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Sympathetic Under-Arousal and Externalizing Behavior Problems in Children with Autism Spectrum Disorder

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Abstract

Children with autism spectrum disorder (ASD) commonly exhibit co-occurring externalizing behavior problems, which can impede learning opportunities and contribute significantly to caregiver stress. Substantial theory and research has linked under-arousal of the sympathetic nervous system to increased externalizing problems in children without ASD, but under-arousal has not been considered as an explanatory mechanism for individual differences among children with ASD. We tested the notion that lower electrodermal activity (EDA) would predict more externalizing problems in children with ASD, and considered the degree to which parent co-regulatory support could buffer this risk. Forty children with ASD between the ages of 4 and 11 years and their primary caregivers participated in a laboratory visit that included various play, compliance, and problem-solving regulatory tasks. EDA was measured through wireless wrist sensors, parental scaffolding was observed during a dyadic problem-solving task, and parents rated their children's externalizing behavior problems. As predicted, low EDA during the compliance-oriented tasks directly predicted higher child externalizing problems. Parental scaffolding moderated the link between under-arousal during the problem-solving regulatory tasks and externalizing problems such that the relation was observed in the context of low, but not high,

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[5]Analyses omitting the two children who did not meet criteria for ASD on the ADOS resulted in findings that were identical in patterns of significance, with the exception of the emergence of a trend for the interaction between EDA during Free Play and Scaffolding, and significant child age effects in the Problem-Solving models.

ETHICAL APPROVAL STATEMENT:
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

support. Implications for relevant theories (e.g., fearlessness theory, stimulation-seeking theory) are discussed, and the potential for psychophysiological patterns to inform intervention with these children is considered.

Keywords

autism spectrum disorder (ASD); electrodermal activity; externalizing behavior problems; parental scaffolding; psychophysiology

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that is currently estimated to affect 1 out of 68 children, and 1 out of every 42 boys (Christensen et al., 2016). Despite the unitary diagnostic criteria of social communication deficits and the presence of restricted and/or repetitive behaviors, substantial heterogeneity exists in the clinical and behavioral presentation of this population (Georgiades et al., 2013). In addition to significant variation in the degree and manifestation of core symptomatology, associated difficulties are common in children with ASD, most notably externalizing problems such as aggression, non-compliance, disruptiveness, and rule-breaking (McClintock, Hall, & Oliver 2003; Tonge, Brereton, Gray, & Einfeld, 1999). Co-occurring externalizing problems in individuals with ASD not only cause personal distress, but also tend to exacerbate impairment in functioning and impede learning (Bellini, 2004; de Bruin, Ferdinand, Meester, de Nijs, & Verheij, 2007; Mazefsky et al., 2013; White & Roberson-Nay, 2009). Beyond certain specified genetic etiologies, few factors have been identified as predictive of individual differences in the behavioral phenotype of children with ASD. Understanding factors related to the emergence of co-occurring externalizing problems is critical not only to improving our understanding of ASD, but also to identifying and tailoring environmental supports to promote adaptive development in these children.

Emotional reactivity and regulation have been established as important to social, emotional, and behavioral outcomes in both typically-developing children and those with early developmental risk (Baker, Fenning, Crnic, Baker, & Blacher, 2007; Cole, Martin, & Dennis, 2004), and challenges in this domain have been identified as central to neurodevelopmental disorders (Bunford et al., 2016) and ASD specifically (Mazefsky, Pelphrey, & Dahl, 2012; Picard, 2009; Weiss, 2014). Multiple factors have been theorized to contribute to difficulties with emotion processes in children with ASD and related disorders, including atypicalities in underlying physiological arousal tendencies (Bunford et al., 2016; Mazefsky & White, 2014).

