DEVELOPMENTAL NEUROPSYCHOLOGY
2021, VOL. 46, NO. 6, 447–462
https://doi.org/10.1080/87565641.2021.1981904

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Play with Mom: Insights into Regulatory Processes at Work during Baseline and Parent-infant Play

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ABSTRACT

Frontal alpha asymmetry (FAA) is a neural correlate of approach and avoidance motivational processes. This study examined the shift in FAA from baseline to play, associations to parent-reported regulatory abilities, and parent and infant behaviors during play. Infants exhibited greater left frontal alpha activity (more approach) during baseline relative to play. Shifts in FAA toward greater left frontal alpha activity (more approach) from baseline to play were associated with parent ratings of infants' regulatory behaviors and object exploration exhibited during play. These results highlight ongoing regulatory processes involved in positively valenced tasks typical in infants' daily life.

ARTICLE HISTORY
Received 8 June 2020
Revised 2 August 2021
Accepted 12 September 2021

Approach and avoidance are fundamental motivational processes involved in self-regulation. Approach generates stimulation, while avoidance reduces stimulation. Fox (1994) proposed that the balance between these two processes is essential for effective self-regulation. Children must appropriately match their motivational response to approach or to avoid it based on the specific context in which they are situated. Greater approach tendencies during infancy and toddlerhood are associated with exuberance and a greater propensity toward behavioral problems in early childhood (Degnan et al., 2011; Lahat et al., 2012; Stifter, Putnam, & Jahromi, 2008). Importantly, the bias to approach or avoid a stimulus may be shaped by parent-infant interactions (Hane & Fox, 2006; Hane, Henderson, Reeb-Sutherland, & Fox, 2010; Swingler, Perry, Calkins, & Bell, 2014). The current study aimed to shed light on the approach and avoidance regulatory processes at work during parent-infant play. We thus measure the frontal alpha asymmetry (FAA), which is a neural correlate of ongoing approach and avoidance regulatory processes that are often unobservable at the level of behavior (Perone, Gartstein, & Anderson, 2020; Perone, Weybright, & Anderson, 2019). Importantly, FAA shifts as people adapt to tasks with changing regulatory demands (Jackson et al., 2003; Perone, Anderson, & Weybright, 2020). A recent study with infants showed the degree to which FAA shifts from a relatively neutral baseline task to a more stressful task differ across individuals based on their temperament (Gartstein, 2019). Thus, a second goal of the current study was to examine shifts in FAA from a baseline to a parent-infant play task as it relates to individual differences in temperament.

Frontal alpha asymmetry

FAA is extracted from EEG power in the alpha band (6–9 Hz in infants; Marshall, Bar-Haim, & Fox, 2002; Orekhova, Stroganova, Posikera, & Elam, 2006) as the difference in power at homologous right and left channels placed over the frontal region of the brain. FAA is most often measured during baseline which is typically recorded from infants, while they watch a dynamic display or an actor

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manipulating an object (Bell, 2001; St. John et al., 2016; see Anderson & Perone, 2018 for review). FAA recorded at baseline is often viewed through a dispositional lens. For example, several studies have shown that infants who exhibited greater relative right frontal alpha activity during baseline were prone to avoidance or negative emotionality, such as crying at separation, or displays of fearfulness (Davidson & Fox, 1989; Diaz & Bell, 2012; Fox, Calkins, & Bell, 1994; Fox & Davidson, 1987; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001), whereas greater relative left frontal alpha activity was related to approach behavioral tendencies, such as exuberance (Hane, Fox, Henderson, & Marshall, 2008).

Importantly, longitudinal studies have shown that FAA and associated behavioral tendencies are relatively stable during early development. For example, infants displaying more behavioral reactivity to a stimulus exhibited greater right frontal alpha activity in infancy and childhood (Fox et al., 2001). These infants also showed higher levels of behavioral inhibition during childhood (Calkins, Fox, & Marshall, 1996; Fox et al., 2001; Henderson, Fox, & Rubin, 2001). Infants rated as displaying more approach behaviors, such as preferring novel stimuli, exhibited greater left frontal alpha activity during baseline (Calkins et al., 1996; Hane et al., 2008). Those demonstrating more pronounced approach-oriented behaviors in infancy were also high in approach later in childhood (e.g., social competence, externalizing behaviors; Degnan et al., 2011; Stifter et al., 2008).

Contextual influences on frontal alpha asymmetry

The current study aimed to better understand the origins of approach and avoidance processes as mutually regulatory by examining how they change across contexts during the second half of the first year of life. Our theoretical understanding of what FAA reflects is still evolving. Recent views construe FAA as reflecting ongoing regulatory processes related to approach and avoidance. Hewig (2018), for example, proposed relatively more left or right frontal alpha activity that reflects an intention to act in an approach- or avoidance-oriented fashion, respectively. Further, Gable, Neal, and Threadgill (2018) proposed that the more people must engage in self-regulatory processes over the desire to approach or avoid the more frontal alpha activity shifts rightward. A growing body of empirical evidence indicates FAA reflects ongoing regulatory processes and evolves as children and adults adapt to meet changing task demands (Jackson et al., 2003; Perone et al., 2020, 2020, 2019). Little is known about how FAA varies across contexts during infancy in tasks that are not designed to elicit stress or fear. Play with a social partner involves an interpersonal exchange, which is generally construed as a positive social-emotional experience (Landry, Smith, & Swank, 2006; Stern, 1974). Examining FAA during play provides a window into ongoing regulatory dynamics during a typical parent-infant interaction, which is known to have a foundational role in many domains of development (Bernier, Calkins, & Bell, 2016; Blair, Cybele Raver, & Berry, 2014; Hane & Fox, 2006).

