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Infant Physiological Activity and the Early Emergence of Social Communication

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Abstract

Early in life, social engagement is facilitated by effective regulation during times of rest and stress. Physiological regulation during social play and in response to sudden environmental changes or social stressors may play an important role in sustaining social engagement in infancy and facilitate the acquisition of early social-communication skills. The aim of this study was to investigate the role of physiological activity during social play, including respiratory sinus arrhythmia (RSA) and heart rate-defined attention, in the early emergence of social-communication skills. Using RSA as an index of vagal tone, we measured vagal tone, vagal suppression, and heart rate-defined sustained attention during a social interaction with a caregiver (i.e., the Still-Face procedure) in 21 infants aged 3–4 months. At 9 months, caregivers reported on their infant's early social-communication skills. Results suggest that RSA, RSA suppression, and heart rate-defined sustained attention to a caregiver are significantly associated with early-emerging social-communication skills at 9 months. In addition, RSA and heart rate-defined sustained attention during social play were highly related. Suppression of RSA during the Still Face phase of the infant-caregiver interaction emerged as a particularly strong predictor of later-developing social-communication skills, including 9-month-olds' ability to use eye gaze, facial expression, and gestures to communicate.

Keywords

Social Communication; Respiratory Sinus Arrhythmia; Heart rate-defined Attention; Still Face

Introduction

Sustained, contingent interactions with the environment in early childhood are critical for the development of language and social competence. During infancy, social interactions are supported by sustained attention, effective physiological regulation, positive engagement behaviors (e.g., social smiling), social attunement, and maternal sensitivity (Calkins, Smith, Gill, & Johnson, 1998; Moore & Calkins, 2004; Pratt, Singer, Kanat-Maymon, & Feldman, 2015). Social engagement also requires adaptive responsivity to environmental stressors that facilitates regulatory behaviors and rapid recovery.

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Physiological reactivity to changes in the environment is a dynamic process characterized by flexible changes in heart rate and heart rate variability. Heart rate variability, frequently indexed by estimating respiratory sinus arrhythmia (RSA), is considered a measure of parasympathetic control. RSA occurs at the same frequency of spontaneous breathing and is a recognized measure of the dynamic influence of the myelinated vagus on the heart (Beauchaine, 2001; Porges, 1995). During non-stressful situations, the myelinated vagus exerts increased influence on cardiac activity, inhibiting sympathetic influence to the heart and slowing the heart rate (Porges, 2007). This results in a calm state, allowing restorative processes to occur in the absence of stressors. An increase in RSA and decrease in heart rate is also beneficial for engaging in social interactions. During demanding tasks, a decrease in RSA (i.e., vagal withdrawal), dampens the physiological stress response and inhibits arousal, allowing for effective self-soothing. In a well-functioning autonomic system, vagal tone flexibly increases and decreases to promote adaptive self-regulation and social interaction. The vagus nerve is also linked to muscular control of the face, head, and neck, suggesting that increased vagal tone may support social interaction and engagement behaviors, such as social orienting and facial expression (Porges & Furman, 2011). Thus, vagal tone influence can reveal functioning of the neurophysiological system during social engagement and in response to social stressors.

Physiological reactivity to socially stressful situations has been studied as an index of social adaptability. During infancy, this is often tested using the face-to-face-still-face procedure (Adamson & Frick, 2003; Tronick, Als, Adamson, Wise, & Brazelton, 1978). This experimental paradigm is a caregiver-infant interaction consisting of three phases: social interaction, caregiver withdrawal of social interaction accompanied with a neutral facial expression (“Still Face”), and a second social interaction that serves as a reunion. Although there are individual differences in the pattern of RSA change during this experimental procedure (Qu & Leerkes, 2018), there is a general consensus that infants exhibit a decrease in RSA from the Play to Still Face phase, followed by a return to baseline levels during the Reunion phase (Jones-Mason, Alkon, Coccia, & Bush, 2018; Moore et al., 2009). This pattern of reactivity is suggestive of a healthy, adaptive, neurophysiological system.

