Received: 27 April 2021 | Revised: 18 August 2021 | Accepted: 6 September 2021

DOI: 10.1002/dev.22198

Developmental Psychobiology WILEY

RESEARCH ARTICLE

Understanding emerging regulation: The role of frontal electroencephalography asymmetry and negative affectivity

Allegra X. Campagna | Christie N. Pham | Maria A. Gartstein

Department of Psychology, Washington State University, Pullman, Washington, USA

Correspondence
Allegra X. Campagna, M.S., Washington State University, Johnson Tower 233, PO Box 644820, Pullman, WA 99163, USA.
Email: allegra.campagna@wsu.edu

Abstract

The present study examined frontal electroencephalography (EEG) asymmetry and negative affectivity (NA) as predictors of infant behaviors during the Still-Face Paradigm (SFP). It was hypothesized that infants with lower NA subscale scores who also demonstrate greater left frontal activation would exhibit more frequent social engagement and self-soothing behaviors during the SFP. Mothers reported infant temperament at 6–12 months of age ($N = 62$), and EEG was recorded during a baseline task and the SFP. Social engagement, distress, and self-soothing behaviors were coded during the SFP. A three-factor solution emerged based on exploratory factor analysis of eight infant behaviors. After considering bivariate relations, multiple regression analyses predicting the behavior factor labeled social engagement (containing vocalizations and handwaving; average factor loading = .56) were conducted separately for asymmetry and NA subscales, controlling for infant sex and age. The SFP asymmetry predicted social engagement after controlling for covariates and baseline asymmetry; however, NA subscales (falling reactivity and distress to limitations) did not uniquely explain significant variance. These findings highlight the importance of frontal EEG asymmetry in contributing to emerging social engagement and regulation in infancy. Implications include potentially utilizing asymmetry markers as screening and intervention targets in the first year of life.

KEYWORDS
EEG asymmetry, emotion regulation, negative affectivity, social engagement, temperament

1 | INTRODUCTION

1.1 | Infant regulatory and social engagement behaviors

Advanced early emotion regulation behaviors predict higher academic achievement in kindergarten (Harrington et al., 2020) and are associated with peer popularity (Blankson et al., 2017), resilience (Terranova et al., 2015), and a reduced risk of conduct and behavioral problems (Degnan et al., 2014). Difficulties with emotion regulation lead to increased risk of internalizing symptoms (i.e., depression and anxiety; Shapero & Steinberg, 2013), lower social competence (Penela et al., 2015), and externalizing problems (i.e., conduct difficulties and hyperactivity; Halligan et al., 2013). Infant emotion regulation is associated with later self-regulation and executive functioning (Frick et al., 2018).

Emotion regulation emerges in infancy as attention and inhibitory motor control come online (Toda & Fogel, 1993). Infants as young as 3 months of age begin to alter behavior in response to environmental inputs (e.g., reaching and grasping; Kopp, 1989) and demonstrate self-soothing motor behaviors (e.g., thumb sucking or repetitive self-manipulation; Braungart-Rieker et al., 1998; Zimmer-Gembeck & Skinner, 2016). Infant behaviors utilizing motor control can also manifest as social referencing by reaching for mother, withdrawal (e.g., turning away from an alarming stimulus), and self-distraction with objects (e.g., playing with a toy; Gross & Jazaieri, 2014; Wu et al., 2017). Notably, emotion regulation research has primarily focused on attention capacity in infancy largely neglecting other infant self-soothing behaviors and social engagement serving a regulatory function (Perry et al., 2016).

Infant social engagement skills enable individuals to enter, form, and maintain social ties and are the foundation for social adaptation and the capacity for intimacy throughout life (Feldman et al., 2009). Social engagement strategies are also critical to meeting personal needs and reducing infant distress. Beginning at birth, early social engagement includes a preference for the human face and a selective response to social contingencies (Feldman & Eidelman, 2007; Tarabulsy et al., 1996). Specifically, infant gaze maintenance, joint attention, and vocalizations represent tools for social engagement signaling parents that typically elicit adult responses (Symons & Moran, 1987). Prelinguistic vocalizations and resulting parent–child interactive patterns inform the capability for dyadic interactions and coregulation. Early social engagement strategies have been considered in the context of maternal depression and anxiety, where increased symptoms predict a reduced frequency of social behaviors (Feldman & Eidelman, 2009). However, social engagement has not been sufficiently studied in tandem with other regulation-related behaviors, or in association with infant temperament and brain activity.

Infant social engagement and regulatory capacity have been assessed via laboratory procedures, most commonly the Still-Face Paradigm (SFP; Adamson & Frick, 2003; Barbosa et al., 2019; Mesman et al., 2009). The SFP was designed by Tronick and colleagues (1978) to capture an infant's contributions to social interactions. The SFP evokes infant reactivity in response to their caregiver's emotional unavailability (i.e., mother displaying flat facial expression; Haley & Stansbury, 2003; Tronick et al., 1978). This violation of parent–child interaction expectations challenges early regulatory capacity, including self-soothing and social engagement. Infants have responded to this task by averting their gaze from the caregiver, smiling less, and displaying overall increased negative affect/crying, as well as frustration or anger (Graham et al., 2018; Kogan & Carter, 1996). Sustained negative responses indicate poor self-regulation (Tronick et al., 1978; Yaari et al., 2018) and are stable over time (Mesman et al., 2009), predicting externalizing and internalizing difficulties (e.g., Bosquet Enlow et al., 2011; Zimmer-Gembeck & Skinner, 2016). Thus, a goal of the current study was to examine infant behaviors during this task to support the early identification and prevention of social and regulation-related difficulties.

1.2 | Negative affectivity

Temperament represents biologically based and environmentally informed individual differences in reactivity and regulation (Rothbart & Derryberry, 1981). Negative affectivity (NA) is the most widely studied temperament domain, linked with emotional and behavioral outcomes (Kozlova et al., 2019; Lipscomb et al., 2017; Trofimova & Sulis, 2018). This construct reflects susceptibility to distress, discomfort, fear, frustration, sadness, and a lack of soothability.

Distress-related attributes "come online" first and set the stage for developing self-regulation and resulting behavior strategies (Cole et al., 2019; Derryberry & Rothbart, 1997). Infant NA has been associated primarily with regulation deficits (e.g., utilizing fewer emotion regulation behaviors; Braungart-rieker & Stifter, 1994; Zimmer-Gembeck & Skinner, 2016). Infants high in NA utilized fewer attentional regulation and more avoidance behaviors (Thomas et al., 2017) and experience greater difficulties with socioemotional competence (Calkins, 1998). Fine-grained dimensions of NA were shown to have differential predictive utility insofar as fear and sadness made more substantial contributions to internalizing difficulties, whereas anger and frustration were related primarily to externalizing problems (Lengua, 2006; Oldehinkel et al., 2004; Nigg, 2006). Although fearful children were better able to suppress a prohibited behavior (Kochanska et al., 2000), anger and frustration have been linked to regulation deficits (Calkins et al., 2002). Thus, further study of NA components is essential to enhance our understanding of emerging regulation in infancy.

1.3 | EEG

Frontal electroencephalography (EEG) asymmetry informs neurophysiological foundations of infant temperament (Fox, 1994). This asymmetry is based on the discrepancy between frontal alpha power values/activation linked to approach/withdrawal emotions and motivation. Specifically, greater relative left activation is associated with approach behaviors and preference for novel stimuli, whereas greater relative right activation is linked with avoidance and negative affect (Crespo-Llado et al., 2018; Davidson & Fox, 1989).

