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BRIEF REPORT

Brief Report: Social Skills, Internalizing and Externalizing Symptoms, and Respiratory Sinus Arrhythmia in Autism

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Abstract Theoretical and empirical models describe respiratory sinus arrhythmia (RSA) as a peripheral biomarker of emotion regulation and social competence. Recent findings also link RSA to individual differences in social functioning within autism spectrum disorder (ASD). However, associations between RSA and symptoms of internalizing/externalizing psychopathology in ASD have not been explored. We assessed RSA, social functioning, and internalizing/externalizing symptoms among boys with and without ASD. Compared with controls, participants with ASD evidenced reduced parasympathetic cardiac control, which correlated with social behavior. Symptoms were associated with deficiencies in RSA, over-and-above the contribution of social functioning. These findings yield a more nuanced understanding of parasympathetic function in ASD, and suggest a role for integrative intervention strategies that address socioemotional difficulties.

Keywords Autism · Respiratory sinus arrhythmia · Heart rate variability · Emotion regulation · Internalizing · Externalizing · Social skills

Introduction

Recently, there has been increased interest in the autonomic correlates of autism spectrum disorder (ASD). Among the most consistent findings is that of lowered heart rate variability (frequently assessed via respiratory sinus arrhythmia, RSA) among participants with ASD relative to those with typical development. Compared to controls, children with ASD show lower RSA at rest, as well as altered patterns of RSA reactivity during social engagement tasks (Bal et al. 2010; Porges et al. 2012; Vaughan Van Hecke et al. 2009). Moreover, RSA correlates with a variety of social skills and behaviors, including social responsiveness, emotion recognition, peer engagement, spontaneous eye gazes, and receptive language, among both ASD and typically developing samples (Bal et al. 2010; Eisenberg et al. 1995; Fabes et al. 1993; Heilman et al. 2007; Henderson et al. 2004; Patriquin et al. 2013a, 2013b).

To date, autonomic findings within the ASD literature have been interpreted within the context of Porges's (2001) social engagement system theory, according to which social behavior emerges from three hierarchically-organized response systems within the central nervous system. According to this framework, the most advanced of these is mediated peripherally by the parasympathetic nervous system (PNS), specifically the myelinated vagus (Porges 2001). Vagal control of organs including the heart, larynx, and pharynx allows the PNS substantial influence over socially-oriented behaviors such as facial gestures and vocalizations, and consequently increases both the flexibility and sophistication of an individual's repertoire of social and communicative behaviors (e.g., vocal intonation/prosody, facial expression). In this way, vagal control facilitates quicker, more sensitive, and more finely tuned responses to social and environmental challenges (Porges 2001). Under proper stimulus conditions, parasympathetic efference to the heart can be indexed by RSA, defined as high frequency heart rate variability associated with respiration (Beauchaine 2001; Berntson et al. 1997).

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Given the centrality of social and communication impairment in ASD, it is logical that questions have emerged over links between RSA and autism. However, theoretical and empirical models have also long portrayed RSA as a biomarker of emotion regulation, which is also a precondition for effective social engagement (Beauchaine 2001, 2007). Furthermore, both emotion dysregulation and attenuated RSA characterize a variety of clinical disorders spanning both internalizing and externalizing spectra (Beauchaine and Gatzke-Kopp 2012). For example, anxiety, depression, non-suicidal self-injury, ADHD, and conduct disorder have all been associated with reduced RSA and/or excessive RSA reactivity to emotional challenges (Beauchaine et al. 2001; Crowell et al. 2005; Thayer et al. 1996). Thus, deficiencies in RSA are not specific to ASDs, and appear to mark both social problems and emotion dysregulation across a wide range of conditions. Within the ASD literature, however, RSA has thus far been examined only with respect to social functioning, and the extent to which reduced RSA among this group reflects co-occurring emotional difficulties has not yet been investigated. This issue is particularly pertinent because children and adults with ASD exhibit higher levels of comorbid internalizing and externalizing disorders than individuals without ASD (Simonoff et al. 2008), and these comorbid symptoms are often a significant focus of clinical intervention (Reaven et al. 2012) and psychiatric treatment (Coury et al. 2012).

Our goal in conducting the current study was to enhance understanding of relations among RSA, social skills, and internalizing and externalizing symptoms in children with and without ASD. In particular, we sought to determine whether social and emotional functioning make unique contributions to RSA. We predicted that children with ASD would have reduced baseline RSA, which would be correlated with social functioning, consistent with existing literature. Moreover, we predicted that emotional functioning (internalizing and externalizing symptoms) would make independent contributions to parasympathetic functioning, as assessed by RSA, over-and-above the effects of social functioning alone.