Baseline RSA and RSA reactivity has been linked to concurrent social engagement and communication. In preschool children, higher baseline RSA has been associated with increased frequency of social engagement behaviors (Heilman, Bal, Bazhenova, & Porges, 2007). Predictive relationships have also been identified linking RSA to later language skills (Whedon, Perry, Calkins, & Bell, 2018). These authors suggest that infants with higher RSA during social interaction may be more socially responsive, eliciting more language input and reciprocal interaction, leading to greater opportunities for language learning. Lower baseline RSA has also been associated with neurodevelopmental disorders characterized by differences in social interaction, e.g., autism spectrum disorder (Cheng, Huang, & Huang, 2020). Studies have identified significantly reduced RSA in children and adolescents with autism, as well as associations between RSA and social functioning (Cohen, Masyn, Mastergeorge, & Hessl, 2015; Patriquin, Lorenzi, Scarpa, & Bell, 2014; Van Hecke et al., 2009; Watson, Baranek, Roberts, David, & Perryman, 2010).

In early infancy, the autonomic nervous system is still maturing (Longin, Gerstner, Schaible, Lenz, & König, 2006). Myelination of the vagus is particularly rapid during the first three months of life and some suggest that deficits in this neurodevelopmental process may disrupt effective vagal tone regulation, leading directly to social-communication impairments (Porges & Furman, 2011). During this critical neurodevelopmental window, infant behavior transitions from primarily reflexive and subcortically driven, to volitional and cortically mediated (Shultz, Klin, & Jones, 2018). The emergence of active, sustained attention that is coordinated with heart rate decelerations also occurs within the first three months (Richards, 1989). Heart rate-defined sustained attention is characterized by a deceleration in heart rate that occurs while looking at a particular stimulus. The magnitude of heart rate change has been linked to more active attention, decreased levels of distractibility, and enhanced cognitive processing (Frick & Richards, 2001; Richards, 2010). Individual differences in RSA are associated with depth of heart rate deceleration during episodes of sustained attention (Richards, 1987), suggesting that RSA may also be an index of active attention and cognitive processing. In the context of early caregiver-infant interactions, it is possible that disrupted physiological regulation may limit the infant's capacity to sustain attention to the caregiver, possibly limiting early social learning opportunities. Some research suggests that the development of attention in the midst of this critical transition is disrupted for infants with ASD and infants with a family history of ASD (Bradshaw et al., 2020; Jones & Klin, 2013; Macari et al., 2020). Moreover, heart rate-defined sustained attention in older infants at an elevated likelihood of ASD may be disrupted (Tonnsen, Richards, & Roberts, 2018). Still, the relationship between autonomic reactivity and sustained attention during social interactions in infancy and the early emergence of social-communication skills remains unknown.

Given the facilitative role of vagal activity in sustaining social attention and engagement, identification of poor vagal regulation in the first few months of life may shed light on early mechanisms in the development of social interaction and communication. Research in this area is emerging as some studies have identified associations between RSA during this critical window and a later diagnosis of autism (McCormick et al., 2018) as well as later joint attention skills (Mateus et al., 2018). Much is still to be learned about the association between RSA reactivity during social interactions and early emerging social-communication skills. Moreover, the role of heart rate-defined social attention in vagal regulation and social-communication development has not been investigated. The current study seeks to build on this emerging body of literature to examine how infant RSA and heart rate rate-defined attention during a social interaction, as well as RSA reactivity to a social stressor, at 3–4 months of age predicts emerging social-communication skills at 9 months.

Methods

Participants

Participants included 21 infants (11 female, 10 male) between 3–4 months of age (*M*=3.84 months, *SD*=0.53) who were part of a longitudinal study on social development and early detection of autism spectrum disorder (ASD). Eligibility criteria for all participants included: enrollment into the study prior to 5 months of age, full term birth (≥ 37 weeks gestation), no congenital vision or hearing abnormalities, and no known genetic syndromes (e.g., Down Syndrome, Fragile-X Syndrome). Because this sample was part of a study on early detection of ASD, n=16 participants were at low familial likelihood of ASD and had no 1st or 2nd degree relatives with ASD and n=5 participants were at an elevated familial likelihood of ASD, defined as having a full biological sibling with a confirmed diagnosis of ASD. Siblings of children with ASD exhibit greater variability in their social-communication development compared to the typical population (Messinger et al., 2013; Ozonoff et al., 2011). For this study, all participants were analyzed together. All procedures were approved by the University Institutional Review Board and families completed informed consent prior to study procedures.