Sympathetic Nervous System Tendencies in Children with ASD

Electrodermal activity (EDA) is a marker of the sympathetic nervous system (SNS) and the behavioral inhibition system (BIS). The BIS is a neurophysiological motivational system that increases arousal and attention to support risk assessment and to inhibit impulsive behaviors in situations that involve threat, potential negative consequences, or conflicting approach and avoidance motivations (Beauchaine, 2001; Fowles, Kochanska, & Murray, 2000, McNaughton & Corr, 2004). Much of the work on EDA in individuals with ASD has focused on examination of baseline arousal and brief EDA reactions to certain stimuli in order to try to better understand sensory-sensitivity issues in this population (see Lydon et al., 2015, Rogers & Ozonoff, 2005, and White et al., 2014 for reviews). More recently, group differences in EDA reactivity in response to social stimuli have been considered, with decidedly mixed findings (Lydon et al., 2015), including evidence for both heighted (Joseph et al., 2008; Kylliainen & Hietanen, 2006; Kylliainen et al., 2012) and blunted responses (Hirstein et al., 2001; Hubert et al., 2009; Riby et al., 2012) in children with ASD compared to children with typical development, as well as no significant differences between groups (Ben Shalom et al., 2006; Louwerse et al., 2013).

Recent evidence linking variation in EDA reactivity to *individual differences* in children with ASD has been similarly mixed. Increased EDA in response to certain social stimuli has been positively linked with impairment in social functioning (Joseph et al., 2008; Kaartinen et al., 2012; Neuhaus et al., 2015; Stagg et al., 2013). However, Faja and colleagues (2013) also found that increasing EDA trajectories during anticipation of outcomes over the course of a decision-making task was associated with lower levels of social-affective impairment, and several studies have failed to find significant associations between EDA reactivity and individual differences in children with ASD (e.g., Louwerse et al., 2013; McCormick et al., 2014; Stagg et al., 2013).

Extant research on EDA in individuals with ASD has tended to consider baseline EDA (*skin conductance level*; SCL) or brief EDA response following presentation of an isolated stimulus in a non-interactive context (*skin conductance response*; SCR). More recently, the frequency of *nonspecific fluctuations in skin conductance responses* (NSCRs; Boucsein et al., 2012; Beauchaine et al., 2015) has been considered as an important individual difference variable for children with ASD. Neuhaus and colleagues (2015) examined NSCRs at baseline and across a number of conditions involving social and behavioral rewards, but did not find that these measures significantly predicted parent-reported social skills for the children with ASD. A recent study from our laboratory utilizing a portion of the current sample examined NSCRs in children with ASD across several structured laboratory tasks (e.g., free play, compliance, and problem-solving tasks), and found consistent positive relations between EDA variability and core ASD symptom levels as measured through direct assessment (Fenning et al., 2017).

Electrodermal Activity and Externalizing Behavior Problems

Sympathetic nervous system under-arousal has been identified as a relatively reliable risk factor for the emergence of externalizing behavior problems among children without neurodevelopmental disorders (see Cappadocia et al, 2009). Two theories have been proposed to explain this link. *Fearlessness theory* (Raine, 1993) posits that sympathetic under-arousal reflects a lower physiological response to threat and/or disciplinary consequences, reducing the children's sensitivity to social conditioning (Cappadocia et al., 2009). *Stimulation-seeking theory* proposes that the relatively stable low arousal state indexed by reduced EDA may be experienced as unpleasant by children, who may then be drawn to engage in disruptive or antisocial behavior in order to increase arousal (Cappadocia et al., 2009; Raine, Venables, & Mednick, 1997). These theories are not contradictory and in fact can be combined to understand why certain externalizing behavior may be appealing to particular children seeking stimulation, who would then also be less inclined to inhibit problematic behavior due to diminished fear of consequence. Supporting these theories is a host of evidence showing that low sympathetic nervous system arousal, as indexed by low resting EDA and a less intense EDA response to certain stimuli, is associated with risk for conduct problems in children (Beauchaine, 2001; El-Sheikh & Erath, 2011; Lorber, 2004). Despite the wealth of information on the development of externalizing problems in children with otherwise typical development, no study to our knowledge has examined under-arousal theory as a potential explanatory model for the emergence of co-occurring externalizing problems in children with ASD.