Methods

All study procedures were approved by the university's institutional review board. Prior to participating, all parents and children provided informed consent and assent, respectively.

Participants

Thirty-six male children participated in the study (18 ASD, 18 control). Participants were recruited from a registry of families at a university Autism Center, and from the general community through fliers and advertisements. Parents received $40.00 and parking reimbursement for their participation in the study, and children had the opportunity to win a small additional amount of money during a game (not included in the current hypotheses). Interested parents completed a preliminary phone screen that included (1) demographic information; (2) a brief developmental history; (3) the Social Communication Questionnaire (SCQ; Rutter et al. 2003); and (4) the Child Behavior Checklist (CBCL; Achenbach 1991).

Eligibility for the ASD group was established with the Autism Diagnostic Interview-Revised (Lord et al. 1994), Autism Diagnostic Observation Schedule (Lord et al. 2003), and expert clinician judgment. The mean age of children with ASD was 119.9 months (*SD* = 13.2). The racial/ethnic composition of this group was 72.2 % Caucasian, 5.6 % Asian/Pacific Islander, 5.6 % Latino, and 16.7 % who identified as more than one race.

Control group participants were screened for subthreshold features of ASD using the lifetime version of the SCQ, and for behavior problems using the CBCL. Participants were excluded if their score on the SCQ exceeded 9, their symptom *T*-score on the thought problems subscale of the CBCL exceeded 65 (i.e., >1.5 *SD* above national norms), they had ever received a diagnosis related to their development, they had a history of significant head injury or seizures, or they had a first-degree relative with an ASD. The mean age of controls was 120.2 months (*SD* = 11.1). The racial/ethnic composition of the control group was 61.1 % Caucasian, 5.6 % Asian/Pacific Islander, 11.1 % African American, and 22.2 % who identified as more than one race. Participant characteristics are reported by group in Table 1.

Measures

Internalizing and externalizing symptoms were measured via parent report on the CBCL, a 113-item questionnaire on which parents rated their child's behaviors using a 3-point scale ranging from 0 (*not true*) to 2 (*very true or often true*). The measure yields continuous scores on eight subscales as well as broadband internalizing and externalizing scales. The internalizing scale is a composite of the anxious/depressed, withdrawn/depressed, and somatic complaints subscales, whereas the externalizing scale is a composite of the rule-breaking behavior and aggressive behavior subscales. Both scales generate *T*-scores that were used for analyses. Parent-reported social skills were assessed via (1) the Social Skills Improvement System (SSIS; Gresham and Elliott 2008), on which parents rated the frequency of a variety of social behaviors on a 3-point scale ranging from 0 (*never*) to 2 (*very often*), yielding an

Table 1 Group characteristic means and standard deviations

	Controls	ASD	*F* value	*p* value	Effect size (*d*)
Age in months	120.2 (11.1)	119.9 (13.2)	0.01	.94	0.00
Full scale IQ	114.8 (13.5)	108.3 (21.4)	1.17	.29	0.37
Verbal IQ	115.3 (9.9)	102.4 (23.0)	4.78*	.04	0.75
Performance IQ	110.7 (15.7)	113.3 (19.6)	0.20	.66	0.16
SCQ score	3.0 (2.3)	19.7 (5.0)	172.65***	.00	4.50
SSIS social skills standard score	101.3 (10.8)	79.8 (10.7)	36.13***	.00	2.06
Vineland-2 adaptive behavior composite	116.44 (9.1)	84.4 (13.1)	72.98***	.00	2.93
Vineland-2 communication standard score	108.1 (12.6)	82.2 (13.6)	35.22***	.00	2.04
Vineland-2 socialization standard score	119.3 (6.9)	77.6 (17.7)	87.18***	.00	3.20
Vineland-2 daily living skills standard score	117.3 (11.3)	98.0 (14.3)	20.19***	.00	1.54
CBCL internalizing broadband *T*-score	52.0 (9.3)	61.4 (10.4)	8.21**	.01	0.98
CBCL anxious/depressed *T*-score	55.2 (6.8)	60.2 (9.7)	3.22	.08	0.62
CBCL withdrawn/depressed *T*-score	55.6 (6.5)	65.6 (8.4)	16.24***	.00	1.38
CBCL somatic complaints *T*-score	53.3 (5.1)	57.6 (8.7)	3.18	.08	0.61
CBCL externalizing broadband *T*-score	48.6 (8.0)	56.9 (10.4)	7.30**	.01	0.93
CBCL rule-breaking *T*-score	54.3 (5.3)	57.0 (6.7)	1.75	.20	0.45
CBCL aggressive behavior *T*-score	53.3 (4.4)	59.7 (9.5)	6.74*	.01	0.89
CBCL social problems *T*-score	53.8 (4.5)	62.6 (7.6)	17.92***	.00	1.45
CBCL thought problems *T*-score	53.8 (3.8)	64.9 (8.1)	28.12***	.00	1.82
CBCL attention problems *T*-score	52.7 (3.1)	64.7 (8.0)	35.05***	.00	2.03