Greater right frontal activation was demonstrated in infants who cried more when separated from their mothers (Davidson & Fox, 1989). When 8-month-old infants watched videos of peers crying and laughing, those who looked longer at the laughing child demonstrated greater left frontal EEG asymmetry (Crespo-Llado et al., 2018; Davidson & Fox, 1989). Infants with left frontal asymmetry were also more likely to approach their peers. In older children, EEG asymmetry was linked to internalizing and externalizing problems (Liu & Bell, 2020).

Infant social engagement, like increased vocalizations, have been considered during the SFP (Goldstein et al., 2009); however, not in concert with other regulatory behaviors (e.g., self-soothing), or distress, and not as a function of temperament or brain activity (Franklin et al., 2015).

The majority of research measuring neural activity via EEG does so during a baseline state, not in the context of a social encounter designed to challenge emerging regulation by inducing mild stress (St. John et al., 2016). Frontal EEG asymmetry recorded during baseline is interpreted as a dispositional tendency toward approach versus avoidance (Coan et al., 2006). In contrast to this traditional trait approach, the capability model emphasizes dynamic responses and focuses on approach versus withdrawal processing and responses during emotion-eliciting tasks, as indexed by frontal alpha asymmetry

(Reznik & Allen, 2018). Measurement of brain activity in response to a mildly stressful social context informs our understanding of regulation and social-emotional development more broadly. Assessing infant brain activity is particularly critical as this point in development is foundational with respect to later regulatory capacity, more advanced in its flexibility and the attentional networks involved (Page et al., 2010; Posner et al., 2012). The capability model of alpha asymmetry has been understudied relative to its dispositional counterpart, especially in the context of a socially stressful task, and with respect to regulation development.

The present study aims to examine frontal alpha asymmetry, an established correlate of temperament, during the SFP in line with the capability model, predicting infant regulatory behaviors including self-soothing and social engagement.

1.4 | The present study

The overarching goal of this study was to evaluate temperamental negative emotionality and frontal alpha asymmetry as predictors of regulation-related behaviors. The present study addresses a critical gap in research by examining how NA components and EEG asymmetry contribute to infant regulatory behaviors during the SFP, including self-soothing, social engagement, as well as distress – the object of regulation. It was hypothesized that infants scoring lower on NA scales and demonstrating greater left frontal activation would exhibit lower distress and more frequent social engagement and self-soothing behaviors during the SFP.

2 | METHODS

2.1 | Participants

This study was approved by the Institutional Review Board of Washington State University and consent was obtained from each participant. Mothers with infants 6–12 months of age (N = 62; males = 28, females = 34) were recruited via Facebook advertisements and local birth centers/parent-infant programs in two Inland Northwest communities. Children with significant medical or birth complications, including infants identified as born preterm (<37 weeks of gestation) and those with developmental delays/disabilities, were excluded as such conditions were expected to result in altered patterns of social engagement and regulation development. Families involved in this study were primarily White (90%), with a number of Asian/Asian-American (3.3%), Latinx (1.7%), Native American (1.7%), and multiracial (3.3%) participants. Mothers were typically married (90.9%), between 21 and 42 years of age (28.72 years, SD = 4.64 years), and well educated (M = 16.01 years, SD = 2.04 years) with a family income above $30,001 (81.1%). A number of mothers (24%) identified their occupation as "stay-at-home" at the time of the evaluation, with the remainder of the sample reporting a variety of occupations (e.g., insurance agent, librarian, physical therapist).

2.2 | Procedures and measures

2.2.1 | The Still-Face Paradigm

The SFP (Tronick et al., 1978) begins with the experimenter instructing the mother to play with her infant utilizing stacking cups for 2 min. Following this, the mother is asked to display a still face (i.e., emotionless, flat facial expression) for an equivalent duration (or until 15 s of hard crying), refraining from any communication with the infant. The SFP was then followed by a 2-min reunion sequence and repeated. The task ended with another 2-min reunion to reduce infant distress.

2.2.2 | Behavioral coding

Infant behavior categories were developed based on existing literature (e.g., Fogel, 1982; Hornik & Gunnar, 1988) and observations of infants in the study, with infant self-soothing and social engagement strategies including the following behaviors: hand waving, kicking feet, looking to mother, banging on the table, playing with cups, hand/object to mouth, and vocalizations. Distress manifested during the task was also coded and considered in analyses because of inherent links to regulatory behaviors, implemented to modulate reactivity. Infant behavior ratings were assigned during the second phase of the SFP, expected to be more challenging in terms of demands for infant emotion regulation (Haley & Stansbury, 2003). Infant behavior was coded from the video as being present or absent every 10 s throughout the episode, for a total of 12 codes across a 2-min task. The number of different self-soothing and socially engaging behaviors summed across epochs formed composites for further analyses. Distress was operationalized to include bodily tension, facial affect signaling distress, whining/fussing/crying, escape behaviors (e.g., turning/twisting, leaning, or looking away; sinking into chair) and was also coded as present or absent during the second phase of the SFP and summed across epochs, similar to regulation-related behaviors. Interrater reliability was evaluated for independently rated training cases (20%), with intraclass correlations (ICCs) above .60 deemed acceptable, as in prior research (e.g., Gartstein et al., 2017; Hallgren, 2012).

2.2.3 | The Infant Behavior Questionnaire-Revised

This parent-report measure of temperament was developed for infants between 3 and 12 months of age (Gartstein & Rothbart, 2003). The Infant Behavior Questionnaire-Revised (IBQ-R) contains 191 items, yielding 14 scales shown to form three overarching factors. Reliability of the IBQ-R has been supported for mothers and fathers, as well as samples from different cultures, with Cronbach's α values ranging from .77 to .96 (Gartstein et al., 2003, 2005; Parade & Leerkes, 2008). Furthermore, evidence supports predictive and construct validity (Gartstein et al., 2010; Gartstein & Marmion, 2008).

The IBQ-R NA and its subscales components (i.e., fear, distress to limitations, sadness, and negatively loading falling reactivity) were utilized as infant temperament predictors in this study.

2.2.4 | EEG recording

An EEG cap (Cortech Solutions, Inc., Wilmington, NC) was placed on the infant's head while seated in a highchair. After the cap's placement, small amounts of electro-conductive gel were administered to each site. Individual "pin-type" electrodes (BioSemiCortech Solutions, Inc., Wilmington, NC) were then connected to each corresponding site. The EEG data was collected via the BioSemi Active Two amplifiers and initial screening via the BioSemi acquisition software at a sampling rate of 256 Hz. The EEG was referenced to Cz online.

Baseline EEG was recorded for ~60 s while infants watched a Baby Einstein Baby Mozart video, wherein colorful moving shapes are shown as classical music plays. The duration of EEG recording and the stimuli are consistent with existing infant baseline EEG studies (Bell, 2001; Morasch & Bell, 2011). Mothers were instructed to limit interactions to only directing their infants' attention to the screen when necessary. EEG was then recorded during the SFP. Baseline and components of the SFP procedure were time locked to the EEG recording via E-Prime software (Psychology Software Tools, Inc.), preprogrammed to transmit triggers initiated by specific keyboard presses into the EEG acquisition software. That is, E-Prime relayed triggers into the BioSemi acquisition software and marked each task's beginning and endpoints. All E-Prime triggers were assigned unique numerical values, allowing baseline and second the SFP episode data to be extracted for further processing.