Play also offers a naturalistic context to examine approach processes at work during self-generated stimulation, such as object exploration, and external stimulation provided by a parent. Previous literature has compared FAA between baseline and play in infants with depressed and non-depressed mothers to understand how parents influence their infants' brain activity across conditions. Infants of non-depressed mothers showed greater left frontal alpha activity during positive interactions with parents and familiar experimenters relative to the infants of depressed parents (Dawson et al., 1999; Dawson, Panagiotides, Klinger, & Hill, 1992). In the current study, we examined FAA during play with a social partner relative to baseline. Play is a positive social-emotional experience and provides an opportunity for mothers to set the emotional tone and involves demands on approach processes to engage in object exploration and social interactions. Previous studies have shown that positive states and approach states are linked to greater left frontal alpha activity (Choi, Sekiya, Minote, & Watanuki, 2016; Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Harmon-Jones & Allen, 1998; see also Bernier et al., 2016). Thus, we expected infants to exhibit greater left alpha activity during play relative to baseline.

Maternal behaviors during parent-infant interactions have been associated with attentional and emotional aspects of play. Mothers are thought to influence their infant's object exploration by guiding attention to, and maintaining attention on an object during play (Belsky, Goode, & Most, 1980; Landry & Chapieski, 1988; Lawson, Parrinello, & Ruff, 1992; Parrinello & Ruff, 1988). High-quality maternal caregiving observed in the lab, typically measured during interactions, such as play, has been associated with lower levels of negative affect during infancy, less fearfulness, more joint attention, and greater left frontal alpha activity (Hane & Fox, 2006). Low-quality maternal caregiving behaviors observed in the lab at 9-months of age were associated with more social inhibition, aggressive play, and more right frontal alpha activity at 2 and 3 years of age (Hane et al., 2010). These real-time interactions have long-term implications. For example, programs that teach high-quality caregiving practices were shown to improve later social, language, and cognitive abilities for at-risk infants (Landry et al., 2006). We measured parental behaviors and expected more positive emotional parental support to relate to more left alpha activity.

Infant temperament

Coan, Allen, and McKnight (2006) proposed a capability model elucidating why FAA changes from one context to another and does so differently across individuals. The model posits that individuals bring their capacity to regulate their emotions to a specific context, such as baseline or parent-infant play. Based on the capability model, we should expect FAA to change from a relatively neutral baseline task to a more positively valenced play task, with notable individual differences. Consistent with this possibility, Gartstein (2019) found that infants whose parents interacted with greater intensity (e.g., loud vocal exchanges) and higher emotional tone (e.g., frequent enthusiastic/positive comments) exhibited a greater rightward shift in FAA during a stress-inducing task. However, this rightward shift was not significant if the infants were rated higher on approach in their home environment. Thus, the degree to which infants engage in approach behaviors outside the lab is related to neural correlates of their capacity to regulate themselves in response to a stressful context in the lab, consistent with the capability model (Coan et al., 2006).

We examined the relations between a shift in FAA from baseline to play and infants' attention and regulatory abilities as measured via parent-report using the Infant Behavior Questionnaire-Revised (IBQ-R; Gartstein & Rothbart, 2003). The IBQ-R is grounded in Rothbart's psychobiological model of temperament (Rothbart, 2011), which views early individual differences in reactivity and regulation as foundational to shaping development through their influence on infants' daily interactions with objects and people. We focused on four fine-grained attention and regulatory dimensions identified by Gartstein and Rothbart (2003) to investigate how these behavioral tendencies come to bear on approach and avoidance processes as measured via FAA in real time. The four dimensions are low-intensity pleasure (e.g., pleasure related to low levels of intensity), duration of orienting (e.g., attention to an object for extended lengths of time), soothability (e.g., reduction in distress by parental intervention), and cuddliness (e.g., expressed enjoyment while being held by a caregiver). While the IBQ-R factors are frequently used, previous studies have shown IBQ-R fine-grained scales make unique predictive contributions to explaining behaviors later in toddlerhood and early childhood (Putnam, Rothbart, & Gartstein, 2008; Willoughby, Waschbusch, Moore, & Propper, 2011). Specific hypotheses about interrelations between the attentional and regulatory dimensions and FAA are detailed in the next section.

The current study

The goal of the current study was to probe FAA across baseline and play contexts as it relates to infants' attentional and regulatory capacity, with additional expectations related to object exploration and maternal scaffolding, resulting in three sets of hypotheses. Few studies have examined shifts in FAA in infancy from baseline to a positive social-emotional context in relation to temperament. Our first hypothesis was that play with a social partner is a positive social-emotional context that should elicit a positive emotional experience and engage the approach system. Thus, we expected FAA to be more left-dominant during play than baseline.