Interactions Between EDA and Parenting in the Prediction of Externalizing Problems

Consistent with a person-by-environment perspective (Cicchetti, 2006), sympathetic under-arousal may interact with environmental factors to impart risk for externalizing problems. Utilizing both cross-sectional (Erath, El-Sheikh, & Cummings, 2009) and longitudinal designs (Erath, El-Sheikh, Hinnant, & Cummings, 2011), Erath and colleagues found that parenting behaviors moderated links between EDA reactivity and externalizing problems such that problems were most evident in the context of both EDA under-arousal *and* exposure to harsh parenting (see also Kochanska, Brock, & Boldt, 2016; Kochanska, Brock, Chen, Aksan, & Anderson, 2015). The authors proposed that harsh parenting methods may be particularly detrimental for children with low arousal, who may also be more apt to engage in negative responses that can trigger coercive parent-child interactions. Conversely, Kochanska et al. (2015) found that father-child mutually responsive orientation was associated with lower externalizing problems among children with low EDA but not among children with high EDA, suggesting that positive parenting may be particularly protective for children with low arousal.

While neither harsh nor positive parenting has been examined as a moderator of links between psychophysiological risk and psychosocial outcomes in children with ASD, several parenting factors have been shown to promote resilience in children with early developmental risk and/or ASD. Supportive parent-child interactions, such as those that involve scaffolding, sensitive structuring, and dyadic attunement, seem to reduce social skill and adaptive behavior deficits in children with early cognitive risk (Baker et al., 2007; Fenning & Baker, 2012), and have predicted increased language development and empathy in young children with ASD (Baker, Messinger, Lyons, & Grantz, 2010; McDonald, Baker, & Messinger, 2016). Emerging evidence also suggests that better parental scaffolding may relate to fewer externalizing problems in children with ASD (Ting & Weiss, 2017). There are many mechanisms by which supportive parenting could buffer physiological risk for externalizing problems. First, parent provision of clear and reasonable instructions, appropriate structure, and sensitive limit-setting represent key components of parent-training programs successful at reducing externalizing problems in children (see Thomas & Zimmer-Gembeck, 2007 for a review). Moreover, positive parenting strategies contribute to higher quality parent-child relationships, which some evidence suggests may be key to moral internalization in behaviorally uninhibited or fearless children (Kochanska, 1997). Outside of a compliance or limit-setting context (which is most relevant to fearlessness theory), it is also possible that parent behaviors that can positively engage, motivate, and focus children may also increase more functional child arousal (e.g., enthusiasm, concentration) and reduce the likelihood of inappropriate stimulation-seeking.

The Current Study

Aims of the current study were to examine EDA under-arousal, in the form of lower NSCRs, as a predictor of parent-reported externalizing problems in children with ASD between the ages of 4 and 11 years, and to consider parent co-regulatory scaffolding as a potential buffer of this risk. As conceptualized and measured in previous studies of children with ASD and related disorders (e.g., Baker et al., 2007; Ting & Weiss, 2017) scaffolding involves the parents' ability to successfully support their children through a challenging task, including the provision of developmentally-appropriate motivational, emotional, and technical assistance (Baker et al., 2007). We predicted that children with lower NSCRs would be reported to have higher externalizing problems (Hypothesis 1), and that this relation would be weaker in the context of higher quality parental scaffolding (Hypothesis 2). We examined children's EDA reactivity across a series of structured laboratory tasks, in order to obtain more robust and ecologically-valid measurement of reactivity, as well as to consider the possibility of context-specificity in measured EDA response (Fenning et al., 2017). Much of the cross-context investigation was somewhat exploratory; however, consistent with fearlessness theory, we did predict that relations between EDA under-arousal and externalizing problems would be particularly salient when EDA was measured in tasks specifically designed to elicit child compliance/defiance (Hypothesis 3).

Method

Participants

Participants included 40 children with ASD between the ages of 4 and 11 years, and their primary caregivers (see Table 1). The sample was diverse with regard to race/ethnicity, socioeconomic status, intellectual ability, and ASD symptom levels. Children with an existing diagnosis of ASD provided by a physician or psychologist were recruited from the community. Exclusionary criteria for the child included the presence of a genetic disorder of known etiology, measured IQ below 40 (to address task validity considerations), and motor impairment that would prevent independent ambulation. One child was on stimulant medication at the time of the visit. Outcome data for one child were unavailable and are not included in the final regressions.