2.2.5 | EEG processing

EEG data were processed in Matlab using EEGLAB. Specifically, a high-pass filter at 1 Hz and a notch filter at 60 Hz were applied. Excessively noisy electrodes were removed and interpolated, and the EEG data were then rereferenced to the average. The continuous EEG was divided into 1 s epochs with 50% overlap. Epochs were rejected if the absolute voltage of any electrode exceeded 100 μV for more than 100 ms. Time-frequency decomposition was performed on the remaining epochs using fast Fourier transformation with a 1 s Hanning window for 3–50 Hz. The independent component analysis was then utilized to remove large, nonstereotyped artifacts produced by infant movement and external sources of interference (Onton et al., 2006).

Frontal power was calculated in alpha (6–9 Hz), consistent with prior research (Degnan et al., 2011), and subsequently, natural log-transformed. F3 and F4 were used to calculate asymmetry scores: subtracting the natural log of alpha power on the left (F3) from the natural log of alpha power on the right (F4) as previously described (Fox et al., 2001; Reznik & Allen, 2018). Lower levels of alpha reflect cortical activation (Barry et al., 2007). Thus, lower asymmetry scores reflect right lateralization, and higher scores signal left lateralization (Hane & Fox, 2006).

2.3 | Analytic strategy

Exploratory factor analysis (principal axis extraction) was conducted for the purpose of data reduction; specifically, to develop the infant behavior composites, using the eight coded behaviors (i.e., hand waving, kicking feet, looking to mother, banging on the table, playing with cups, hand/object to mouth, vocalizations, and distress).

Behaviors with a factor loading of above |.5| were retained as strongly defining the relevant factor; behaviors with cross-loadings greater than |.3| were discarded to promote simple/interpretable structure. In determining the number of factors, we considered Kaiser's criterion of an initial eigenvalue greater than one, the inflection point of the scree plot, and the extent to which a greater number of factors reflected meaningful conceptual distinctions among infant behaviors.

Simple correlations between infant behavior factors, EEG asymmetry measured at baseline and the second SFP episode, and IBQ-R NA scales: fear, distress to limitations, sadness, and falling reactivity were computed. Hierarchical multiple regression analyses were then performed to identify unique contributions of EEG asymmetry and NA scales. Only indicators with significantly bivariate correlations were included in the regression analyses to reduce the number of predictors and analyses. Infant behavior, considered as the dependent variable, was regressed on infant sex and age to control for their contributions, with baseline asymmetry included as a covariate in the model addressing the SFP asymmetry as a predictor.

TABLE 1 Descriptive statistics

Variable	*Mean*	*SD*	Range
Asymmetry scores			
Asymmetry change from baseline to SFP	.07	.52	−.76–1.44
Infant temperament factors			
Distress to limitations	−.0008	.85	−1.91–1.98
Fear	−.002	.88	−1.46–2.17
Sadness	.005	.91	−1.67–1.90
Falling reactivity	.002	.78	−1.98–1.46
Infant self-soothing behaviors			
Hand waving	1.34	2.33	0.0–10.0
Kicking feet	1.40	2.58	0.0–10.0
Looking to mother	3.92	3.35	0.0–12.0
Banging on the table	2.61	2.64	0.0–10.0
Playing with cups	7.50	3.98	0.0–12.0
Hand/object to mouth	2.92	3.20	0.0–12.0
Vocalizations	5.00	3.25	0.0–12.0
Distress	2.42	3.52	0.0–12.0

Note. SD, standard deviation.

3 | RESULTS

Descriptive statistics and correlations coefficients for all variables included in the study were computed first and presented in Tables 1 and 2.

TABLE 2 Correlation coefficients: covariates, independent, and dependent variables included in the study

	1	2	3	4	5	6	7	8	9	10	11
1. Sex	–	.01	.03	–.04	.45**	–.24	–.21	.23	–.02	–.03	–.004
2. Age	.01	–	.27*	.11	–.14	.09	.19	.09	–.12	–.13	–.19
3. Baseline asymmetry	.03	.27*	–	.16	–.02	.01	–.09	–.04	–.16	.002	.06
4. SF2 asymmetry	–.04	.11	.16	–	–.21	–.18	.14	–.19	–.04	–.05	.28*
5. Distress to limitations	.45**	.14	–.02	–.21	–	.23	–.41**	.64**	–.12	–.11	–.28*
6. Fear	–.24	.09	.01	–.18	.23	–	–.09	.32*	–.17	.20	–.01
7. Falling reactivity	–.21	.19	–.09	.14	–.41**	–.09	–	–.33**	.05	.06	.29*
8. Sadness	.23	.09	–.04	–.19	.64**	.32*	–.33**	–	.04	.19	–.04
9. Ineffective regulation	–.02	–.12	–.16	–.04	–.12	–.17	.05	.04	–	.23	.12
10. Regulatory motor activity	–.03	–.13	.002	–.05	–.11	.20	.06	.19	.23	–	–.01
11. Social engagement behaviors	–.004	–.19	.06	.28*	–.28*	–.01	.29*	–.04	.12	–.01	–

Note. Infant sex was coded as 1, girls; 2, boys; age was coded in months.
*$p < .05$.
**$p < .01$.

TABLE 3 Correlations between Factor 3, baseline and SFP asymmetry scores, and IBQ-R NA scales

Predictor	Factor 3 (*r*)	*p*
Baseline asymmetry	.063	.629
SF2 asymmetry	**.277***	**.029***
Distress limit	**–.278***	**.046***
Fear	–.008	.957
Sadness	–.043	.760
Falling reactivity	**.286***	**.040***

*$p < .05$.

3.1 | Exploratory factor analysis

A three-factor solution emerged from an exploratory factor analysis of eight infant behaviors, utilizing principal axis extraction with Oblimin rotation. The three factors obtained included: *ineffective regulation*—looking to mother, distress, playing with cups (negatively loading); *regulatory motor activity*—kicking feet, hand/object to mouth; *social engagement behaviors*—vocalizations and handwaving (average factor loading = .56). Banging on table did not reliably load onto any of the three factors.

3.2 | Bivariate correlations

Three infant behavior factors were correlated with asymmetry indicators measured at baseline and the second SFP episode, and the IBQ-R NA scales: fear, distress to limitations, sadness, and falling reactivity (negatively loading). Significant correlations were observed for social engagement behaviors, the SFP asymmetry score, IBQ-R distress to limitations, and falling reactivity (Table 3) in the predicted direction. Greater observed regulatory social engagement was associated with relative left frontal activation, higher falling reactivity, and lower distress to limitations.

3.3 | Linear regression models

Hierarchical multiple regression analyses predicting social engagement behaviors were conducted separately for EEG and IBQ-R indicators, controlling for infant sex and age, and baseline asymmetry for the former. The SFP asymmetry was predictive of social engagement behaviors after controlling for covariates (Table 4A), whereas NA scales were not associated with significant effects, accounting for overlapping variance (Table 4B).

4 | DISCUSSION

The present study examined infant NA and frontal EEG asymmetry as contributors to emerging social engagement and regulatory behaviors. Infant behaviors during the SFP included the following: hand waving, kicking feet, looking to mother, banging on the table, playing with cups, hand/object to mouth, vocalizations and distress, and a three-factor structure emerged.