Our second set of hypotheses focused on the relationship between shifts in FAA and infant and maternal behaviors within the play session. We expected a leftward shift in FAA from baseline to play to be associated with behaviors that generate stimulation consistent with the use of approach, such as active object exploration and the positive emotional tone of the experience.

Our third set of hypotheses were centered on the IBQ-R subscales. We hypothesized that higher levels of duration of orienting reflect infants' ability to control attention in an endogenous fashion during play. Thus, we expected infants high in duration of orienting to exhibit a leftward shift in FAA when exploring an object, relative to baseline. We also hypothesized that cuddliness reflects an other-oriented regulatory ability. Previous studies have shown cuddliness to be associated with greater effortful control ratings in toddlerhood (Erickson, Gartstein, & Beauchaine, 2017). We expected higher levels of cuddliness to be associated with a leftward shift in FAA from baseline to a play context in which the mother served as a social partner. Both duration of orienting and cuddliness have been linked to neural correlates of regulatory processes in early infancy (Perone & Gartstein, 2019). Due to the dearth of existing research, we had no a priori expectations regarding low-intensity pleasure or soothability. The current study will inform our understanding of these regulatory dimensions as they relate to FAA in the contexts studied here.

Finally, we performed supplementary analyses to facilitate comparisons with existing literature. Since many studies have shown FAA during a single context is related to behavioral tendencies across the lifespan (Degnan et al., 2011; Fox et al., 1994; Harmon-Jones & Allen, 1997), we explored how individual differences in behavioral tendencies are associated with FAA under specific contexts. Based on previous literature, greater left frontal alpha activity during both baseline and play was expected to be associated with greater parent-reported regulatory abilities and greater exploration of the object during play.

Method

Participants. The final sample consisted of 55 infants ranging in age from 6 to 12 months (M = 9.02 months, SD = 1.49 months, 31 females). All 55 infants contributed EEG data to analyses of baseline and play. The IBQ-R was not completed for five of these infants, and the behavior for seven of these infants and their mother was not coded during play due to video malfunction. Additional 24 infants participated in a larger study but were excluded because they did not have useable EEG for both baseline and play due to equipment malfunction (n= 2), fussiness (n= 1), computer/equipment error (n= 18), or procedural differences (n= 3). All infants were born full-term (>37 weeks) with no significant medical/birth complications, developmental delays, or disabilities. Families received a t-shirt in appreciation for their participation. Participants were mostly White (81.80%), with a family income above $30,000 (70.90%). Mothers completed an average of 15.78 years of education.

Design and procedure

Baseline EEG. Infants first completed the baseline task. While seated in a high chair, a 32 electrode EEG cap (Cortech Solutions, Inc.; Wilmington, NC) was placed on the infant's head. Electro-conductive gel and individual electrodes were placed into each site. The EEG was recorded via the BioSemi Active Two amplifiers. The EEG was referenced online to Cz and sampled at 1024 Hz. While EEG was recording, the infant was shown a 60 s clip of Baby Einstein Baby Mozart. Previous baseline tasks for EEG studies with infants have used similar recording duration (1–2 minutes) with dynamic objects or videos to keep the infant calm and relatively still to improve recording quality (Bell, 2002; Gartstein, 2019; Marshall, Fox, & Core Group, 2004; Perone & Gartstein, 2019; Tomalski et al., 2013). Mothers were asked to limit their interaction with the infant to redirecting them to the video if needed.

Parent-Infant Play. Following baseline, mothers were instructed to play with their infant using a ring with plastic fruits for 90 s as they would at home. This duration is similar to other studies examining individual differences with play (Baumgartner & Oakes, 2013; Gartstein, Hancock, & Iverson, 2018; Ruff & Lawson, 1992). Infants were seated in a highchair during this task.

Behavioral Coding. Parent-infant play was coded for the frequency and duration of infants both looking at and touching the toy (Needham, 2000; Ruff, 1986). For each behavior, interrater reliability was examined for 25% (17 from the full sample) of the coded videos. Looking at the toy resulted in an interclass correlation coefficient (ICC) of .989 (95% CI is .985-.992), and ICC was .997 (95% CI of .995 to .998) for touching the toy. The two coded behaviors were not significantly related, $r = .19$, $p > .10$. The behaviors were combined into a bimodal object exploration composite score defined as the proportion of the task that infants were simultaneously looking at and touching the toy (Needham, 2000; Soska, Adolph, & Johnson, 2010).

Maternal behaviors were coded using the Maternal Emotion Scaffolding Scale (Dilworth-Bart, Poehlmann, Hilgendorf, Miller, & Lambert, 2010) during parent-infant play. This scale assesses the parent's verbal, nonverbal, and physical behaviors that soothe negative emotions, help the infant soothe themselves, or promote positive emotions. See Table 1 for the anchors. Interrater reliability on 25% of dyads resulted in an ICC of .969 (95% CI of .906 to .990).