SCQ Social Communication Questionnaire (Rutter et al. 2003), *SSIS* Social Skills Improvement System (Gresham and Elliot 2008), *Vineland-2* Vineland Adaptive Behavior Scales, 2nd Edition (Sparrow et al. 2005), *CBCL* Child Behavior Checklist (Achenbach 1991)

* $p < .05$

** $p < .01$

*** $p < .001$

age-normed standard score for social skills; (2) the Socialization score of the survey interview form of the Vineland Adaptive Behavior Scales, second edition (Vineland-2; Sparrow et al. 2005); and (3) the social problems subscale of the CBCL. Children's cognitive abilities were assessed with the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler 1999), which yielded an IQ composite and scores for verbal and performance ability.

Respiratory Sinus Arrhythmia (RSA)

RSA data were collected via an electrocardiograph (ECG) signal, obtained through a three-lead spot configuration (Qu, Zhang, Webster and Tompkins 1986) while children sat alone in a quiet room for approximately 5 min (ten 30-s epochs). From this baseline, the final four 30-s epochs (2 min total) were averaged to produce mean baseline RSA scores for each participant. The ECG signal was obtained using a Grass Model 15LT Physiodata Amplifier System (West Warwick, RI), sampled at 1 kHz, and ECG data were collected and digitized using COP-WIN software, version 6.10 (Bio-Impedance Technologies, Chapel Hill, NC). Parasympathetic-linked cardiac activity was quantified by spectral-analyzing the R-wave time series of the ECG using software developed by Richard Sloan and colleagues at Columbia University. Interbeat intervals were inspected for possible artifacts (e.g., missed or extraneous heartbeats), which were hand-corrected as appropriate. High frequency spectral densities (>0.15 Hz) were computed via Fast Fourier Transform of each 30-s epoch, which is acceptable when averaging across multiple epochs (see Berntson et al. 1997). As is standard, RSA values were natural log-transformed prior to analyses.

Results

Throughout our analyses and results, findings were interpreted as significant if their associated p values fell below 0.05. Consistent with our predictions and previous findings, ASD participants exhibited lower baseline RSA ($M = 6.94$, $SD = 1.09$) than controls ($M = 7.66$, $SD = .87$), $t(34) = 2.18$, $p = .036$, $d = 0.75$. In addition, of the three measures of social behavior provided by parents (SSIS standard score, Vineland-2 socialization domain, CBCL social problems), all were correlated significantly with baseline RSA. As shown in Table 2, higher RSA was associated with better social functioning as measured by the SSIS ($r = .41$, $p = .007$) and Vineland-2 ($r = .45$, $p = .006$), and with fewer social problems as measured by the CBCL ($r = -.35$, $p = .039$). Baseline RSA was also significantly correlated with several subscales of the CBCL, including the internalizing broadband *T*-score ($r = -.48$, $p = .003$) and its associated subscales (anxious/depressed, $r = -.36$, $p = .03$; withdrawn/depressed, $r = -.53$, $p = .001$; somatic complaints, $r = -.34$, $p = .04$), but not with the CBCL externalizing subscales ($ps < .09$, $rs > .6$). Whereas higher baseline RSA was associated with fewer internalizing symptoms across our sample, it was not significantly associated with externalizing symptoms.

Next, we created a regression model to examine independent prediction of RSA by internalizing and externalizing symptoms. To test whether symptoms were associated with RSA, over-and-above the effects of social skills, SSIS social skills standard scores, CBCL Internalizing *T*-scores, and CBCL Externalizing *T*-scores were entered simultaneously into a regression model. The model accounted for 38.3 % of the variance in baseline RSA, F (2, 32) $= 6.63$, $p = .001$, with significant independent effects of social skills ($\beta = .35$, $p = .03$), internalizing symptoms ($\beta = -.55$, $p = .003$), and externalizing symptoms ($\beta = .38$, $p = .03$). Consistent with predictions, parent-reported social skills and internalizing/externalizing symptoms all made independent contributions to baseline RSA.