The first factor was labeled ineffective regulation, with a positive loading for the distress score and a negative one for playing with cups. Of interest, looking at the mother positively loaded onto this factor, indicating more extensive looking was consistent with higher levels of distress/dysregulation. It is possible that gazing towards the mother maintained infant distress, as the mother was instructed to ignore the infant during the task, which potentially signaled atypical unavailability. Regulatory motor activity consisted of kicking feet and hand-to-mouth behaviors and is reflective of more dynamic and motor-related regulation behaviors. Banging on the table did not significantly load onto an emotion regulation-related factor. While infant banging facilitates the

TABLE 4A Results from hierarchical regression analyses with EEG asymmetry predicting factor 3

Step 1	Model statistics			
	R^2	F	p	
	0.035	1.072	.349	
Predictors	Predictor statistics			
	β/b	SE	t	p
Sex	.000/.004	1.091	.003	.997
Age	−.187/−.447	.305	−1.464	.149
Step 2	Model statistics			
	$R^2\Delta$	$F\Delta$	p	
	0.15	.905	.346	
Predictors	Predictor statistics			
	β/b	SE	t	p
Sex	−.001/−.005	1.092	−.004	.997
Age	−.224/−.534	0.319	−1.675	.099
Baseline asym.	.127/1.311	1.378	.951	.346
Step 3	Model statistics			
	$R^2\Delta$	$F\Delta$	p	
	0.132	5.415	**.024***	
Predictors	Predictor statistics			
	β/b	SE	t	p
Sex	.027/.299	1.058	.216	.830
Age	−.245/−.584	.308	−1.895	.063
Baseline asym.	.091/.938	1.338	.701	.486
SF2 asym.	.292/3.312	1.423	2.327	**.024***

*$p < .05$.

TABLE 4B Results from hierarchical regression analyses with IBQ-R NA Significant predictors predicting Factor 3

Step 1	Model statistics			
	R^2	F	p	
	.033	.832	.441	
Predictors	Predictor statistics			
	β/b	SE	t	p
Sex	−.105/−.874	1.174	−.745	.460
Age	−.134/−.331	.349	−.948	.348
Step 2	Model statistics			
	$R^2\Delta$	$F\Delta$	p	
	.135	2.782	.072	
Predictors	Predictor statistics			
	β/b	SE	t	p
Sex	.013/.104	1.261	.083	.934
Age	−.137/−.338	.349	−.968	.338
Distress limit.	−.169/−.823	.799	−1.029	.309
Fall. react.	.243/1.303	.791	1.648	.106

development of tool use (Kahrs et al., 2013), it may be that this strategy is less effective as a social engagement or emotion regulating strategy, or for re-engaging the parent in interaction.

Infant vocalizations and handwaving clustered together to form the final factor of infant social engagement in the service of regulation: social engagement behaviors. Infant vocalizations are critical signals serving to elicit responses from nearby adults (Warlaumont et al., 2010), contributing to language acquisition (Goldstein et al., 2009; Margolis et al., 2019), social interactions, and emotional development (e.g., Filippa & Kuhn, 2017; Fogel & Garvey, 2007; Hsu & Fogel, 2003). Importantly, these signals likely engage adults in co-regulation, diminishing infant distress. Handwaving may also elicit responses from caregivers to reduce distress (Adolph & Franchak, 2017). These specific behaviors were significantly associated with frontal EEG asymmetry and distress-related temperament dimensions. As hypothesized, infants scoring lower on NA scales and demonstrating greater left frontal activation exhibited more frequent vocalizations and handwaving behaviors.

Components of infant NA are important to consider as predictors of early emotion regulation, including self-soothing and social engagement (MacNeill & Pérez-Edgar, 2020). Falling reactivity refers to an infant's rate of recovery from peak distress and is associated with self-soothing. This subscale was positively correlated with social engagement behaviors (i.e., infants high in Falling Reactivity utilized vocalizations and hand waving more frequently). Still, the effect was not significant when considered jointly with Distress to Limitations and infant age and sex. However, Geangu and colleagues (2011) found that 3-month-old infants who were higher in falling reactivity demonstrated better regulation of peak emotional reactions. Specifically, these infants exhibited less vocal distress, a longer delay of onset of distress, and less expressed sadness in response to crying from another infant (Geangu et al., 2011). Furthermore, higher levels of falling reactivity predicted more advanced emotion regulation skills when assessed 2 years later among 3–7-year olds (Domínguez-Álvarez et al., 2020). Thus, falling reactivity should be studied further, although our results suggest its regulation-related contribution overlaps with distress to limitations, another NA dimension.

Distress to limitations (anger/frustration) is described as negative affect related to blocked goals or the interruption of a task (Gartstein & Rothbart, 2003). This temperament domain is related to deficits in regulation and increased aggression in infancy and later childhood (Vertsberger & Knafo-Noam, 2019). As hypothesized, distress to limitations was negatively correlated with regulatory social engagement behaviors. Infants lower in frustration demonstrated a higher frequency of vocalizations and hand waving, although this effect was not significant when accounting for falling reactivity and covariates. Greater distress to limitations at 6-months was positively associated with negative vocalizations (e.g., fussing, crying, screaming while upset or angry) during an arm restraint task (Sullivan et al., 2015). This temperament subscale may be a stronger independent predictor of vocalizations signaling distress than social engagement behaviors. Despite emerging research, this aspect of NA has often been overlooked (Lorber et al., 2014) and deserves further attention.

Frontal EEG power asymmetry provides a snapshot of the neuronal activation that underlies expressions of approach and avoidance neurobehavioral systems, as well as their coregulation (Fox, 1994; Gartstein et al., 2020). A pattern of relative left frontal EEG dominance has been viewed as most adaptive and associated with emotion regulation across the lifespan (for review Reznik & Allen, 2018), although extreme left dominance results in risk for externalizing symptoms (Davis & Suveg, 2014; Degnan et al., 2011; Smith & Bell, 2010). Consistent with hypotheses, relative left frontal activation during the second SFP trial predicted emerging social engagement as regulation controlling for age and sex. Specifically, greater left frontal activation was associated with social engagement behaviors (i.e., more frequent vocalization and hand waving).

The association between left frontal activation and vocalizations and hand waving is consistent with the literature on communication and social engagement. Greater left frontal asymmetry may be a physiological marker of an infant's behavioral and social approach tendencies to support regulation. Relatively higher infant (14 months old) left frontal activation while watching a 3-min bubble recording predicted child involvement (i.e., initiating interaction with the mother) at 50 months of age (Licata et al., 2015). Additionally, infant left frontal activation predicted regulatory behaviors during a mild stressor (arm restraint procedure) in the context of higher maternal sensitivity (Swingler et al., 2014). Overall, left frontal EEG activation is linked with self-regulation development (Allen et al., 2018; Davidson & Fox, 1989). Additionally, our findings further support the use of the capability model of alpha asymmetry and suggest frontal EEG activation is particularly salient in the context of a socially stressful and regulation-challenging task. This work highlights how individual differences in frontal EEG asymmetry are associated with interactions between social situations and emotion-regulating abilities (Coan et al., 2006; Reznik & Allen, 2018). Assessing frontal asymmetry in response to social challenges can elucidate emerging regulation, leading to a better understanding of its neurophysiological underpinnings.

Understanding the connection between EEG frontal asymmetry, temperament, and infant regulatory behaviors in early life has implications for developmental psychopathology and intervention. Relative right frontal activation, associated with emotion dysregulation, predicted future depression in a community sample of adolescents (Mitchell & Pössel, 2012; Pössel et al., 2008). Furthermore, right frontal asymmetry at four years-of-age predicted reduced emotion regulation at 9, specifically, a greater physiological response to a stressful performance task (Allen et al., 2018; Hannesdóttir et al., 2010; Nusslock et al., 2015). Associations between infant frontal asymmetry and behaviors suggest that EEG may be an early marker of risk for emotional dysregulation, social deficits, and related impairment.