Procedure

Between 3–4 months of age, infants and caregivers were invited to the lab to participate in the face-to-face-still-face procedure. Upon arrival to the lab, there was a brief warmup period to allow the infant to acclimate to the new environment. A wireless electrocardiogram recorder (Actiwave, CamNtech Inc, Boerne, TX), was then placed on the infant's chest and the parent was given instructions for the Still-Face procedure, as follows. The caregiver was told to interact with their infant as they normally would at home for five minutes. At that time, the research assistant would cue the parent to stop interacting for two minutes. Instructions for this phase included: no touching the infant, no talking to the infant, and maintain a neutral facial expression. Finally, the parent was told to interact with their infant again for two minutes. During the entire experimental procedure, infants were placed on their back on an elevated, soft surface with the mother positioned in front of their infant.

At nine months, caregivers were contacted again to complete the Communication and Symbolic Behavior Scales Caregiver Questionnaire (CSBS-CQ; Wetherby & Prizant, 2002) to evaluate their emerging prelinguistic social-communication skills. The CSBS-CQ is a 45-item questionnaire about current social-communication skills. The results of the CSBS-CQ include seven cluster scores, three composite scores, and an overall total score. The Social composite measures the infant's emotional expression and use of eye gaze (Emotion and Eye Gaze cluster), frequency and function of communication (Communication cluster), and gesture use (Gestures cluster). The Speech composite is a measure of the infant's use of sounds (Sounds cluster) and words (Words cluster) in communication. The symbolic composite measures the infant's receptive language (Understanding cluster) and play skills (Object Use cluster). At nine months, infant social-communication skills, as measured by the CSBS-CQ, are most represented by their use of eye gaze, communication, and gestures (Reilly et al., 2006). At this age, communicative speech (Speech domain) and functional play skills (Symbolic domain) are just emerging and the greatest period of development in these domains is not apparent until after 12 months of age (Wetherby & Prizant, 2005). The Social domain raw scores are higher than the other domains at nine months and represent a relative midpoint for when these social skills emerge, between 6–18 months (Wetherby & Prizant, 2005). While we explored all CSBS-CQ composites in this study, we expected any significant associations to be observed in the Social domain.

Physiological data processing

Infant electrocardiograms were recorded at a sampling rate of 1.024 KHz. Trained research assistants detected and removed artifacts due to movement, ectopic beats, and periodic bradycardias. Editing was completed offline using CardioEdit software (Brain Body Center, University of Illinois at Chicago).

Sustained Attention.—Infant videos were reviewed and coded for periods of attention to the face of the caregiver during the Play phase. Coders were trained to exceed a 0.80 Kappa statistic for inter-rater reliability (McHugh, 2012). Inter-rater reliability was checked periodically for 20% of the coded videos, resulting in an average 0.74 Kappa indicating substantial agreement. Changes in heart period during periods of fixation were then analyzed, with longer heart period indicating a heart rate deceleration. Sustained attention was defined by a heart period longer than the pre-look heart period median for five consecutive beats (Richards & Casey, 1991). Following a deceleration, five successive beats with a heart period shorter than the median pre-look heart period marked the end of sustained attention. The maximum deceleration for each episode of sustained attention was calculated, resulting in an overall mean deceleration across all periods of sustained attention for each participant. The total amount of time spent in heart rate-defined sustained attention for each infant was also calculated.