Discussion

Taken together, the results of this study suggest that RSA is a complex biomarker tied to both social and emotional functioning, particularly among individuals with autism. Although control participants exhibited higher baseline RSA than participants with ASD, differences in RSA did not reflect solely social deficits associated with ASD. Instead, they appear to reflect independent contributions from emotional and social functioning, an association that has not previously been demonstrated among those with ASD. Although recent studies have compared RSA between groups with and without ASD, none have yet considered the potential influence of internalizing and externalizing symptoms. This is particularly relevant given the high rates of psychiatric comorbidity observed among individuals with ASD over their lifespan (Simonoff et al. 2008).

Our finding that higher RSA is associated with better social skills and fewer internalizing symptoms is consistent with previous findings. In contrast, the finding that externalizing symptoms had a positive association with RSA in our regression model is counter-intuitive, as externalizing among non-ASD samples is generally associated with reduced RSA (Beauchaine et al. 2007). One possibility for this finding is that parents' reports of externalizing symptoms in our sample reflect behaviors that actually indicate social interest. Indeed, the mean externalizing score for the entire sample was only $T = 52.7$, or .27 *SD* above the mean. Scores in this range reflect normative variation, not problematic behavior, and may better be construed as exuberance (Degnan et al. 2011). In the case of ASD, children who wish to engage with peers in the classroom or playground but lack the skill to do so in conventional ways may resort to strategies that appear hyperactive/impulsive (e.g., interrupting at inappropriate times) or inattentive (e.g., initiating tangential conversations), but are best understood as atypical or odd social overtures. Although speculative, this hypothesis fits well with clinical observations of children with ASD, for whom social *interest* and social *skill* can diverge.

As a whole, our findings fit well within the context of the social engagement system theory, where higher RSA is associated with more flexible, responsive, and sophisticated social behavior (Porges 2001), as well as within conceptualizations of RSA as a biomarker of emotion regulation (Beauchaine 2001). Not only do social and emotional processes appear to share evolutionary and physiological bases (Porges 1999), but they share ontogenetic underpinnings over the course of typical development (Denham and Grout 1993; Porges and Furman 2011). For instance, social interaction and engagement promote the development of emotion regulation among infants and young children (Coan 2010) and contribute to the implementation of effective emotion regulation among older children and adults (Conner et al. 2012), with growing evidence of effects at both the behavioral and psychophysiological levels (Beckes and Coan 2011; Conner et al. 2012).

Within the context of ASD, these findings speak to the value of intervention approaches that address social difficulties as well as emotional concerns in an integrated fashion. For example, a recent pilot study described a program of cognitive behavioral therapy targeting social communication and emotion regulation in ASD, and found that social skills and anxiety symptoms improved in tandem over the course of treatment (Wood et al. 2009). Furthermore, although no research to date has explored the effects of these interventions on RSA or other measures of parasympathetic function, changes in PNS activity may mediate positive outcomes, contributing to the development of more flexible and appropriate social behavior, as well as more effective and efficient emotion regulation. Indeed, behavioral genetics studies indicate heritable and environmental effects on RSA, with approximately 50 % of the variance in RSA due to each (Kupper et al. 2005). Thus, social-emotional improvement elicited by behavioral

Table 2 Correlations between RSA and parent-report measures

	Full scale IQ	SCQ	SSIS social skills	Vineland-2 composite	Communication	Socialization	Daily living skills	CBCL internalizing	Anxious/ depressed
Baseline RSA	.28	−.46**	.41*	.37*	.30	.45**	.28	−.48**	−.36*
Full scale IQ	–	−.24	.24	.22	.40*	.18	.04	.05	.10
SCQ	–	–	−.73***	−.87***	−.78***	−.90***	−.64***	.54**	.36*
SSIS social skills	–	–	–	.80***	.69***	.79***	.64***	−.39*	−.23
Vineland-2 composite	–	–	–	–	.91***	.92***	.84***	−.52**	−.36*
Communication	–	–	–	–	–	.75***	.66***	−.40*	−.31
Socialization	–	–	–	–	–	–	.67***	−.57***	−.35*
Daily living skills	–	–	–	–	–	–	–	.40*	−.30
CBCL internalizing	–	–	–	–	–	–	–	–	.87***
Anxious/depressed	–	–	–	–	–	–	–	–	–
Withdrawn/depressed	–	–	–	–	–	–	–	–	–
Somatic complaints	–	–	–	–	–	–	–	–	–
CBCL externalizing	–	–	–	–	–	–	–	–	–
Rule-breaking	–	–	–	–	–	–	–	–	–
Aggressive behavior	–	–	–	–	–	–	–	–	–
Social problems	–	–	–	–	–	–	–	–	–
Thought problems	–	–	–	–	–	–	–	–	–
Attention problems	–	–	–	–	–	–	–	–	–