This study has several limitations, as our homogeneous middle-class sample limits the generalizability of the results. Furthermore, this work's scope was somewhat limited due to its cross-sectional nature and because only one temperament domain was considered. Additionally, neurodevelopmental disorders (e.g., autism spectrum and attention deficit hyperactivity disorders) are associated with emotion regulation and social engagement deficits (Samson et al., 2015; Seymour et al., 2019); however, at-risk children were not included in the current study. The origins of regulation in infancy are initially externally driven (i.e., fostered by parents), yet parent–child interactions were not addressed in the current investigation. Additionally, observations in a laboratory setting may not reflect stable regulation strategies that should be measured in more naturalistic situations (e.g., home, public spaces, etc.; Goossens & Melhuish, 1996). The structural coherence of distress, looking to mother, and not playing with cups is suggestive of inefficient regulation, as evidenced by the distress code joining this constellation. However, the factor analytic findings do not shed light on cooccurrence of these behaviors in real time, which should in future investigations.

Future research should recruit larger and more diverse samples to enable greater generalizability. Other dimensions of infant temperament and parent–child interaction dynamics should also be considered as contributors to emerging regulation and social engagement. Infant behaviors should be assessed in the home as well as in the laboratory. By utilizing longitudinal data, future work could employ growth curve analyses, and the change in infant behaviors could be considered as a predictor of later outcomes. Additionally, infants at risk for neurodevelopmental disorders (e.g., siblings of those diagnosed) should be included in emotion regulation and social engagement research. Finally, person-centered approaches, such as latent profile analysis (LPA) should be considered in future studies with larger samples of infants. LPA would allow infants to be classified into meaningful groups based on their patterns of temperament, frontal EEG asymmetry, and behavior across the SFP task, for example, determining whether or not components of the ineffective regulation factor help to differentiate a type of infant struggling with regulation.

Understanding how EEG asymmetry and temperament factors influence emotion regulation has direct applications. Targeted parent-oriented interventions could be designed to facilitate emerging child self-regulation, in particular, social engagement skills. For example, individualized parental guidance programs could promote emerging regulation skills among at-risk infants, encouraging use of cues that serve to engage adults. Similar to existing interventions (for review, see Iverson & Gartstein, 2018), services could target parents of infants with greater right frontal EEG activation and support caregiver efforts to foster communication and regulatory strategies. Future research addressing infant temperament, neural activity, and behavior can further inform such efforts, promoting a healthy socioemotional development.

ACKNOWLEDGMENTS

We would like to thank the families that participated in this study and the research assistants who made invaluable contributions to this work, including Jonathan Bayley, Kaitlyn Campbell, and Joshua Underwood.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are available on request from the authors.

ORCID

Allegra X. Campagna https://orcid.org/0000-0002-9079-008X
Christie N. Pham https://orcid.org/0000-0002-7729-1788

REFERENCES

Adamson, L. B., & Frick, J. E. (2003). The still face: A history of a shared experimental paradigm. *Infancy*, *4*(4), 451–473. https://doi.org/10.1207/S15327078IN0404_01

Adolph, K. E., & Franchak, J. M. (2017). The development of motor behavior. *Wiley Interdisciplinary Reviews: Cognitive Science*, *8*(1–2), 1–30. https://doi.org/10.1002/wcs.1430

Allen, J. J. B., Keune, P. M., Schönenberg, M., & Nusslock, R. (2018). Frontal EEG alpha asymmetry and emotion: From neural underpinnings and methodological considerations to psychopathology and social cognition. *Psychophysiology*, *55*(1), 1–6. https://doi.org/10.1111/psyp.13028

Barbosa, M., Beeghly, M., Gonçalves, J. L., Moreira, J., Tronick, E., & Fuertes, M. (2019). Predicting patterns of regulatory behavior in the Still-Face Paradigm at 3 months. *Infancy*, *24*(4), 501–525. https://doi.org/10.1111/infa.12293

Barry, R. J., Clarke, A. R., Johnstone, S. J., Magee, C. A., & Rushby, J. A. (2007). EEG differences between eyes-closed and eyes-open resting conditions. *Clinical Neurophysiology*, *118*(12), 2765–2773. https://doi.org/10.1016/j.clinph.2007.07.028

Bell, M. A. (2001). Brain electrical activity associated with cognitive processing during a looking version of the A-Not-B Task. *Infancy*, *2*(3), 311–330. https://doi.org/10.1207/S15327078IN0203_2

Blankson, A. N., Weaver, J. M., Leerkes, E. M., O'Brien, M., Calkins, S. D., & Marcovitch, S. (2017). Cognitive and emotional processes as predictors of a successful transition into school A. *Early Education Development*, *28*(1), 1–20. https://doi.org/10.1080/10409289.2016.1183434. Cognitive

Bosquet Enlow, M., Kitts, R. L., Blood, E., Bizarro, A., Hofmeister, M., & Wright, R. J. (2011). Maternal posttraumatic stress symptoms and infant emotional reactivity and emotion regulation. *Infant Behavior and Development*. https://doi.org/10.1016/j.infbeh.2011.07.007

Braungart-Rieker, J., Garwood, M. M., Powers, B. P., & Notaro, P. C. (1998). Infant affect and affect regulation during the still-face paradigm with mothers and fathers: The role of infant characteristics and parental sensitivity. *Developmental Psychology*, *34*(6), 1428–1437. https://doi.org/10.1037/0012-1649.34.6.1428

Braungart-rieker, J. M., & Stifter, C. A. (1994). Infants' responses to frustrating situations: Continuity and change in reactivity and regulation. *Child Development*, *65*(5), 1767–1779.

Calkins, S. D. (1998). Toddler regulation of distress to frustrating events: Temperamental and maternal correlates. *Infant Behavior and Development*, *21*(3), 379–395. https://doi.org/10.1016/S0163-6383(98)90015-7

Calkins, S. D., Dedmon, S. E., Gill, K. L., Lomax, L. E., & Johnson, L. M. (2002). Frustration in infancy: Implications for emotion regulation, physiological processes, and temperament. *Infancy*, *3*(2), 175–197.

Coan, J. A., Allen, J. J. B., & McKnight, P. E. (2006). A capability model of individual differences in frontal EEG asymmetry. *Biological Psychology*, *72*(2), 198–207. https://doi.org/10.1016/j.biopsycho.2005.10.003

Cole, P. M., Ram, N., & English, M. S. (2019). Toward a unifying model of self-regulation: A developmental approach. *Child Development Perspectives*, *13*(2), 91–96. https://doi.org/10.1111/cdep.12316

Crespo-Llado, M. M., Vanderwert, R., Roberti, E., & Geangu, E. (2018). Eight-month-old infants' behavioral responses to peers' emotions as related to the asymmetric frontal cortex activity. *Scientific Reports*, *8*(1), 1–11. https://doi.org/10.1038/s41598-018-35219-4

Davidson, R. J., & Fox, N. A. (1989). Frontal brain asymmetry predicts infants' response to maternal separation. *Journal of Abnormal Psychology*, *98*(2), 127–131. https://doi.org/10.1037/0021-843X.98.2.127

Davis, M., & Suveg, C. (2014). Focusing on the positive: A review of the role of child positive affect in developmental psychopathology. *Clinical Child and Family Psychology Review*, *17*(2), 97–124. https://doi.org/10.1007/s10567-013-0162-y

Degnan, K. A., Calkins, S. D., Keane, S. P., Hill-soderlund, A. L., Development, S. C., Oct, N. S., & Calkins, D. (2014). Profiles of disruptive behavior across early childhood: Contributions of frustration of profiles of disruptive behavior across early childhood: Contributions and maternal behavior frustration reactivity. *Physiological Regulation*, *79*(5), 1357–1376.