Respiratory Sinus Arrhythmia (RSA).—Following the method developed by Porges (1986), the IBI time series was first time-sampled at regular intervals (5 Hz.), then a 51-point bands-pass local cubic polynomial filter was used to estimate and remove the slow periodic and aperiodic components of the time-series. Finally, an FIR-type bandpass filter was applied that further isolated the variance in the IBI series to only the frequency range of spontaneous breathing for infants (0.3–1.3 Hz.). The Porges & Bohrer (1990) technique for RSA magnitude estimation includes parsing this component signal into two minute epochs (for each phase of the Still Face paradigm), then calculating the natural log of the variance in each epoch. RSA is reported in units of $\ln(\mathrm{ms})^2$. Higher RSA estimates suggest higher vagal tone. Lower heart period estimates suggest higher physiological arousal. Vagal suppression was defined by a reduction in RSA from the Play phase to the Still Face phase. This was calculated by subtracting the Play phase RSA estimate from the Still Face phase RSA estimate. Negative estimates of vagal suppression indicate that an infant suppressed vagal tone going from the Play phase to the Still Face phase. Physiological arousal was calculated by subtracting the Play phase heart period estimate from the Still Face phase heart period estimate. Negative estimates of physiological arousal suggest that an infant has higher physiological arousal going from the Play phase to the Still Face phase.

Results

Descriptive statistics for physiological variables are presented in Table 1. Average estimates and correlations were calculated for Play phase RSA, Play phase heart period, Play phase sustained attention duration, Play phase sustained attention heart rate deceleration, RSA suppression, and physiological arousal. These analyses reveal significant associations between Play phase RSA and RSA suppression, as well as Play phase RSA and sustained attention heart rate deceleration. In addition, there was a significant association between Play phase sustained attention heart rate deceleration and RSA suppression during the Still Face phase. The primary analytic aim of this study was to examine the predictive association between changes in physiological responses and social attention during a mildly stressful social interaction and emerging social-communication skills. We first conducted a power analysis to determine whether we would have sufficient power, with a relatively small sample size, to observe a strong correlation among physiological activity and social communication. Results of this power analysis indicated that we have sufficient power, estimated power of 0.85, for a sample size of 21 to detect a correlation coefficient of r=0.60.

Zero-order correlations were then calculated to determine associations between estimates of physiological activity during the parent-infant interaction at 3–4 months and parent-reported social communication at nine months. We expected significant associations to be observed in the Social domain of the CSBS, as these skills are most representative of social-communication skills of nine-month-olds. To be comprehensive, we present the results of this analysis across all social-communication domains that were assessed using the CSBS-CQ. These results are presented in Table 2. First, there was a significant negative correlation between the CSBS Total score and RSA suppression ($r[19] = -0.43$, $p = .05$), suggesting that higher amounts of vagal suppression (lower negative values) at 3–4 months was associated with higher CSBS Total scores at 9 months. This relationship was largely driven by a set of significant negative correlations between specific clusters and composites on the CSBS and RSA suppression. Specifically, there was a significant negative relationship between RSA suppression and the Social Composite ($r[19] = -0.43$, $p = .01$; Fig. 1), driven by the Emotion and Eye Gaze cluster ($r[19] = -0.50$, $p = .02$) and Communication cluster ($r[19] = -0.43$, $p = 001$). These results indicate a significant predictive association between greater vagal suppression at 3–4 months and higher scores on composites related to nonverbal social skills. In addition, Play phase RSA significantly predicted infant use of communication at 9 months (Communication cluster: $r[19] = 0.45$, $p = .04$) and sustained attention heart rate deceleration was significantly associated with overall social communication (CSBS Total score: $r[19] = 0.50$, $p = .02$). Finally, play skills as measured by the Object Use cluster of the CSBS were only significantly predicted by sustained attention duration. Infants in our sample who had an older sibling with autism (“high-likelihood” infants) are depicted in Figure 1 for descriptive purposes, however these infants were not analyzed separately due to small sample size.

Discussion

Infant physiological reactivity during social play and mild social stress early in life, prior to the emergence of social-communication skills, may serve as an important predictor of social functioning. This may be particularly relevant for infants at an elevated likelihood of social-communication abnormalities and language impairments, such as those born preterm or with a family history of ASD. The current study sought to better understand the predictive link between developing vagal tone, measured with RSA, and sustained attention during social play at 3–4 months and the emergence of early prelinguistic social-communication skills at 9 months.