Infant Temperament. Mothers completed the IBQ-R within 2 weeks of their laboratory visit. Individual items reflect the frequency of occurrence of behavioral manifestations of infant temperament within the last week. Responses are made on a 7-point scale. This IBQ-R has good psychometric properties (Gartstein & Rothbart, 2003), including predictive validity (e.g., predicting a range of relevant early behavior problems; Gartstein & Bateman, 2008; Gartstein et al., 2010; Gartstein, Putnam, & Rothbart, 2012). We examined the four subscales reflecting infants' regulatory capacity/orienting: soothability, duration of orienting, low-intensity pleasure, and cuddliness. Reliability was good for all subscales in this sample (α = .73-.88).

EEG Processing. The EEG recorded during baseline and parent-infant play were processed identically using custom Matlab scripts relying on functions from EEGLAB (Makeig & Delorme, 2004), ERPLAB (Lopez-Calderon & Luck, 2014), and FieldTrip (Oostenveld, Fries, Maris, & Schoffelen, 2011). The continuous EEG was high-pass filtered at 1 Hz and notch filtered at 60 Hz. Excessively noisy electrodes were removed and interpolated. The EEG was then re-referenced to the average and divided into 1 s epochs with 75% overlap. If any electrode had an absolute voltage greater than 100 μV for more than 100 ms that epoch was excluded from further analysis. Time-frequency decomposition was performed on the remaining epochs using Fast Fourier Transformation (FFT) with a 1 s Hanning window from 1 to 50 Hz. A mean of 53.18 (88.70%) seconds was processed for the baseline task, and a mean of 76.72 (87.00%) seconds was processed for the parent-infant play task. Absolute power was computed in alpha, measured in the 6–9 Hz range in infants (Marshall et al., 2002; Stroganova, Orekhova, & Posikera, 1999). FAA was computed by subtracting the natural log(ln) of alpha at the left frontal site F3 from the analogous value for the right frontal site F4 (Fox et al., 2001). Lower alpha is associated with greater activation, whereas higher alpha reflects inhibitory processes (Allen, Coan, & Nazarian, 2004; Barry, Clarke, Johnstone, Magee, & Rushby, 2007; Klimesch, Sauseng, & Hanslmayr, 2007). Thus, lower FAA scores reflect more relative right frontal activation. We computed the FAA

Table 1. Maternal emotion scaffolding scale from Dilworth-Bart et al. (2010).

1	3	5
Mother makes minimal efforts to help child identify his/her emotions, to help maintain positive emotions, to soothe negative emotions, or to facilitate child's self-soothing behavior and/or her efforts to scaffold emotion are unsuccessful.	Mother attempts to help child identify his/her emotions, to help maintain positive emotions, to soothe negative emotions, or to facilitate child's self-soothing behavior for at least half the segment. About half of her efforts to scaffold emotion are successful.	Mother helps child identify his/her emotions, maintain positive emotions or to soothe negative emotions and/or facilitates child's self-soothing behavior throughout the segment. Her efforts to scaffold emotion are successful.

during baseline and play. We also calculated changes in FAA across contexts by subtracting FAA during baseline from play such that positive values indicate a leftward shift, and negative values indicate a rightward shift.

Results

We tested our first hypothesis that infants would exhibit more left frontal alpha activity during play relative to baseline, using a paired samples *t*-test comparing FAA during baseline and play. FAA during baseline and play can be seen in Figure 1. Contrary to our expectations, infants exhibited more left frontal alpha activity during baseline than play, $t(54) = 2.80$, $p = .007$, $d = .45$, suggesting that on the whole, infants were more approach-oriented during the baseline task compared to play. During baseline, greater left frontal alpha activity was related to greater left frontal alpha activity during play, $r = .30$, $p = .02$. Figure 2 shows variability in the change between baseline FAA and play FAA with each line depicting an individual's change between tasks.

The second set of analyses focused on the relations between infants' and mothers' behaviors during play. The degree to which infants exhibit a leftward shift in FAA from baseline to play was expected to be related to greater object exploration and maternal scaffolding. As anticipated, higher levels of object exploration were associated with a greater leftward shift in FAA, $r = .35$, $p = .02$ (see Figure 3). Maternal emotion scaffolding was unrelated to the shift in FAA across contexts (see Table 2 for descriptive statistics and correlations).

Our third set of hypotheses were centered on the IBQ-R subscales. We hypothesized that higher levels of duration of orienting and cuddliness would be associated with a leftward shift in FAA from baseline to play. We computed bivariate correlations between change in FAA and the duration of orienting and cuddliness subscales. The results revealed that only higher levels of cuddliness were associated with a leftward shift in FAA from baseline to play, $r = .41$, $p = .003$. Figure 4 shows a scatterplot depicting this relation. Our exploration of soothability and low-intensity pleasure were unrelated to FAA (all *p*s > .10).

