat processing across two measures are at the highest risk for internalizing problems.

Several limitations should be considered when interpreting the current findings. Our main limitation is the nature of our sample. The sample is relatively small, which was additionally reduced by including children with artifact-free EEG data and good performance across several tasks. Although the amount of data loss in the current study is comparable to other EEG studies with young children (Lo et al., 2015), it did diminish the power to detect relations of interest. In addition, we employed a community sample of mostly Caucasian families, limiting the generalizability of our findings to other populations.

Although we employed a novel, ecologically valid paradigm to assess children's sensitivity to peer feedback, the paradigm was not without limitations. First, the scale children used to rate their feelings was limited in range (1–4), which may minimize the ability to capture individual variation in affective response. Second, the number of trials per condition was small (n = 15). Both of these caveats may limit our power to detect potential relations. For example, it is possible that had children been provided a wider range of affective ratings or completed more trials in each condition that relations between personal interest, peer feedback and internalizing problems may have emerged. Our initial design was meant to minimize the risk that children would not understand a more complex rating scale or that fatigue or boredom would preclude children from providing good data over the course of a longer task.

Finally, as a cross sectional study, we were unable to examine developmental patterns. Future studies should examine how children process and respond to peer feedback and its implications to socioemotional development across childhood and into adolescence. There have been several studies examining the development of behavioral and neural responses to social feedback in adolescence (Guyer et al., 2012; Guyer and Jarcho, 2018; Silk et al., 2014), but to our knowledge, none has been longitudinal and no study has focused on early childhood. Our findings suggest that it would be feasible to use similar methods to examine the development of how young children process and respond to social feedback and its consequences on socioemotional development.

In conclusion, the current study used an ecologically valid experimental paradigm to study young children's processing of peer feedback. We replicated and extended previous findings (Howarth et al., 2013) by examining children's affective, behavioral, and neural responses to peer feedback. In addition, we found relations between these measures and children's internalizing problems and that the relations between responses to peer feedback and internalizing problems may be stronger for children with an attention bias to threat. Together, the current findings further validate and illustrate the utility of the playdate task as a developmentally sensitive paradigm for studying how young children process and respond to peer feedback.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.dcn.2018.12.008.

References

Abend, R., Voogd, L., Salemink, E., Wiers, R.W., Pérez-Edgar, K., Fitzgerald, A., et al., 2018. Association between attention bias to threat and anxiety symptoms in children and adolescents. Depress. Anxiety 35 (3), 229–238. https://doi.org/10.1002/da.22706.

Achenbach, T.M., 1991. Child Behavior Checklist 4-18. Department of Psychiatry, University of Vermont, Burlington, VT.

Achenbach, T.M., Rescorla, L., 2001. Manual for the ASEBA School-age Forms and Profiles: an Integrated System of Multi-informant Assessment. University of Vermont Department of Psychiatry, Burlington, VT.

Achterberg, M., van Duijvenvoorde, A.C., Bakermans-Kranenburg, M.J., Crone, E.A., 2016. Control your anger! The neural basis of aggression regulation in response to negative social feedback. Soc. Cogn. Affect. Neurosci. 11 (5), 712–720.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M.J., van IJzendoorn, M.H., 2007. Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. Psychol. Bull. 133 (1), 1–24. https://doi.org/10.1037/0033-2909.133.1.1.

Burgess, K.B., Wojslawowicz, J.C., Rubin, K.H., Rose-Krasnor, L., Booth-LaForce, C., 2006. Social information processing and coping strategies of Shy/Withdrawn and aggressive children: does friendship matter? Child Dev. 77 (2), 371–383. https://doi.org/10.1111/j.1467-8624.2006.00876.x.

Buzzell, G.A., Troller-Renfree, S.V., Barker, T.V., Bowman, L.C., Chronis-Tuscano, A., Henderson, H.A., et al., 2017. A neurobehavioral mechanism linking behaviorally inhibited temperament and later adolescent social anxiety. J. Am. Acad. Child Adolesc. Psychiatry 56 (12), 1097–1105. https://doi.org/10.1016/j.jaac.2017.10.007.

Cavanagh, J.F., Shackman, A.J., 2015. Frontal midline theta reflects anxiety and cognitive control: meta-analytic evidence. J. Physiol. 109 (1–3), 3–15. https://doi.org/10.1016/j.jphysparis.2014.04.003.

Craddock, M., 2018. A Collection of Utilities for Eeg Analysis. https://craddm.github.io/eegUtils/.

Crick, N.R., Dodge, K.A., 1994. A review and reformulation of social information-processing mechanisms in children's social adjustment. Psychol. Bull. 115 (1), 74–101. https://doi.org/10.1037/0033-2909.115.1.74.