Procedures

All procedures were approved by our institutional review board and informed consent was obtained from all individual participants included in the study. Parents consented for themselves and for their children, and assent was obtained from the children following a standardized, IRB-approved script. After obtaining consent, the primary wireless EDA sensors were placed on the outer right wrist of each child (as recommended by Picard et al., 2015). Approximately three-quarters of the children also easily tolerated an additional sensor on the left wrist, and high reliability across sites has been reported (Fenning et al., 2017). A short introductory period followed in which the child became accustomed to the sensors while the parent and the experimenter discussed the visit (*M* = 5.18 min, *SD* = 3.03). The dyads then engaged in a series of established parent-child and child-alone laboratory tasks in a room set at 74 degrees Fahrenheit. The five tasks, described below in the standardized order in which they were performed, were grouped into three conceptual categories: parent-child compliance tasks (2 tasks), goal-oriented problem-solving tasks (2 tasks), and parent-child free play (1 task). All of the tasks have been used in previous studies of children with developmental disabilities and/or ASD (e.g., Baker et al., 2007, 2010, 2015; Fenning et al., 2017; Jahromi et al., 2012). The visit concluded with administration of a measure of ASD symptoms performed by a licensed clinical psychologist with expertise in ASD.

***Prohibition Task (Compliance Task 1;* Baker et al., 2007; Fenning et al., 2017; Kochanska et al., 1998)—**The experimenter guided the parent and child to a large room with a clear open box containing desirable toys placed on the floor. The dyad was seated across the room from the toys, with the child facing the toys and the parent seated to the child's left. The child was asked not to touch the toys until the experimenter returned. The parent was provided with a set of questionnaires to complete, but was instructed to help the child resist touching the toys if necessary. The child was given an uninteresting toy (a wooden apple) with which to play during the delay. The experimenter returned after four minutes.

***Free Play* (Baker et al., 2007; 2010; 2015; Fenning et al., 2017: McDonald et al., 2016)—**Following completion of the prohibition task, the parent and child were asked to play with the toys together as they typically would at home. The dyad was left to play for four minutes.

***Clean-Up Task (Compliance Task 2;* Baker et al., 2007; Fenning et al., 2017; Kochanska et al., 1998)—**Prior to beginning the free play, the experimenter privately informed the parent that a knock would occur on the observation window after a few minutes of play to signify that the parent should tell the child to clean up the toys. The experimenter knocked to initiate the cleanup at the end of the free play. Three minutes were allotted for the clean-up task, but EDA was considered only during the active clean-up period (defined by the time required to return all toys to the designated box).

***Dyadic Problem-Solving Task* (*Problem-Solving Task 1*; Baker et al., 2007; Fenning et al., 2017)—**The dyad was positioned at the corner of a table, with the parent to the child's left. The dyad was provided with 32 colorful block tiles and a photo of a completed fish puzzle. The child was instructed to make the structure depicted in the photo. The parent was asked to let the child try it on his or her own, and then to provide any help that the parent deemed necessary. The experimenter returned after five minutes.

***Frustration Task* (*Problem-Solving Task 2;* Fenning et al., 2017; Jahromi et al., 2012)—**Children participated in a five-minute "locked box" frustration task alone. The child was asked to select a favorite item from a selection of prizes and the item was placed in a translucent hard-plastic box, which was then locked with a padlock. The experimenter demonstrated using a key to open the lock and retrieve the prize. The child was given a keychain with 15 visually similar, non-functional keys. The experimenter instructed the child to try to find a key that would open the box and allow him/her to get the toy. After five minutes, the experimenter returned and informed the child that he/she was given incorrect keys. The child was then provided with a set of appropriate keys and he/she had the opportunity to retrieve the prize.

Measures

Child IQ—An estimate of child IQ was obtained using the SB5 ABIQ (Roid, 2003). The ABIQ is comprised of two subscales with high loading on *g*: a Matrix Reasoning task that assesses non-verbal fluid reasoning and a Vocabulary task that evaluates expressive word knowledge. The SB5 has sound psychometric properties and has been used previously for children with ASD (Baker et al., 2015; Fenning et al., 2017; Matthews et al., 2015; Roid, 2003).