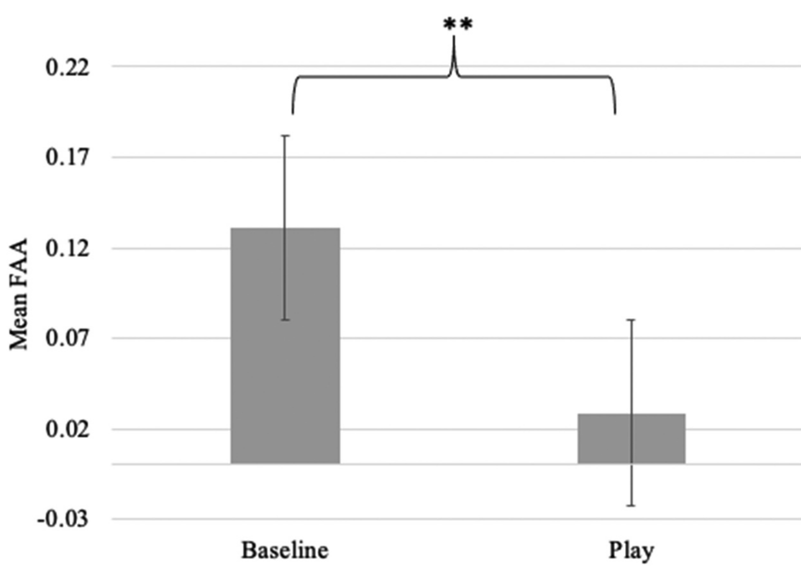

Figure 1. Mean FAA at baseline and play.

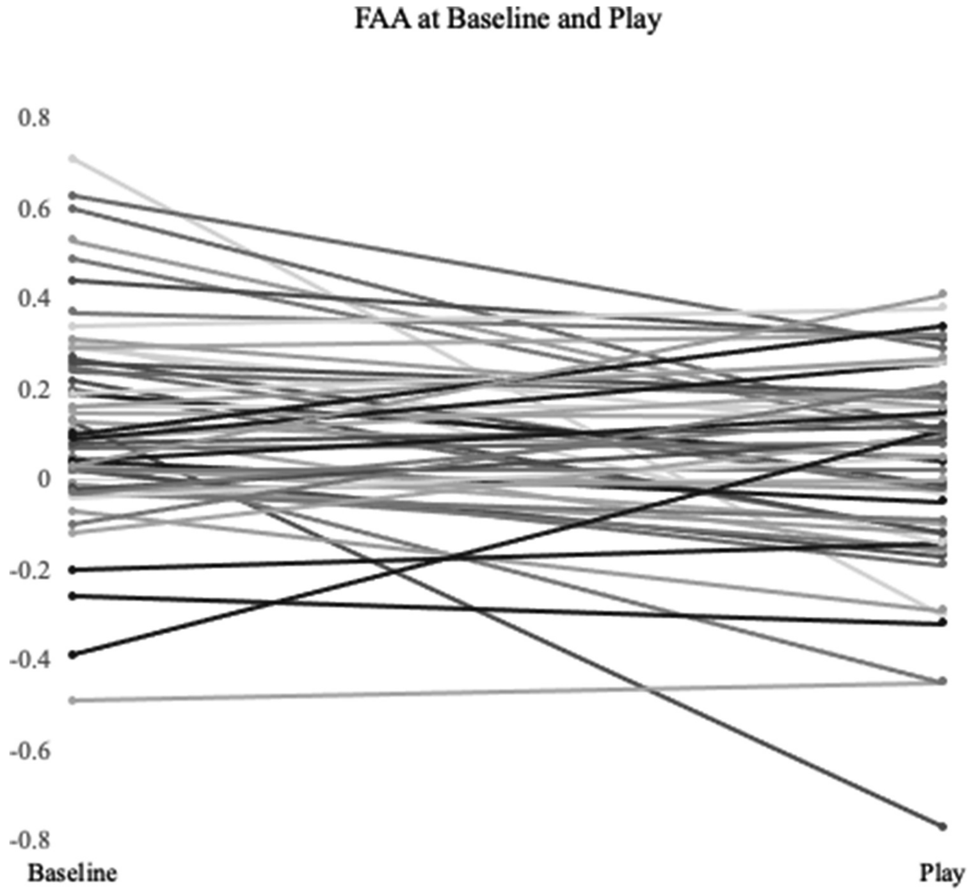

Figure 2. Spaghetti plot showing the variability in frontal alpha asymmetry between baseline (left) and play (right).

In a follow-up analysis, we used hierarchical multiple regression to test whether exploration and cuddliness explain a significant amount of variance in change in FAA across contexts. Cuddliness made a unique and significant contribution to change in FAA, whereas object exploration predicted change in FAA at the trend-level. Additionally, higher levels of both cuddliness and object exploration were associated with more left frontal alpha activity during play (see Table 3).

Supplementary Analyses. To build on previous literature examining FAA under specific conditions, we examined whether the attention and regulatory subscales were related to FAA during baseline and play. Once again, only cuddliness was related to FAA (all other ps > .10). Higher levels of cuddliness were related to more right frontal alpha activity during baseline, $r = -.28$, $p = .047$. Specifically, during baseline, infants rated as more cuddly were in a more avoidant state than those rated low in cuddliness. We performed the same analyses by examining relations between infants' object exploration and mothers' emotion scaffolding. Only object exploration was related to FAA during play, $r = .32$, $p = .03$, such that infants who explored the toy more during play were in a more approach-oriented state as reflected by greater left frontal alpha activity (higher FAA).