Cristofori, I., Moretti, L., Harquel, S., Posada, A., Deiana, G., Isnard, J., et al., 2012. Theta signal as the neural signature of social exclusion. Cereb. Cortex 23 (10), 2437–2447.

Crowley, M.J., van Noordt, S.J., Wu, J., Hommer, R.E., South, M., Fearon, R.M.P., Mayes, L.C., 2014. Reward feedback processing in children and adolescents: medial frontal theta oscillations. Brain Cogn. 89, 79–89.

DuPuis, D., Ram, N., Willner, C.J., Karalunas, S., Segalowitz, S.J., Gatzke-Kopp, L.M., 2015. Implications of ongoing neural development for the measurement of the error-related negativity in childhood. Dev. Sci. 18 (3), 452–468.

Eisenberger, N.I., 2012. The pain of social disconnection: examining the shared neural underpinnings of physical and social pain. Nat. Rev. Neurosci. 13 (6), 421.

Eisenberger, N.I., Lieberman, M.D., 2004. Why rejection hurts: a common neural alarm system for physical and social pain. Trends Cognit. Sci. 8 (7), 294–300. https://doi.org/10.1016/j.tics.2004.05.010.

Eriksen, B.A., Eriksen, C.W., 1974. Effects of noise letters upon the identification of a target letter in a nonsearch task. Percept. Psychophys. 16 (1), 143–149. https://doi.org/10.3758/BF03203267.

Gazelle, H., Druhen, M.J., 2009. Anxious solitude and peer exclusion predict social helplessness, upset affect, and vagal regulation in response to behavioral rejection by a friend. Dev. Psychol. 45 (4), 1077–1096. https://doi.org/10.1037/a0016165.

Gazelle, H., Ladd, G.W., 2003. Anxious solitude and peer exclusion: a diathesis-stress model of internalizing trajectories in childhood. Child Dev. 74 (1), 257–278. https://doi.org/10.1111/1467-8624.00534.

Gazelle, H., Rudolph, K.D., 2004. Moving toward and away from the world: social approach and avoidance trajectories in anxious solitary youth. Child Dev. 75 (3), 829–849. https://doi.org/10.1111/j.1467-8624.2004.00709.x.

Gratton, G., Coles, M.G., Donchin, E., 1983. A new method for off-line removal of ocular artifact. Electroencephalogr. Clin. Neurophysiol. 55 (4), 468–484.

Gunther Moor, B., van Leijenhorst, L., Rombouts, S.A.R.B., Crone, E.A., Van der Molen, M.W., 2010. Do you like me? Neural correlates of social evaluation and developmental trajectories. Soc. Neurosci. 5 (5–6), 461–482. https://doi.org/10.1080/17470910903526155.

Guyer, A.E., Jarcho, J.M., 2018. Neuroscience and Peer relations. In: Burkowski, W.M., Laursen, B., Rubin, K.H. (Eds.), Handbook of Peer Interactions, Relationships, and Groups, 2nd ed. Guilford Press, New York, NY, pp. 177–199.

Guyer, A.E., Lau, J.Y., McClure-Tone, E.B., Parrish, J., Shiffrin, N.D., Reynolds, R.C., et al., 2008. Amygdala and ventrolateral prefrontal cortex function during anticipated peer evaluation in pediatric social anxiety. Arch. Gen. Psychiatry 65 (11), 1303–1312.

Guyer, A.E., Choate, V.R., Pine, D.S., Nelson, E.E., 2012. Neural circuitry underlying affective response to peer feedback in adolescence. Soc. Cogn. Affect. Neurosci. 7 (1), 81–92. https://doi.org/10.1093/scan/nsr043.

Guyer, A.E., Benson, B., Choate, V.R., Bar-Haim, Y., Perez-Edgar, K., Jarcho, J.M., et al., 2014. Lasting associations between early-childhood temperament and late-adolescent reward-circuitry response to peer feedback. Dev. Psychopathol. 26 (1), 229–243.

Harrewijn, A., van der Molen, M.J.W., van Vliet, I.M., Tissier, R.L.M., Westenberg, P.M., 2018. Behavioral and EEG responses to social evaluation: a two-generation family study on social anxiety. Neuroimage Clin. 17, 549–562. https://doi.org/10.1016/j.nicl.2017.11.010.

Howarth, G.Z., Guyer, A.E., Pérez-Edgar, K., 2013. Young children's affective responses to acceptance and rejection from peers: a computer-based task sensitive to variation in temperamental shyness and gender. Soc. Dev. 22 (1), 146–162.