Overall, our findings are consistent with polyvagal theory (Porges, 2003, 2007), suggesting that RSA during caregiver-infant play and RSA suppression during social withdrawal (i.e., the Still Face) predict higher social-communication scores in infancy. In addition, we observed an association between heart rate-defined sustained attention to the caregiver during social play and RSA, RSA suppression, and later social-communication skills. Deeper heart rate deceleration during episodes of sustained attention was associated with higher RSA during play and later social-communication skills. In contrast, overall time spent in sustained attention during social play was not associated with cardiac measures and was only associated with object play skills. Previous research has shown the depth of heart rate deceleration to be associated with more efficient information processing (Richards, 2004) and we hypothesize that in our sample, effective physiological regulation, indexed by higher RSA, allowed for higher quality sustained attention during social interactions. Thus, in addition to RSA, the magnitude of active attention to caregivers during play may be an important predictor of social functioning in infancy. On the other hand, ability to sustain attention for longer durations, regardless of cardiac activity, may reflect an emerging generalized attention capacity, possibly linked to general cognitive and object use skills (Colombo, 2001), however additional research is necessary to examine this speculation.

It remains unclear whether RSA and heart rate-defined sustained attention uniquely predict social communication outcome. It is possible that both RSA and sustained attention heart rate deceleration reflect overall functioning of the same underlying cardio-respiratory system that coordinates heart activity and breathing during social interactions and environmental stressors. Notably, however, there was a large amount of unshared variance between Play phase RSA and attention-related heart rate changes, suggesting that these two properties, although related, might reflect different processes that support social interaction and emotion regulation. Nevertheless, in this study, infants who demonstrated high RSA also showed larger sustained attention decelerations and more RSA suppression, all suggestive of an adaptive and healthy regulatory system that predicts social communication. Moderation analyses with larger samples will help determine the unique and shared variance among these measures in predicting infant outcomes.

Play phase RSA most strongly predicted infant scores on the Communication cluster of the caregiver report measure. The Communication cluster measures the frequency and function of infant communicative behavior, such as communicating for help, social interaction, and joint attention. According to polyvagal theory, elevated vagal tone during social play can allow for sustained social engagement. That is, high RSA facilitates a calm behavioral state, enabling engagement in social interactions. This argument is bolstered by our finding that RSA was also linked to heart rate-defined sustained attention, with higher RSA during social play associated with more heart rate deceleration during sustained attention to a caregiver. We speculate that infants who demonstrated higher RSA during social play were more regulated, perhaps enabling a higher degree of social attunement to the interaction, which could elicit more social and language learning opportunities from caregivers (Bornstein & Suess, 2000). Notably, the bidirectional effects of physiological and behavioral regulation within dyadic mother-infant interactions were not directly examined in this study. Therefore, we cannot determine the underlying mechanism responsible for physiological regulation during these interactions, for example whether infants with high RSA during social play were more biologically equipped to sustain social interaction or whether high maternal sensitivity and responsivity was maintaining high RSA during the interaction. While our analyses limit the causal interpretation of this data, it is possible that higher RSA and sustained attention during social play early in life reflects infant individual differences or a dyadic context that may elicit more social and communication learning opportunities from social partners, leading to better communication skills six months later.

The prototypical physiological response to a withdrawal of social interaction is vagal suppression, indexed by a decrease in RSA during the Still Face phase compared to the Play phase. Physiologically, this serves to support self-soothing behavior and attentional control. In the present study, more vagal suppression during the social withdrawal phase significantly predicted the infant's frequency and function of communication, as well as use of facial expression and eye gaze to communicate, at nine months of age. The pattern of results suggests that vagal suppression during the Still Face phase was a slightly better predictor of social-communication skills than was vagal tone during the Play phase. It is useful to consider the necessary conditions for vagal suppression during the Still-Face paradigm. First, the infant must be sufficiently attuned to the social interaction during the Play phase to notice the sudden withdrawal of caregiver interaction. Second, they must be sufficiently distressed by the social withdrawal during the Still Face phase to elicit a physiological response. In this framework, it is possible that infants exhibiting weaker or no RSA suppression may be less stressed by the sudden perturbation in the social interaction. One potential explanation for this may be that these infants find social interactions to be less rewarding, thus the perturbation in the social interaction does not necessitate physiological recovery. Infants with reduced social reward may be less motivated to initiate and maintain social interaction, leading to a developmental cascade that ultimately decreases opportunities for social learning and communication. This is consistent with social motivation theories of autism, whereby diminished social reward may be a key neurobiological mechanism in reduced social-communication skills and ASD (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). Alternatively, the dyadic context may work to support or counteract physiological regulation (Davis, West, Bilms, Morelen, & Suveg, 2018). Future studies should investigate unique contributions of dyadic context (e.g., maternal sensitivity) and social reward in physiological reactivity during the Still Face paradigm.