ASD symptoms—Level of ASD symptoms was assessed through direct testing with the Autism Diagnostic Observation Schedule-2 (ADOS-2; Lord et al., 2012), a semi-structured assessment that facilitates observation and recording of child behaviors related to language, social communication, play, repetitive behaviors, and restricted interests. The ADOS-2 comparison score was used to characterize the sample according to overall ASD symptom severity. The comparison score allows for examination of symptomatology across different modules, with *1* indicative of minimal to no evidence of ASD-related symptoms, and *10* reflecting a high level of symptoms. The ADOS-2 comparison score was also considered as a potential covariate in examining the association between EDA and child externalizing problems. We did not anticipate a significant relation between externalizing behavior problems and symptomatology as measured by the ADOS-2 given a lack of such findings between these factors in several prior studies (e.g., Hill et al., 2014; Mazefsky, Anderson, Conner, & Minshew, 2011; Sikora, Hall, Hartley, Gerrard-Morris, & Cagle, 2008). Nonetheless, this association was examined in light of our prior work linking EDA with ASD symptom severity (Fenning et al., 2017). The majority of the children received the ADOS-2 Module 3 (64%), while 24% received Module 2 and 13% received Module 1. Two children did not meet current criteria for ASD on the ADOS-2 but were retained due to established diagnoses by local developmental pediatricians with expertise in ASD, and having met criteria on the Social Responsiveness Scale (Constantino & Gruber, 2012), a widely-used parent report measure of ASD symptoms.[1]

Electrodermal activity (EDA)—EDA was recorded in microsiemens (*us*) at 8 hertz using watch-like wireless *Affectiva* Q-Sensors (Picard et al., 2015). The sensors utilized 12mm Ag/AgCl dry disc electrodes and data were recorded and stored within the sensor itself. Although measurement from the wrist is less standard, it is reliable with traditional measurement locations, may be more sensitive under certain conditions, and has demonstrated validity for children with ASD (Baker, et al, 2015; Fenning et al., 2017; Sano

[1]Final analyses were performed with and without these children and are reported.

et al., 2014; van Dooreen et al., 2012). The sensors also recorded movement data, which were summed for each task and considered as a potential covariate. Data from the right wrist were used in the current study (as recommended by Picard et al., 2015), although high reliability across sites has been noted in our previous studies (Fenning et al., 2017).

The degree of variability of EDA for each child within each task was measured through calculation of non-specific skin conductance responses (NSCRs). NSCRs (Beauchaine et al., 2015; Dawson et al., 2000) were calculated with the use of an algorithm that determined the number of EDA increases of at least .03*us* over a period of three seconds.[2] Previous analyses of these data established psychometric support for this method, demonstrating high reliability across tasks and sensor sites, and validity with alternative measures of EDA variability (e.g., the use of the *SD*), and with ASD symptomatology (Fenning et al., 2017). NSCRs for the clean-up task were adjusted by the duration of the active time to account for across-child variability in length. NSCRs from the clean-up and prohibition task ($r = .46$, $p < .01$) were standardized and averaged to produce the EDA compliance task scores, and those from the dyadic problem-solving task and the frustration task ($r = .67$, $p < .001$) were similarly combined to generate the composite of EDA during the problem-solving tasks.

Scaffolding—Parental support was coded through videotapes of the dyadic problem-solving task (Problem-Solving Task 1), using the Parental Scaffolding Observation System (Hoffman, Crnic, & Baker, 2006). This system considers parents' ability to provide motivational, emotional, and technical support to their children during a challenging activity. Motivational scaffolding includes the ability of the parent to recruit the child's attention to the task, foster enthusiasm for the task, and to refocus the child should he or she become distracted. Emotional scaffolding scores reflect parents' ability to provide co-regulatory emotional support to the children (e.g., through affective attunement, modeling, calming, and/or direct emotion coaching) and to contribute to the children's feelings of accomplishment. Technical scaffolding evaluates the parent's ability to provide structure and support for the child with regard to the task through instruction, guidance, prompting, and/or modification of the task or goal. Each of these subscales are rated from 1 (*very low or absent support*) to 5 (*characteristically high support*). Although these subscales can be used individually, the scores are highly positively correlated and the measure is most commonly used as a single overall score (Baker et al., 2007). Although this system has been used with children both with and without developmental delays (Hoffman et al., 2006), scaffolding scores have demonstrated particular utility for children with delays and/or ASD (Baker et al., 2007; Fenning & Baker, 2012; Gulsrud, Jahromi, & Kasari, 2010; Ting & Weiss, 2017). Inter-rater reliability based on 43% of cases was *ICC* =.73.