Jarcho, J.M., Leibenluft, E., Walker, O., Fox, N.A., Pine, D.S., Nelson, E.E., 2013. Neuroimaging studies of pediatric social anxiety: paradigms, pitfalls and a new direction for investigating the neural mechanisms. Biol. Mood Anxiety Disord. 3 (1), 14. https://doi.org/10.1186/2045-5380-3-14.

Jarcho, J.M., Davis, M.M., Shechner, T., Degnan, K.A., Henderson, H.A., Stoddard, J., et al., 2016. Early-childhood social reticence predicts brain function in preadolescent youths during distinct forms of peer evaluation. Psychol. Sci. 27 (6), 821–835. https://doi.org/10.1177/0956797616638319.

Kraatz-Keiley, M., Bates, J.E., Dodge, K.A., Pettit, G.S., 2000. A cross-domain growth analysis: externalizing and internalizing behaviors during 8 years of childhood. J. Abnorm. Child Psychol. 28 (2), 161–179. https://doi.org/10.1023/A:1005122814723.

Kujawa, A., Arfer, K.B., Klein, D.N., Proudfit, G.H., 2014. Electrocortical reactivity to social feedback in youth: a pilot study of the Island Getaway task. Dev. Cogn. Neurosci. 10, 140–147. https://doi.org/10.1016/j.dcn.2014.08.008.

Ladd, G.W., Troop-Gordon, W., 2003. The role of chronic peer difficulties in the development of children's psychological adjustment problems. Child Dev. 74 (5), 1344–1367.

Lemerise, E.A., Arsenio, W.F., 2000. An integrated model of emotion processes and cognition in social information processing. Child Dev. 71 (1), 107–118.

Lo, S.L., Schroder, H.S., Moran, T.P., Durbin, C.E., Moser, J.S., 2015. Neurophysiological evidence of an association between cognitive control and defensive reactivity processes in young children. Dev. Cogn. Neurosci. 15, 35–47. https://doi.org/10.1016/j.dcn.2015.09.001.

LoBue, V., Thrasher, C., 2015. The Child Affective Facial Expression (CAFE) set: validity and reliability from untrained adults. Front. Psychol. 5. https://doi.org/10.3389/fpsyg.2014.01532.

Loftus, G.R., Masson, M.E., 1994. Using confidence intervals in within-subject designs. Psychon. Bull. Rev. 1 (4), 476–490.

Long, J.A., 2017. jtools: Analysis and Presentation of Social Scientific Data (Version 0.9.3). Retrieved from. https://cran.r-project.org/package=jtools.

MacLeod, C., Mathews, A., Tata, P., 1986. Attentional bias in emotional disorders. J. Abnorm. Psychol. 95 (1), 15–20. https://doi.org/10.1037//0021-843X.95.1.15.

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., Holker, L., 2002. Selective attention and emotional vulnerability: assessing the causal basis of their association through the experimental manipulation of attentional bias. J. Abnorm. Psychol. 111 (1), 107–123. https://doi.org/10.1037/0021-843X.111.1.107.

McLaughlin, K.A., Sheridan, M.A., Tibu, F., Fox, N.A., Zeanah, C.H., Nelson, C.A., 2015. Causal effects of the early caregiving environment on development of stress response systems in children. Proc. Natl. Acad. Sci. 112 (18), 5637–5642. https://doi.org/10.1073/pnas.1423363112.

Morales, S., Taber-Thomas, B.C., Pérez-Edgar, K.E., 2016. Patterns of attention to threat across tasks in behaviorally inhibited children at risk for anxiety. Dev. Sci. https://doi.org/10.1111/desc.12391.

National Institute of Child Health and Human Development Early Child Care Research Network, 2008. Social competence with peers in third grade: associations with earlier peer experiences in childcare. Soc. Dev. 17 (3), 419–453. https://doi.org/10.1111/j.1467-9507.2007.00446.x.

Parker, J.G., Asher, S.R., 1987. Peer relations and later personal adjustment: are low-accepted children at risk? Psychol. Bull. 102 (3), 357–389. https://doi.org/10.1037/0033-2909.102.3.357.

Parker, J.G., Rubin, K.H., Erath, S.A., Wojslawowicz, J.C., Buskirk, A.A., 2006. Peer relationships, child development, and adjustment: a developmental psychopathology perspective. In: Cicchetti, D., Cohen, D.J. (Eds.), Developmental Psychopathology, second edition. pp. 419–493.

Pérez-Edgar, K.E., Bar-Haim, Y., McDermott, J.M., Chronis-Tuscano, A., Pine, D.S., Fox, N.A., 2010. Attention biases to threat and behavioral inhibition in early childhood shape adolescent social withdrawal. Emotion 10 (3), 349–357. https://doi.org/10.1037/a0018486.