Alternatively, infants who demonstrated little-to-no RSA suppression during the Still-Face phase may have been sufficiently distressed, but did not effectively utilize vagal suppression as a physiological regulation strategy. Previous research suggests that decreased RSA suppression in response to the sudden perturbation in social interaction during the Still-Face phase is associated with fewer positive social engagement behaviors during social play (Moore & Calkins, 2004). This is consistent with the findings here, demonstrating an association between lower estimates of RSA and reduced sustained attention during play and a lack of RSA suppression, suggesting that infants who demonstrated lower estimates of vagal tone and heart rate-defined attention during social play were also less likely to regulate during a social stressor.

Limitations

It is important to note several study limitations. First, maternal-infant co-regulation and maternal sensitivity is a critical component of infant physiological reactivity, especially during social interactions. This study did not examine such relationships and it will be important to do so in the future, given the dynamic and bidirectional relationship between mother and infant physiology. Replication of the current findings in a larger sample of infants is a critical next step. Our sample of infants contained a small number of siblings of children with ASD. While this may have created more variability in social-communication outcome at 9 months, it is notable that RSA and heart rate-defined sustained attention may differ for very young infant siblings of children with ASD. While excluding these infants from the present analyses did not change the pattern of results, replication with larger samples to identify any effects of genetic liability is necessary.

Conclusions

Overall, our findings identified cardiac indices of regulation and attention at 3–4 months of age, prior to the onset of prelinguistic communication, that predicted the emergence of early social-communication skills. This supports the idea that both physiological regulation across an entire play session and the magnitude of heart rate responses during moments of social attention are important for social learning and the development of communication skills. Disentangling the unique contribution of vagal tone and sustained attention during social play to later social outcome is an important future direction. Infant RSA reactivity during the withdrawal of social interaction also emerged as a strong early indicator of later social communication. In fact, this measure appeared to be a more robust predictor of infant communication and, specifically, use of eye gaze and facial expression, compared to RSA and sustained attention during play. Identifying specific neurodevelopmental and behavioral mechanisms implicated in RSA suppression during the Still-Face paradigm is essential for understanding the role of vagal suppression in the development of social communication.

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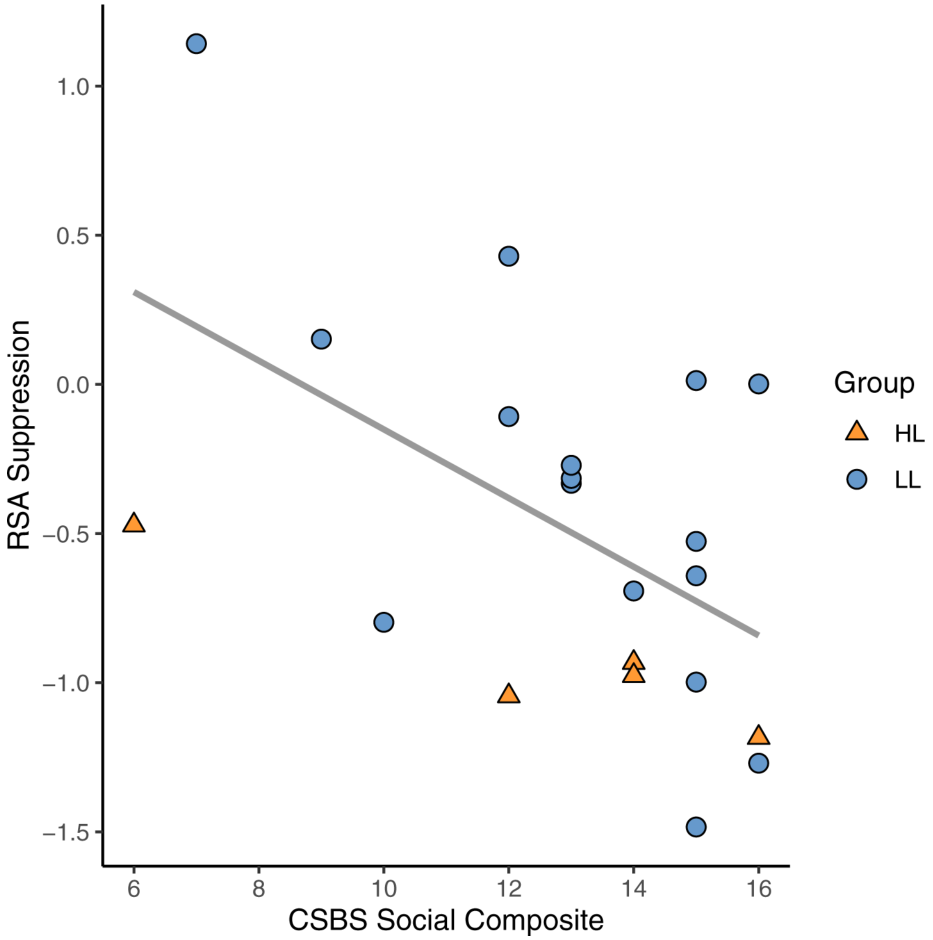