Externalizing behavior problems—Externalizing problems were indexed by parent report using the standardized *T*-score from the age-appropriate version of the Child Behavior

[2]Data cleaning procedures, outlined in (Fenning et al., 2017) included consideration of any data that were either too high or increased too quickly to be attributable to physiological processes, as well as any increase directly following a significant decrease in EDA, which could have reflected loss of contact with the sensor and subsequent re-connection. Such artifacts were extremely rare and new data correlated with original data very highly (e.g., $r = .999$).

Checklist (Achenbach, 2009), a widely-used measure with demonstrated validity in children with ASD (e.g., Pandolfi, Magyar, & Dill, 2009; 2012).

Data Analysis

Descriptive data and correlations among the variables of interest were initially examined. Any demographic or contextual (e.g., sensor movement) factor that was associated with the outcome variable was controlled in the final analyses. Three hierarchical regressions were performed, one for each of the EDA task predictors. Previous research with this sample suggested some task specificity in EDA scores (Fenning et al., 2017), and the high multi-collinearity precluded including these in the same regression. For each regression, any covariates, the task-specific EDA, and scaffolding were entered on the first step, with the interaction term entered on the second step. Some missing data that were to be composited were represented by scores from the similar context (see below). Remaining missing data were estimated through multiple imputation across 10 data sets.[3]

Results

As is often the case in psychophysiological research, some data were missing due to equipment malfunction and/or child removal of sensors. Compliance scores from children who were missing data from the prohibition task but who had valid data from the clean-up (n =3) were represented by the standardized score of the latter task. Problem-solving composite scores for children missing data for the dyadic problem-solving task but who had data from the locked box (n =2) were represented by the latter task. Due to high reliability across measurement sites (Fenning et al., 2017), left hand data were used for one child for whom the right sensor malfunctioned, and one child wore the sensor on the right ankle.[4] Total sample sizes for the final variables can be found in Table 2.

The mean externalizing behavior score was similar to that of previous studies (e.g., Stoppelbein, Biasini, Pennick, & Greening, 2016) and fell at the upper limit of the borderline clinical range, with about half (49%) of the children exhibiting clinically-significant externalizing problems. Consistent with (Fenning et al., 2017), high correlations were observed between EDA scores across the various task groupings. EDA was only related by correlation to externalizing behaviors as measured in the compliance tasks, although relations involving the other tasks were in the expected directions and did not differ significantly from the compliance correlation. Scaffolding was unrelated to child EDA.

ADOS-2 comparison scores ($r = -.25$, $p = .12$), child IQ ($r = .07$, $p = .67$), and average task movement (ranging from $r = .04$, $p = .83$ to $r = .19$, $p = .29$, for each task) were not significantly related to externalizing behavior problems and these data were therefore not controlled in subsequent analyses. Child age was controlled in the final analyses due to a trend-level association with externalizing scores and a significant correlation with EDA in

[3]Complete case analyses were also performed and did not differ from those reported, with the exception of the emergence of significant relations for child age in the problem-solving regression.
[4]The ankle data were all within the normal range, and patterns and significance of study findings were unchanged with these data removed.

certain contexts (see Table 2). All other demographic variables considered (e.g., child race, gender, and family income) were not significantly related to externalizing behavior scores.

As seen in Table 3, the main effect of EDA during free play on externalizing behaviors was a non-significant trend, and the interaction between free-play EDA and scaffolding was not significant. In the second regression, lower EDA NSCRs during the compliance tasks predicted higher externalizing behavior problems (accounting for 16% of variance; Cohen's f^2 = .21; CI = −11.02 to −2.54), and this relation was not moderated by scaffolding. Finally, in the third regression, while EDA measured during the problem-solving tasks was not directly related to externalizing problems, the interaction between EDA and scaffolding was significant, accounting for 15% of the variance, Cohen's f^2 = .22, CI = 1.92 to 14.37.[5]

The significant interaction between EDA during problem solving and scaffolding was probed in several ways, in accordance with recommendations from Roisman et al. (2012). First, EDA-externalizing slopes were estimated at the mean for scaffolding, as well as 1 *SD* above and 1 *SD* below the scaffolding mean using Modgraph-I (Jose, 2013; see Figure 1). Simple slope computations determined that only the low scaffolding slope was significant, $t = -2.72$, $p = .01$, indicating that EDA under-arousal during the problem-solving tasks only predicted higher externalizing problems in the context of low parental scaffolding. Regions of significance (RoS) analysis (Roisman et al., 2012) indicated that the association between lower EDA and higher externalizing problems was significant at scaffolding values less than −0.25 *SD* (scale value 3 or below, out of 5). The association between EDA and externalizing problems was not significant at the high end of scaffolding (RoS exceeded true scale values, at 5.81 out of 5).