General discussion

Parent-infant play is an important context for early socio-emotional and cognitive development, yet infants' brain activity during play has been understudied (see Dawson et al., 1992, 1999 for exceptions). Studying brain activity during parent-infant interactions can shed light on neurophysiological

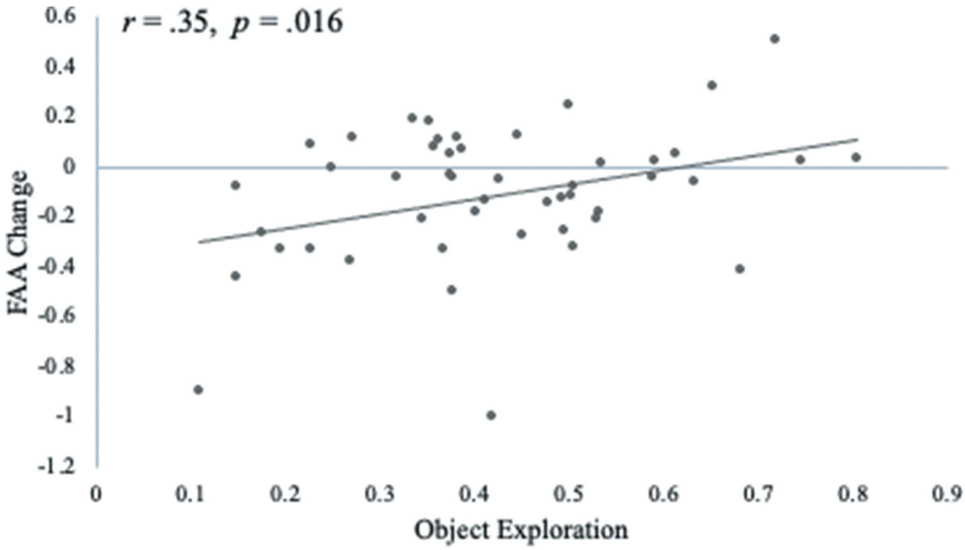

Figure 3. Scatterplot showing association between object exploration during play and change in FAA from baseline to play.

processes not observable at the behavioral level that may play a role in socio-emotional and cognitive development. We examined the neural correlates of approach and avoidance processes in baseline and play contexts. We proposed that the positive social-emotional context created by play would engage the approach system and elicit greater left frontal alpha activity during play relative to baseline because of object exploration, which, we hypothesized, would allow for self-generated stimulation and a positive emotional experience. Contrary to our expectations, we found that, on average, infants showed greater left frontal alpha activity during baseline relative to play.

Our second set of hypotheses centered around the associations between FAA and mother-infant behaviors during the play session. We expected that infants who shift more toward greater left frontal alpha activity would engage more in object exploration and have mothers who engaged more in emotion scaffolding during play. This hypothesis was partially supported as object exploration was related to a leftward shift in FAA between conditions, and maternal emotional scaffolding did not significantly predict a leftward shift in FAA.

The third set of hypotheses tested were focused on the regulatory subscales of the IBQ-R. We hypothesized that infants higher in cuddliness and duration of orienting would exhibit a greater leftward shift in FAA from baseline to play. We found that only cuddliness was associated with a leftward shift in FAA. In a follow-up analysis, we found that cuddliness predicted unique variance in FAA during play, controlling for baseline, but object exploration produced only trend-level results. Our supplementary analyses also revealed that infants who exhibited greater left frontal alpha activity during play explored the toy more during that time.

One open question is what baseline EEG activity actually measures. Baseline EEG is often interpreted as a reflection of an individual's disposition or stable affective style regardless of the situation (Davidson, 1998; Davidson & Fox, 1989). The capability model of FAA, proposed by Coan and colleagues, posits that individuals bring their ability to respond and modulate these reactions, depending on the demands of a specific situation (Coan et al., 2006). The capability model is most typically ascribed to ongoing processes present during an emotion-eliciting task only as an individual engages those processes to approach or avoid an emotional stimulus. However, baseline places regulatory demands on participants as well (see Camacho, Quiñones-Camacho, & Perlman, 2020 for discussion). Baseline EEG with older children and adults is collected, while participants sit with their eyes closed or look at a fixation cross (see Anderson & Perone, 2018 for review). While older

Table 2. Means standard deviations and correlations.

	Mean (SD)	Baseline Asymmetry	Play Asymmetry	Change in Asymmetry	Maternal Emotion Scaffolding	Object Exploration	IBQ Duration of Orienting	IBQ Low Intensity Pleasure	IBQ Soothability	IBQ Cuddliness
Age	9.01 (.23)	.20	–.09	–.25	.21	.21	.02	.06	.08	–.09
Baseline Asymmetry	0.13 (.23)		.30*	–.59**	–.16	–.08	–.04	–.07	.02	–.28*
Play Asymmetry	0.03 (.23)			.60**	.06	.32*	–.09	.002	.11	.18
Change in Asymmetry	–0.07 (.28)				.19	.35*	–.04	.06	.07	.41**
Maternal Emotion	2.52 (1.24)					–.01	–.12	–.08	–.01	.32*
Scaffolding							.07			
Object Exploration	0.43(.16)							–.11	.04	.14
IBQ Duration of	3.60(.86							.53**	.16	.04
Orienting										
IBQ Low Intensity	5.22(.93)									.33*
Pleasure									.20	
IBQ Soothability	5.14(62)									.16
IBQ Cuddliness	5.54(67)									

* Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

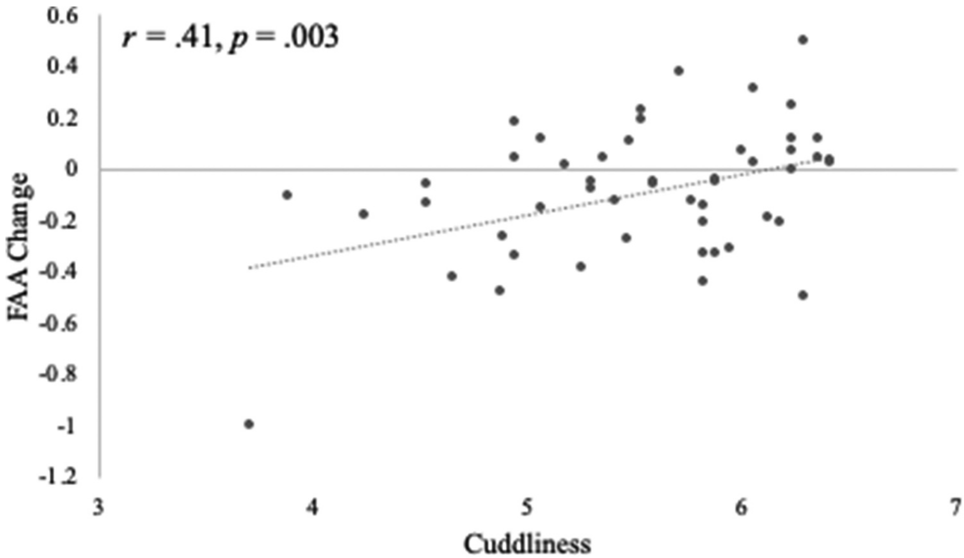

Figure 4. Scatterplot showing association between cuddliness as measured in the IBQ-R and change in FAA from baseline to play.

Table 3. Hierarchical regression predicting FAA during play from cuddliness and object exploration after controlling for baseline.

Block	Predictors	R^2	R^2 change	*F* change	*p*	*beta*	*β*	*P*
1	Baseline FAA	0.150	0.150	7.405	0.009	0.348	0.387	0.009
2	Baseline FAA	0.295	0.145	4.111	0.024	0.456	0.508	<0.001
	Cuddliness					0.096	0.289	0.046
	Object Exploration							

children and adults use endogenous control to complete such tasks, younger children and infants typically watch videos or an experimenter manipulating an object. These tasks are designed to keep the young participants relaxed and still and are necessary to acquire quality imaging data over sufficient periods of time. So, while baseline likely requires some endogenous control to remain still and watch the stimulus, this context also involves exogenous control from the dynamic stimulus (Cohen, 1972; Courage, Reynolds, & Richards, 2006; Horst et al., 2009; Robinson & Sloutsky, 2004).

Our analysis of FAA across contexts adds to our understanding of what the baseline task is measuring. Our findings suggest that the dynamic visual displays used in infant EEG tasks stimulate greater left frontal alpha activity. The attention-capturing properties of the dynamic stimuli could manifest in greater left frontal alpha activity in two ways. First, it is possible that the attention-capturing properties of the baseline task recruit attentional resources in an exogenous fashion and then allow infants to maintain attention to the display endogenously. This pattern may result in greater left frontal alpha activity relative to the right. Secondly, it is possible that looking at the dynamic stimuli is arousing and provides a positive emotional experience, which results in greater left frontal alpha activity relative to the right. Future research should consider alternative benchmarks to better understand the role that task parameters play with respect to the pattern of results we observed. For example, including solo play for the infant as a comparison task to the parent-infant play period would provide insight into the role of the parent on regulatory processes and their relations to temperament.

Our analysis of FAA across tasks as it relates to individual differences in temperament adds to our understanding of how individuals adapt across tasks with differing contextual factors. Cuddliness was the only IBQ-R regulatory subscale that emerged in relation to FAA at baseline or play. We observed that infants rated as cuddlier exhibited greater right frontal alpha activity during baseline and exhibited a leftward shift in FAA from baseline to play. Cuddliness has been conceptualized as the degree to which infants seek and enjoy physical closeness with their parents (Gartstein & Rothbart, 2003). Our findings indicate that, relative to their peers, infants high on cuddliness may be in a more negative emotional state, or in a less stimulated state during an isolating baseline task than during a period of play with their mother. From a dispositional lens of FAA, our baseline EEG results would suggest that cuddliness is associated with a more stable negative affect across situations, and it may be that infants seek physical proximity to help regulate this state. However, we also observed that cuddliness was associated with a leftward shift in frontal alpha activity from baseline to play, a more approach-oriented state during play with their mother. An increase in right frontal activity has been observed under increasingly stressful conditions (Perone et al., 2020) and has been viewed as reflecting the need for more active self-regulation (Gable et al., 2018). In this context, our pattern of results suggests that it is more difficult for cuddlier infants to effectively self-regulate during baseline – a task completed alone – than while playing with their mother. This is also consistent with the capability model (Coan et al., 2006). It may be more difficult for cuddly infants to self-regulate during a task completed alone than a task completed with their mother.