Pérez-Edgar, K.E., Reeb-Sutherland, B.C., McDermott, J.M., White, L.K., Henderson, H.A., Degnan, K.A., et al., 2011. Attention biases to threat link behavioral inhibition to social withdrawal over time in very young children. J. Abnorm. Child Psychol. 39 (6), 885–895. https://doi.org/10.1007/s10802-011-9495-5.

R Core Team, 2017. R: a Language and Environment for Statistical Computing. Retrieved from. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Rabbitt, P.M.A., 1966. Error correction time without external error signals. Nature 212 (5060), 438. https://doi.org/10.1038/212438a0.

Rimm-Kaufman, S.E., Pianta, R.C., 2000. An ecological perspective on the transition to kindergarten. J. Appl. Dev. Psychol. 21 (5), 491–511. https://doi.org/10.1016/S0193-3973(00)00051-4.

Rubin, K.H., Krasnor, L.R., 1986. Social-cognitive and social behavioral perspectives on problem solving. In: In: Perlmutter, W. (Ed.), Cognitive Perspectives on Children's Social and Behavioral Development. The Minnesota Symposia on Child Psychology, vol. 18. Psychology Press, New York, NY, US, pp. 1–68.

Salum, G.A., Mogg, K., Bradley, B.P., Gadelha, A., Pan, P., Tamanaha, A.C., et al., 2013. Threat bias in attention orienting: evidence of specificity in a large community-based study. Psychol. Med. 43 (4), 733–745. https://doi.org/10.1017/S0033291712001651.

Shackman, A.J., Salomons, T.V., Slagter, H.A., Fox, A.S., Winter, J.J., Davidson, R.J., 2011. The integration of negative affect, pain and cognitive control in the cingulate cortex. Nat. Rev. Neurosci. 12 (3), 154–167. https://doi.org/10.1038/nrn2994.

Silk, J.S., Siegle, G.J., Lee, K.H., Nelson, E.E., Stroud, L.R., Dahl, R.E., 2014. Increased neural response to peer rejection associated with adolescent depression and pubertal development. Soc. Cogn. Affect. Neurosci. 9 (11), 1798–1807. https://doi.org/10.1093/scan/nst175.

Tang, A., Lieshout, R.J.V., Lahat, A., Duku, E., Boyle, M.H., Saigal, S., Schmidt, L.A., 2017. Shyness trajectories across the first four decades predict mental health outcomes. J. Abnorm. Child Psychol. 45 (8), 1621–1633. https://doi.org/10.1007/s10802-017-0265-x.

Tang, A., Lahat, A., Crowley, M.J., Wu, J., Schmidt, L.A., 2018. Neurodevelopmental differences to social exclusion: an event-related neural oscillation study of children, adolescents, and adults. Emotion (Washington, DC).

Tottenham, N., Tanaka, J.W., Leon, A.C., McCarry, T., Nurse, M., Hare, T.A., et al., 2009. The NimStim set of facial expressions: judgments from untrained research participants. Psychiatry Res. 168 (3), 242–249. https://doi.org/10.1016/j.psychres.2008.05.006.

Van der Molen, M.J.W., Dekkers, L.M., Westenberg, P.M., van der Veen, F.M., Van der Molen, M.W., 2017. Why don't you like me? Midfrontal theta power in response to unexpected peer rejection feedback. NeuroImage 146, 474–483.

van Noordt, S.J.R., White, L.O., Wu, J., Mayes, L.C., Crowley, M.J., 2015. Social exclusion modulates event-related frontal theta and tracks ostracism distress in children. NeuroImage 118, 248–255. https://doi.org/10.1016/j.neuroimage.2015.05.085.

van Rooijen, R., Ploeger, A., Kret, M.E., 2017. The dot-probe task to measure emotional attention: a suitable measure in comparative studies? Psychon. Bull. Rev. 24 (6), 1686–1717. https://doi.org/10.3758/s13423-016-1224-1.

Walker, O.L., Henderson, H.A., Degnan, K.A., Penela, E.C., Fox, N.A., 2014. Associations between behavioral inhibition and children's social problem-solving behavior during social exclusion: behavioral inhibition and social problem solving. Soc. Dev. 23 (3), 487–501. https://doi.org/10.1111/sode.12053.

Wessel, J.R., 2018. An adaptive orienting theory of error processing. Psychophysiology 55 (3), e13041. https://doi.org/10.1111/psyp.13041.

Wichmann, C., Coplan, R.J., Daniels, T., 2004. The social cognitions of socially withdrawn children. Soc. Dev. 13 (3), 377–392. https://doi.org/10.1111/j.1467-9507.2004.00273.x.