Evidence that scaffolding moderated the association between EDA during problem-solving and externalizing problems, but not the association between EDA during compliance situations and externalizing problems, might stem in part from the fact that scaffolding was measured during one of the problem-solving tasks. To consider this possibility, interaction analyses were performed for the individual problem-solving tasks separately. The interaction between scaffolding and EDA emerged for both the dyadic problem solving task, $\beta = .47$, $t = 2.76$, $p < .05$, and the locked box task (the task in which the parent was not present), $\beta = .38$, $t = 2.19$, $p < .05$, suggesting that the context-specific findings were not inflated by shared measurement.

Discussion

The present study tested whether sympathetic nervous system under-arousal predicted individual differences in co-occurring externalizing behavior problems among children with ASD, and whether supportive co-regulatory parenting buffered this risk. Consistent with fearlessness theory (Cappadocia et al., 2009; Raine, Venables, & Mednick, 1997) and a large body of empirical evidence in children without ASD (e.g., Beauchaine, 2001; Erath et al., 2011), hypoactivation of electrodermal activity (EDA) during parent-child compliance interactions was a clear correlate of higher parent-reported child externalizing problems, with a medium effect size observed. Although replication with a larger sample and a longitudinal design would be useful, these finding suggest that certain biobehavioral processes responsible for the emergence of conduct problems in children with otherwise typical development may inform understanding of such heterogeneity in ASD.

Our findings also underscore the complexity of associations between EDA and behavior in children with ASD. Prior studies examining EDA and individual differences in social functioning and core symptomatology in this population have revealed inconsistent results, with a tendency towards identifying *higher* EDA reactivity as more problematic for social functioning (Faja et al., 2013; Fenning et al., 2017; Joseph et al., 2008; Kaartinen et al., 2012; Louwerse et al., 2013; McCormick et al., 2014; Neuhaus et al., 2015; Stagg et al., 2013). In contrast, outcome measurement in the current study focused on externalizing behaviors and in doing so, identified an alternate profile suggestive of problematic hypoactivation.

The autonomic nervous system is complex, and questions about risk require consideration of numerous factors, including when, how, and in what context responding occurs, as well as the specific type of functioning included as a focus for outcome measurement (Bunford et al., 2016). The processes by which EDA reflects risk for externalizing problems versus ASD symptoms may be relatively distinct, as the sympathetic nervous system is likely involved in development in a number of ways. For example, higher EDA may reflect physiological warning signals (i.e., sensitivity to consequences) that underlie risk assessment and impulse control and thereby reduce risk for externalizing behaviors (Beauchaine, 2001; Beauchaine et al., 2015; McNaughton & Corr, 2004), but higher EDA may also reflect greater expenditure of inhibitory control resources (e.g., expressive suppression; Gross, 1998; Sheppes, Catran, & Meiran, 2009) among children with more severe ASD symptoms, who may encounter more demands for risk assessment and impulse control related to their symptomatology.

Prediction of risk for comorbid externalizing behavior problems in children with ASD has clear implications for application. Although early intensive behavioral intervention has demonstrated effectiveness for children with ASD as a group, some children benefit more than others, and relatively few factors appear to clearly predict treatment response (Howlin, Magiati, & Charman, 2009; Smith, Klorman, & Mruzek, 2015). Given that disruptive and non-compliant behaviors are a commonly acknowledged impediment to learning (Koegel, Koegel, & Surratt, 1992), identification of risk for these tendencies may be key to optimizing treatment. Furthermore, low sympathetic arousal tendencies are believed to be somewhat stable, thus this risk could conceivably be identified prior to the initiation of treatment. Researchers have already begun exploring these ideas in the treatment of children with ADHD. Beauchaine and colleagues (2015), found that child EDA NSCRs moderated the effect of parent training such that treatment was less effective for children who exhibited baseline under-arousal. Much like treatment for ADHD, behavioral interventions for children with ASD are heavily focused on gaining compliance and increasing motivation through delivered consequences (Lovaas, 2002), thus sympathetic responding may represent a critical source of information in the treatment process.