Previous studies have found cuddliness to be a unique predictor of self-regulation. For example, Erickson et al. (2017) showed that cuddliness predicted effortful control in toddlerhood. Klein, Rocha, Martinez, Putnam, and Linhares (2013) reported that cuddliness was higher in full-term than in preterm infants. It is well documented that preterm infants exhibit developmental delays in attention, cognitive, and socio-emotional processes (Landry et al., 2006; Rose, Feldman, & Jankowski, 2012). Lower levels of cuddliness in preterm infants may thus reflect less effective use of others to self-regulate. Higher levels of cuddliness have also been linked to higher levels of theta and lower levels of beta over the posterior regions of the scalp during baseline (Perone & Gartstein, 2019). Notably, this pattern of cortical activity has been associated with poor top-down control in children and adults (e.g., Perone, Palanisamy, & Carlson, 2018; Schutter & Van Honk, 2005). Higher levels of cuddliness during infancy could reflect other-oriented regulation, which later develops into advanced self-regulatory abilities.

Cuddliness may be a reflection of the parent–child relationship. Infants rated as more cuddly have opportunities to share physical closeness with their caregiver. Given that parents report this infant attribute, it could also be that higher ratings of cuddliness in part reflect mothers' awareness of infants' need or desire for physical comfort and closeness. Consistent with this possibility, cuddliness was associated with more maternal emotion scaffolding during play, $r = .32$, $p = .032$. This pattern of results is generally consistent with the overarching idea that cuddliness reflects an other-oriented regulation style. Parent-infant interactions studied in the lab, such as in the current study, are often only observed for minutes. While this provides a window into the parent-infant dynamic, it does not capture the entirety of the parent–child relationship that shapes infants' socio-emotional and cognitive development. Since this study only examined a brief parent-infant play interaction, further research into how ongoing parent-infant exchanges are involved in the development of self-regulation is needed to generalize these findings.

Our results showed that infants who shifted toward greater left frontal alpha activity during play relative to baseline explored the toy more. Object exploration has been linked to perceptual, attentional, and cognitive processes in infancy (Needham, 2000; Perone, Madole, Ross-Sheehy, Carey, & Oakes, 2008; Soska et al., 2010). Supplementary analyses also showed that infants with greater left frontal alpha activity explored the toy more during play. It is possible that infants who engage with the toy more actively are using approach motivational processes to generate greater stimulation, reflected in a leftward shift in frontal alpha activity. It may also be that these infants more endogenously control and maintain attention on an object, driven by approach-related processes. Endogenous control of attention reflects the engagement of neural attentional systems developed over the first year (Bremner et al., 2011; Colombo, 2001; Frick, Colombo, & Saxon, 1999; Johnson, 1990; Reynolds & Romano, 2016) and enables infants to focus attention in the presence of distractors in the environment and modulate their level of stimulation. Maternal behaviors are also known to influence object exploration (Belsky et al., 1980; Landry & Chapieski, 1988; Ruff & Lawson, 1992). However, we did not observe any relation between maternal emotion scaffolding and FAA. It may be that object exploration is more sensitive than maternal emotion scaffolding to the specific approach and avoidance processes measured via FAA in the contexts studied here.

A few limitations should be considered when interpreting our findings. First, this study has a relatively small sample size, making it difficult to detect small but potentially meaningful relations. The current study used a similar sample size and found similarly sized effects as many other exploratory EEG studies with infants (Bell, 2002; Cuevas & Bell, 2011; Diaz & Bell, 2012; Gartstein, 2019; Perone & Gartstein, 2019; Wolfe & Bell, 2004, 2007). Our intriguing findings warrant further investigation with a larger sample to detect potentially small but meaningful effects. This study is also limited to the two contexts: baseline condition and parent-infant play. More studies addressing various contexts are needed to better understand the dynamic regulatory processes at work in daily life. For example, including a baseline task without a dynamic visual display or an independent play task would contribute to understanding exogenous influences on FAA. We expect that the association between the play task and cuddliness results from a social interaction reflective of the dyadic history and relationship. If true, an intriguing possibility is that these effects would disappear if the baby played with a stranger. Future studies should investigate whether the relation between cuddliness and FAA is specific to play with their mother by replicating this play task with a stranger.

In conclusion, the current study sheds light on FAA as reflecting ongoing processes during infancy in the context of social interactions typical of daily life. The pattern of results suggests that ongoing approach and avoidance processes are involved in modulating the attention and emotion regulatory demands that infants likely encounter in their everyday lives. Our findings indicate that the properties of the specific tasks are an important factor in interpreting the relative levels of FAA. Using a positively valenced play task expands our understanding of the approach and avoidance regulatory processes underlying both play and baseline. Our study further indicates that it is equally important to consider individual differences in interpreting relative levels of FAA as not all children may experience a task in the same way. This study raises intriguing questions about cuddliness and its role in the development of self-regulation.

Acknowledgments

We thank the infants and parents who made this research possible. We also thank the graduate and undergraduate research assistants involved in both data collection and coding.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported that there is no funding associated with the work featured in this article.

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