Figure 1.

Association between RSA suppression at 3–4 months and CSBS Social Composite scores at 9 months for high-likelihood (HL) and low-likelihood (LL) infants.

Table 1

Estimates and Intercorrelations for Physiological Variables

	Mean (SD)	Correlation Coefficients				
		1	*2*	*3*	*4*	*5*
(1) Play Phase RSA[a]	3.80 (0.78)	-	-	-	-	-
(2) Play Phase Heart Period[b]	425.21 (28.32)	0.17	-	-	-	-
(3) RSA Suppression[a]	−0.49 (0.63)	−0.56**	−0.10	-	-	-
(4) Physiological Arousal	−26.96 (24.42)	0.20	−0.55 **	−0.06	-	-
(5) Sustained Attention Total Duration (s)	81.93 (56.81)	−0.06	0.002	−0.10	−0.03	-
(6) Sustained Attention Deceleration[c]	48.19 (17.12)	0.61**	0.37	−0.48*	−0.22	0.34

Note: Lower estimates of negative RSA suppression and physiological arousal represent more RSA suppression and physiological arousal, respectively, going from the Play phase to the Still Face phase.

[a] RSA is represented in $\ln(\mathrm{ms})^2$

[b] Heart period is averaged per minute

[c] Average heart period deceleration during episodes of sustained attention

Table 2

Zero-Order Correlations between the Communication and Symbolic Behavior Scales and Physiological Activity

	Play Phase RSA	Play Phase Heart Period	RSA Suppression	Physiological Arousal	Sustained Attention Duration	Sustained Attention Deceleration
Communication and Symbolic Behavior Scales – Caregiver Questionnaire						
Social Composite	0.37	0.02	-0.52^{*}	–0.03	0.26	0.37
Emotion and Eye Gaze	0.38	0.26	-0.50^{*}	–0.20	0.02	0.29
Communication	0.45^{*}	0.05	-0.65^{**}	0.02	0.11	0.45^{*}
Gestures	–0.05	–0.08	–0.12	–0.08	0.23	–0.04
Speech Composite	0.07	–0.13	–0.06	–.004	0.15	0.06
Sounds	–0.12	–0.16	0.18	0.03	0.04	–0.17
Words	0.19	0.06	–0.30	–0.14	0.17	0.25
Symbolic Composite	0.17	0.28	–0.19	.002	0.35	0.30
Understanding	0.20	0.40	–0.22	0.01	0.31	0.27
Object Use	0.02	–0.15	–0.07	0.08	0.53^{*}	0.27
Total	0.37	0.08	-0.43^{*}	–0.15	0.31	0.50^{*}

Note:

$^{*}p \leq .05$,

$^{**}p \leq .01$