	Withdrawn/ depressed	Somatic complaints	CBCL externalizing	Rule-breaking	Aggressive behavior	Social problems	Thought problems	Attention problems
Baseline RSA	−.53**	−.34*	−.06	.08	.02	−.35*	−.30	−.16
Full scale IQ	−.07	−.02	.16	.14	.17	.21	.10	.06
SCQ	.64***	.48**	.39*	.18	.38*	.61***	.70***	.71***
SSIS social skills	−.46**	−.36*	−.42*	−.21	−.44**	−.50**	−.57***	−.47**
Vineland-2 composite	−.59***	−.42*	−.41*	−.12	−.43**	−.66***	−.61***	−.57***
Communication	−.44**	−.30	−.35*	−.02	−.39*	−.45**	−.43**	−.50**
Socialization	−.67***	−.52**	−.44**	−.27	−.45**	−.70***	−.68***	−.65***
Daily living skills	−.48**	−.28	−.24	.08	−.24	−.59***	−.47**	−.31
CBCL internalizing	.88***	.74***	.54**	.38*	.48**	.68***	.59***	.39*
Anxious/depressed	.71***	.53**	.57***	.36*	.52**	.64***	.54**	.23
Withdrawn/depressed	–	.65***	.41*	.28	.38*	.67***	.57***	.42*
Somatic complaints	–	–	.37*	.32	.38*	.42*	.47**	.33*
CBCL externalizing	–	–	–	.76***	.91***	.66***	.58***	.52**
Rule-breaking	–	–	–	–	.62***	.35*	.41*	.43**

Table 2 continued

	Withdrawn/depressed	Somatic complaints	CBCL externalizing	Rule-breaking	Aggressive behavior	Social problems	Thought problems	Attention problems
Aggressive behavior	–	–	–	–	–	.62***	.59***	.46**
Social problems	–	–	–	–	–	–	.69***	.49**
Thought problems	–	–	–	–	–	–	–	.65***
Attention problems	–	–	–	–	–	–	–	–

RSA Respiratory sinus arrhythmia, *SCQ* Social Communication Questionnaire, *SSIS* Social Skills Improvement System, *Vineland-2* Vineland Adaptive Behavior Scales, 2nd Edition, *CBCL* Child Behavior Checklist

* $p < .05$

** $p < .01$

*** $p < .001$

interventions may be due in part to effective shaping of parasympathetic function.

Taking a broader view of intervention across development, RSA is often viewed as a psychophysiological marker of vulnerability or resilience (Shannon et al. 2007), and the current study underscores its value as a marker of risk *across* diagnostic categories. Among children with familial and psychosocial risk factors such as marital conflict, parental psychopathology, and hostile parenting, RSA often moderates outcomes, with higher baseline scores predicting more positive social and emotional functioning, and lower baseline scores predicting internalizing and externalizing symptoms (El-Sheikh et al. 2011; Leary and Katz 2004; Shannon et al. 2007). Within this context, our findings of reductions in RSA relative to controls, and links between RSA and emotional functioning, highlight individuals with ASD as a group at heightened biological risk for negative outcomes following stressors, and emphasize the need for increased supportive, preventive, and intervention services.

At the same time, an alternative view suggests that biomarkers such as reduced RSA might be best conceptualized not solely as indicators of increased risk, but instead as indicators of increased neurobiological sensitivity to contextual factors, both positive and negative (Boyce and Ellis 2005; Ellis et al. 2011). This perspective describes a U-shaped function in which neurobiology influences an individual's susceptibility to environmental factors at either extreme, such that highly sensitive individuals are both vulnerable to detrimental influences but also highly receptive to enriched or positive influences (Ellis et al. 2011). Within this framework, attenuated RSA could indicate not only increased vulnerability to stressful events and circumstances, but also enhanced receptivity to positive (e.g., support, resources) or therapeutic (e.g., intervention efforts) factors within the environment (Ellis et al. 2011). Considered in this light, our findings suggest that individuals with ASD likely require additional support to prevent maladaptive social and emotional outcomes in the face of normative social challenges (e.g., school changes, peer conflict, parental divorce, loss of attachment figures), but also that they may be particularly receptive to the potential benefits and advantages of timely, tailored, and thorough intervention efforts.

Conflict of interest None.

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