Degnan, K. A., Hane, A. A., Henderson, H. A., Moas, O. L., Reeb-Sutherland, B. C., & Fox, N. A. (2011). Longitudinal stability of temperamental exuberance and social- emotional outcomes in early childhood. *Developmental Psychology*, *47*(3), 765–780. file:///Users/mayyungtiet/Documents/My work/PhD/Projects/Otherprojects/Leightreatabolome/Reviewpapers/ReviewreferencesMT/Gempel2007ETFGDH.pdf

Derryberry, D., & Rothbart, M. K. (1997). Reactive and effortful processes in the organization of temperament. *Development and Psychopathology*, *9*(4), 633–652. https://doi.org/10.1017/s0954579497001375

Domínguez-Álvarez, B., López-Romero, L., Gómez-Fraguela, J. A., & Romero, E. (2020). Emotion regulation skills in children during the COVID-19 pandemic: Influences on specific parenting and child adjustment. *Revista de Psicología Clínica Con Niños y Adolescentes*, *7*(3), 81–87. https://doi.org/10.21134/rpcna.2020.mon.2042

Feldman, R., & Eidelman, A. I. (2007). Maternal postpartum behavior and the emergence of infant-mother and infant-father synchrony in preterm and full-term infants: The role of neonatal vagal tone. *Developmental Psychobiology*, *49*(3), 290–302. https://doi.org/10.1002/dev.20220

Feldman, R., & Eidelman, A. I. (2009). Biological and environmental initial conditions shape the trajectories of cognitive and social-emotional development across the first years of life. *Developmental Science*, *12*(1), 194–200. https://doi.org/10.1111/j.1467-7687.2008.00761.x

Feldman, R., Granat, A., Pariente, C., Kanety, H., Kuint, J., & Gilboa-Schechtman, E. (2009). Maternal depression and anxiety across the postpartum year and infant social engagement, fear regulation, and stress reactivity. *Journal of the American Academy of Child and Adolescent Psychiatry*, *48*(9), 919–927. https://doi.org/10.1097/CHI.0b013e3181b21651

Filippa, M., & Kuhn, P. (2017). Early vocal contact and preterm infant brain development. In *Early Vocal Contact and Preterm Infant Brain Development*. https://doi.org/10.1007/978-3-319-65077-7

Fogel, A. (1982). Early adult-infant interaction: Expectable sequences of behavior. *Journal of Pediatric Psychology*. https://doi.org/10.1093/jpepsy/7.1.1

Fogel, A., & Garvey, A. (2007). Alive communication. *Infant Behavior and Development*, *30*(2), 251–257. https://doi.org/10.1016/j.infbeh.2007.02.007

Fox, N. A. (1994). Dynamic Cerebral Processes Underlying Emotion Regulation. *Monographs of the Society for Research in Child Development*, *59*(2), 152–166.

Fox, N. A., Henderson, H. A., Rubin, K. H., Calkins, S. D., & Schmidt, L. A. (2001). Continuity and discontinuity of behavioral inhibition and exuberance: Psychophysiological and behavioral influences across the first four years of life. *Child Development*, *72*(1), 1–21. https://doi.org/10.1111/1467-8624.00262

Franklin, B., Warlaumont, A. S., Messinger, D., Lee, C., & Lambert, B. (2015). Effects of parental interaction on infant vocalization rate, variability and vocal type. *Language Learning and Development*, *10*(3), 1–24. https://doi.org/10.1080/15475441.2013.849176.Effects

Frick, M. A., Forslund, T., Fransson, M., Johansson, M., Bohlin, G., & Brocki, K. C. (2018). The role of sustained attention, maternal sensitivity, and infant temperament in the development of early self-regulation. *British Journal of Psychology*, *109*(2), 277–298. https://doi.org/10.1111/bjop.12266

Gartstein, M. A., Bridgett, D. J., Rothbart, M. K., Robertson, C., Iddins, E., Ramsay, K., & Schlect, S. (2010). A latent growth examination of fear development in infancy: Contributions of maternal depression and the risk for toddler anxiety. *Developmental Psychology*, *46*(3), 651–668. https://doi.org/10.1037/a0018898

Gartstein, M. A., Hancock, G. R., Potapova, N. V., Calkins, S. D., & Bell, M. A. (2020). Modeling development of frontal electroencephalogram (EEG) asymmetry: Sex differences and links with temperament. *Developmental Science*, *23*(1), 1–17. https://doi.org/10.1111/desc.12891

Gartstein, M. A., Knyazev, G. G., & Slobodskaya, H. R. (2005). Cross-cultural differences in the structure of infant temperament: United States of America (U.S.) and Russia. *Infant Behavior and Development*, *28*(1), 54–61. https://doi.org/10.1016/j.infbeh.2004.09.003

Gartstein, M. A., & Marmion, J. (2008). Fear and positive affectivity in infancy: Convergence/discrepancy between parent-report and laboratory-based indicators. *Infant Behavior and Development*, *31*(2), 227–238. https://doi.org/10.1016/j.infbeh.2007.10.012

Gartstein, M. A., Prokasky, A., Bell, M. A., Calkins, S., Bridgett, D. J., Braungart-Rieker, J., Leerkes, E., Cheatham, C. L., Eiden, R. D., Mize, K. D., Jones, N. A., Mireault, G., & Seamon, E. (2017). Latent profile and cluster analysis of infant temperament: Comparisons across person-centered approaches. *Developmental Psychology*, *53*(10), 1811–1825. https://doi.org/10.1037/dev0000382

Gartstein, M. A., & Rothbart, M. K. (2003). Studying infant temperament via the Revised Infant Behavior Questionnaire. *Infant Behavior and Development*, *26*(1), 64–86. https://doi.org/10.1016/S0163-6383(02)00169-8

Gartstein, M. A., Slobodskaya, H. R., & Kinsht, I. A. (2003). Cross-cultural differences in temperament in the first year of life: United States of America (US) and Russia. *International Journal of Behavioral Development*, *27*(4), 316–328. https://doi.org/10.1080/01650250244000344

Geangu, E., Benga, O., Stahl, D., & Striano, T. (2011). Individual differences in infants' emotional resonance to a peer in distress: Self-ther awareness and emotion regulation. *Social Development*, *20*(3), 450–470. https://doi.org/10.1111/j.1467-9507.2010.00596.x

Goldstein, M. H., Shwade, J. A., & Bornstein, M. H. (2009). The value of vocalizing: Five-month-old infants associate their own noncry vocalizations with responses from caregivers. *Child Development*, *80*(3), 636–644. https://doi.org/10.1111/j.1467-8624.2009.01287.x.The

Goossens, F., & Melhuish, E. C. (1996). On the ecological validity of measuring the sensitivity of professional caregivers: The laboratory versus the nursery. *European Journal of Psychology of Education*, *11*(2), 169–176. https://doi.org/10.1007/BF03172722

Graham, K. A., Blissett, J., Antoniou, E. E., Zeegers, M. P., & McCleery, J. P. (2018). Effects of maternal depression in the Still-Face Paradigm: A meta-analysis. *Infant Behavior and Development*, *50*(December 2017), 154–164. https://doi.org/10.1016/j.infbeh.2017.12.001

Gross, J. J., & Jazaieri, H. (2014). Emotion, emotion regulation, and psychopathology: An affective science perspective. *Clinical Psychological Science*, *2*(4), 387–401. https://doi.org/10.1177/2167702614536164

Haley, D. W., & Stansbury, K. (2003). Infant stress and parent responsiveness: Regulation of physiology and behavior during still-face and reunion. *Child Development*, *74*(5), 1534–1546. https://doi.org/10.1111/1467-8624.00621

Hallgren, K. A. (2012). Computing inter-rater reliability for observational data: An overview and tutorial. *Tutorials in Quantitative Methods for Psychology*, *8*(1), 23–34.

Halligan, S. L., Cooper, P. J., Fearon, P., Wheeler, S. L., Crosby, M., & Murray, L. (2013). The longitudinal development of emotion regulation capacities in children at risk for externalizing disorders. *Development and Psychopathology*, *25*(2), 391–406. https://doi.org/10.1017/S0954579412001137

Hane, A. A., & Fox, N. A. (2006). Ordinary variations in maternal caregiving influence human infants' stress reactivity. *Psychological Science*, *17*(6), 550–556. https://doi.org/10.1111/j.1467-9280.2006.01742.x

Hannesdóttir, D. K., Doxie, J., Bell, M. A., Ollendick, T. H., & Wolfe, C. D. (2010). A longitudinal study of emotion regulation and anxiety in middle childhood: Associations with frontal EEG asymmetry in early childhood. *Developmental Psychobiology*, *52*(2), 197–204. https://doi.org/10.1002/dev.20425

Harrington, E. M., Trevino, S. D., Lopez, S., & Giuliani, N. R. (2020). Emotion regulation in early childhood: Implications for socioemotional and academic components of school readiness. *Emotion (Washington, D.C.)*, *20*(1), 48–53. https://doi.org/10.1037/emo0000667

Hornik, R., & Gunnar, M. R. (1988). A descriptive analysis of infant social referencing. *Child Development*, *59*(3), 626–634. URL : http://www.jstor.org/stable/1130562 REFERENCES Linked reference.

Hsu, H. C., & Fogel, A. (2003). Stability and transitions in mother-infant face-to-face communication during the first 6 months: A microhistorical approach. *Developmental Psychology*, *39*(6), 1061–1082. https://doi.org/10.1037/0012-1649.39.6.1061

Iverson, S. L., & Gartstein, M. A. (2018). Applications of temperament: A review of caregiver-focused temperament-driven interventions. *Early Education and Development*, *29*(1), 31–52. https://doi.org/10.1080/10409289.2017.1341805

Kahrs, B. A., Jung, W. P., & Lockman, J. J. (2013). Motor origins of tool use. *Child Development*, *84*(3), 810–816. https://doi.org/10.1111/cdev.12000

Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology*, *36*(2), 220–232. https://doi.org/10.1037/0012-1649.36.2.220

Kogan, N., & Carter, A. S. (1996). Mother-infant reengagement following the still-face: The role of maternal emotional availability an infant affect regulation. *Infant Behavior and Development*, *19*(3), 359–370. https://doi.org/10.1016/S0163-6383(96)90034-X

Kopp, C. B. (1989). Regulation of distress and negative emotions: A developmental view. *Developmental Psychology*, *25*(3), 343–354. https://doi.org/10.1037/0012-1649.25.3.343

Kozlova, E. A., Slobodskaya, H. R., & Gartstein, M. A. (2019). Early temperament as a predictor of child mental health. *International Journal of Mental Health and Addiction*, *18*, 1493–1506. https://doi.org/10.1007/s11469-019-00181-3

Lengua, L. J. (2006). Growth in temperament and parenting as predictors of adjustment during children's transition to adolescence. *Developmental psychology*, *42*(5), 819.

Licata, M., Paulus, M., Kühn-Popp, N., Meinhardt, J., & Sodian, B. (2015). Infant frontal asymmetry predicts child emotional availability. *International Journal of Behavioral Development*, *39*(6), 492–496. https://doi.org/10.1177/0165025415576816

Lipscomb, S., Haimson, J., Liu, A. Y., Burghardt, J., Johnson, D. R., & Thurlow, M. (2017). Preparing for life after high school: The characteristics and experiences of youth in special education. Findings from the National Longitudinal Transition Study 2012. Volume 2: Comparisons across Disability Groups. Executive Summary. NCEE 2017–4019. *National Center for Education Evaluation and Regional Assistance*, *1*(March), 1–36. https://search.proquest.com/docview/1895981586?accountid=12269%0Ahttp://resolver.ebscohost.com/openurl?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rfr_id=info:sid/ProQ%3Aeric&rft_val_fmt=info:ofi/fmt:kev:mtx:book&rft.genre=report&rft.jtitle=&rft.atitle

Liu, R., & Bell, M. A. (2020). Fearful temperament and the risk for child and adolescent anxiety: The role of attention biases and effortful control. *Clinical Child and Family Psychology Review*, *23*(2), 205–228. https://doi.org/10.1007/s10567-019-00306-z

Lorber, M. F., Del Vecchio, T., & Slep, A. M. S. (2014). Infant externalizing behavior as a self-organizing construct. *Developmental Psychology*, *50*(7), 1854–1861. https://doi.org/10.1037/a0036985

MacNeill, L. A., & Pérez-Edgar, K. (2020). Temperament and emotion. *The Encyclopedia of Child and Adolescent Development*, 1–12. https://doi.org/10.1002/9781119171492.wecad180

Margolis, A. E., Lee, S. H., Peterson, B. S., & Beebe, B. (2019). Profiles of infant communicative behavior. *Developmental Psychology*, *55*(8), 1594–1604. https://doi.org/10.1037/dev0000745

Mesman, J., van IJzendoorn, M. H., & Bakermans-Kranenburg, M. J. (2009). The many faces of the Still-Face Paradigm: A review and meta-analysis. *Developmental Review*, *29*(2), 120–162. https://doi.org/10.1016/j.dr.2009.02.001

Mitchell, A. M., & Pössel, P. (2012). Frontal brain activity pattern predicts depression in adolescent boys. *Biological Psychology*, *89*(2), 525–527. https://doi.org/10.1016/j.biopsycho.2011.12.008

Morasch, K. C., & Bell, M. A. (2011). The role of inhibitory control in behavioral and physiological expressions of toddler executive function. *Journal of Experimental Child Psychology*, *108*(3), 593–606. https://doi.org/10.1016/j.jecp.2010.07.003

Nigg, J. T. (2006). Temperament and developmental psychopathology. *Journal of Child Psychology and Psychiatry*, *47*(3-4), 395–422.

Nusslock, R., Walden, K., & Harmon-Jones, E. (2015). Asymmetrical frontal cortical activity associated with differential risk for mood and anxiety disorder symptoms: An RDoC perspective. *International Journal of Psychophysiology*, *98*(2), 249–261. https://doi.org/10.1016/j.ijpsycho.2015.06.004

Oldehinkel, A. J., Hartman, C. A., De Winter, A. F., Veenstra, R., & Ormel, J. (2004). Temperament profiles associated with internalizing and externalizing problems in preadolescence. *Development and Psychopathology*, *16*(2), 421–440.

Onton, J., Westerfield, M., Townsend, J., & Makeig, S. (2006). Imaging human EEG dynamics using independent component analysis. *Neuroscience and Biobehavioral Reviews*, *30*(6), 808–822. https://doi.org/10.1016/j.neubiorev.2006.06.007

Page, M. M., Wilhelm, M. S., Gamble, W. C., & Card, N. A. (2010). A comparison of maternal sensitivity and verbal stimulation as unique predictors of infant social-emotional and cognitive development. *Infant Behavior and Development*, *33*(1), 101–110. https://doi.org/10.1016/j.infbeh.2009.12.001

Parade, S. H., & Leerkes, E. M. (2008). The reliability and validity of the Infant Behavior Questionnaire-Revised. *Infant Behavior and Development*, *31*(4), 637–646. https://doi.org/10.1016/j.infbeh.2008.07.009

Penela, E. C., Walker, O. L., Degnan, K. A., Fox, N. A., & Henderson, H. A. (2015). Early behavioral inhibition and emotion regulation: Pathways toward social competence in middle childhood. *Child Development*, *86*(4), 1227–1240. https://doi.org/10.1111/cdev.12384.Early

Perry, N. B., Swingler, M. M., Calkins, S. D., & Bell, M. A. (2016). Neurophysiological correlates of attention behavior in early infancy: Implications for emotion regulation during early childhood. *Journal of Experimental Child Psychology*, *142*, 245–261. https://doi.org/10.1016/j.jecp.2015.08.007

Posner, M. I., Rothbart, M. K., Sheese, B. E., & Voelker, P. (2012). Control networks and neuromodulators of early development. *Developmental Psychology*, *48*(3). https://doi.org/10.1037/a0025530

Pössel, P., Lo, H., Fritz, A., & Seemann, S. (2008). A longitudinal study of cortical EEG activity in adolescents. *Biological Psychology*, *78*(2), 173–178. https://doi.org/10.1016/j.biopsycho.2008.02.004

Reznik, S. J., & Allen, J. J. B. (2018). Frontal asymmetry as a mediator and moderator of emotion: An updated review. *Psychophysiology*, *55*(1). https://doi.org/10.1111/psyp.12965

Rothbart, M., & Derryberry, D. (1981). Development of individual differences in temperament. *Advances in Developmental Psychology*, *1*, 37–86.

Samson, A. C., Hardan, A. Y., Podell, R. W., Phillips, J. M., & Gross, J. J. (2015). Emotion regulation in children and adolescents with autism spectrum disorder. *Autism Research*, *8*(1), 9–18. https://doi.org/10.1002/aur.1387

Seymour, K. E., Macatee, R., & Chronis-Tuscano, A. (2019). Frustration tolerance in youth with ADHD. *Journal of Attention Disorders*, *23*(11), 1229–1239. https://doi.org/10.1177/1087054716653216

Shapero, B. G., & Steinberg, L. (2013). Emotional reactivity and exposure to household stress in childhood predict psychological problems in adolescence. *Journal of Youth and Adolescence*, *42*(10), 1573–1582. https://doi.org/10.1007/s10964-013-9954-0

Smith, C. L., & Bell, M. A. (2010). Stability in infant frontal asymmetry as a predictor of toddlerhood internalizing and externalizing behaviors cynthia public access. *Developmental Psychobiology*, *52*(2), 158–167. https://doi.org/10.1002/dev.20427.Stability

St John, A. M., Kao, K., Choksi, M., Liederman, J., Grieve, P. G., & Tarullo, A. R. (2016). Variation in infant EEG power across social and nonsocial contexts. *Journal of Experimental Child Psychology*, *152*, 106–122. https://doi.org/10.1016/j.jecp.2016.04.007

Sullivan, E. L., Holton, K. F., Nousen, E. K., Barling, A. N., Sullivan, C. A., Propper, C. B., & Nigg, J. T. (2015). Early identification of ADHD risk via infant temperament and emotion regulation: A pilot study. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *56*(9), 949–957. https://doi.org/10.1111/jcpp.12426

Swingler, M. M., Perry, N. B., Calkins, S. D., & Bell, M. A. (2014). Maternal sensitivity and infant response to frustration: The moderating role of EEG asymmetry. *Infant Behavior and Development*, *37*(4), 523–535. https://doi.org/10.1016/j.infbeh.2014.06.010.Maternal

Symons, D. K., & Moran, G. (1987). The behavioral dynamics of mutual responsiveness in early face-to-face mother-infant interactions. *Child Development*, *58*(6), 1488–1495. URL: https://www.jsto.

Tarabulsy, G. M., Tessier, R., & Kappas, A. (1996). Contingency detection and the contingent organization of behavior in interactions: Implications for socioemotional development in infancy. *Psychological Bulletin*, *122*(1), 25–41. https://doi.org/10.1037//0033-2909.120.1.25

Terranova, A. M., Morris, A. S., Myers, S., Kithakye, M., & Morris, M. D. S. (2015). Preschool children's adjustment following a hurricane: Risk and resilience in the face of adversity. *Early Education and Development*, *26*(4), 534–548. https://doi.org/10.1080/10409289.2015.994463

Thomas, J. C., Letourneau, N., Campbell, T. S., Tomfohr-Madsen, L., Giesbrecht, G. F., Kaplan, B. J., Field, C. J., Dewey, D., Bell, R. C., Bernier, F. P., Cantell, M., Casey, L. M., Eliasziw, M., Farmer, A., Gagnon, L., Goonewardene, L., Johnston, D. W., Kooistra, L., Manca, D. P., … Singhal, N. (2017). Developmental origins of infant emotion regulation: Mediation by temperamental negativity and moderation by maternal sensitivity. *Developmental Psychology*. https://doi.org/10.1037/dev0000279

Toda, S., & Fogel, A. (1993). Infant response to the Still-Face Situation at 3 and 6 Months. *Developmental Psychology*, *29*(3), 532–538. https://doi.org/10.1037/0012-1649.29.3.532

Trofimova, I., & Sulis, W. (2018). There is more to mental illness than negative affect: Comprehensive temperament profiles in depression and generalized anxiety. *BMC Psychiatry*, *18*(1), 1–17. https://doi.org/10.1186/s12888-018-1695-x

Tronick, E., Als, H., Adamson, L., Wise, S., & Brazelton, T. B. (1978). The infant's response to entrapment between contradictory messages in Face-to-Face Interaction. *Journal of the American Academy of Child Psychiatry*, *17*(1), 1–13. https://doi.org/10.1016/S0002-7138(09)62273-1

Vertsberger, D., & Knafo-Noam, A. (2019). Mothers' and fathers' parenting and longitudinal associations with children's observed distress to limitations: From pregnancy to toddlerhood. *Developmental Psychology*, *55*(1), 123–134. https://doi.org/10.1037/dev0000622

Warlaumont, A. S., Oller, D. K., Dale, R., Richards, J. A., Gilkerson, J., & Xu, D. (2010). Vocal interaction dynamics of children with and without autism. *Proceedings of the 32nd Annual Conference of the Cognitive Science Society*, 121–126.

Wu, X., Guo, T., Tang, T., Shi, B., & Luo, J. (2017). Role of creativity in the effectiveness of cognitive reappraisal. *Frontiers in Psychology*, *8*(SEP), 1–9. https://doi.org/10.3389/fpsyg.2017.01598

Yaari, M., Mankuta, D., Harel-Gadassi, A., Friedlander, E., Bar-Oz, B., Eventov-Friedman, S., Maniv, N., Zucker, D., & Yirmiya, N. (2018). Early developmental trajectories of preterm infants. *Research in Developmental Disabilities*, *81*(November), 12–23. https://doi.org/10.1016/j.ridd.2017.10.018

Zimmer-Gembeck, M. J., & Skinner, E. A. (2016). The development of coping: Implications for psychopathology and resilience. *Developmental Psychopathology*, 1–61. https://doi.org/10.1002/9781119125556.devpsy410

How to cite this article: Campagna, A. X., Pham, C. N., & Gartstein, M. A. (2021). Understanding emerging regulation: The role of frontal electroencephalography asymmetry and negative affectivity. *Developmental Psychobiology*, *63*,e22198. https://doi.org/10.1002/dev.22198