Direct links between sympathetic under-arousal and externalizing problems were weaker when EDA was measured during tasks designed to elicit enjoyment or self-regulation in the context of problem-solving. This appeared to be at least partially due to the potential for parent support to buffer this risk, with a medium-sized effect observed for the interaction between scaffolding and EDA in the regulation context. The tendency for parenting to moderate links between sympathetic nervous system risk and child externalizing behavior problems is consistent with previous work (Erath et al., 2009, 2011; Kochanska et al., 2015, 2016). The fact that this interaction in the current study was observed for parent-child problem solving tasks and not for compliance contexts may stem from the nature of the parenting variable considered. Previous work has most often focused on harsh parenting and our study considered the role of positive parent co-regulatory support, which has been most consistently linked to positive outcomes in children with developmental risk (Baker et al., 2007; Baker et al., 2010; Fenning & Baker, 2012), and is thought to be most proximal to child regulatory contexts (Baker et al., 2007). It is possible that addressing parental support more closely tied to the nature of compliance situations (e.g., negative control versus inductive discipline) may reveal moderation by parenting in compliance contexts as well. Alternatively, the much higher direct relationship between sympathetic under-arousal during compliance situations and externalizing problems may suggest less room for parenting to influence relevant processes. In either case, results of the present study point to the value of context-specific assessments of parenting and physiology.

The protective function of parental scaffolding for children with ASD and low EDA is consistent with evidence that typically-developing children who are fearless or autonomically under-aroused especially benefit from a warm, mutually cooperative parent-child relationship, rather than from increased parental disciplinary pressure (e.g., Kochanska, 1997; Kochanska et al., 2015). Furthermore, parental scaffolding, in particular, may serve protective functions similar to the BIS for children with low EDA. For example, parental scaffolding should facilitate children's engagement and attention to the cues and demands of problem-solving challenges, and thus prevent active avoidance or impulsive responses. Results of the present study suggest that parental scaffolding may be particularly protective against externalizing behaviors for children who are less inclined to engage cautiously with problem-solving challenges, as potentially reflected in low EDA (McNaughton & Corr, 2004).

The buffering potential of scaffolding during regulatory tasks may also be understood in the context of stimulation-seeking theory. A large part of effective scaffolding is the ability of the parent to positively motivate the child, promote the child's success, and foster feelings of accomplishment. In the context of this type of positive encouragement, an under-aroused child may feel less boredom and less urge to increase stimulation through more disruptive behaviors. The ability to increase motivation to learn is a key component of behavioral intervention for children with ASD (Lovaas, 2002), and the current findings may suggest an important route for further tailoring behavioral supports, particularly with regard to parent involvement. The significance of evidence that parental scaffolding can be protective against externalizing problems for under-aroused children with ASD is underscored by the ubiquity of problem-solving contexts that require emotion regulation in childhood.

The primary limitation of the present study was our sample size, which was adequate for the regressions performed but relatively modest for testing moderation. Our study utilized new technology, thus the degree to which findings would be replicated with traditional measurement is unknown. Given the centrality of the self-regulation tasks to the moderation findings, it would be useful to augment the measurement of sympathetic arousal with consideration of parasympathetic nervous system activity (e.g., vagal tone), which is thought to more closely index regulatory abilities in children (Beauchaine, 2001). Future research with finer-grained behavioral outcome assessments would also be informative, given some evidence that lower EDA is associated with proactive externalizing behaviors whereas higher EDA is associated with reactive externalizing behaviors (e.g., Hubbard, McAuliffe, Morrow, & Romano, 2010). Although the lack of control for time of day and humidity in the room did not likely confound our findings (were not likely related to externalizing problems), such control might be useful for future studies utilizing EDA. Finally, this study was cross-sectional, and longitudinal examinations may provide additional information regarding casual direction. The present study is the first to examine sympathetic under-arousal as a specific risk factor for co-occurring externalizing behavior problems in children with ASD. Although replication with a larger sample and with additional measurement methods is required, findings highlight EDA under-arousal as a promising area of study with clear implications for tailored interventions for children and families.

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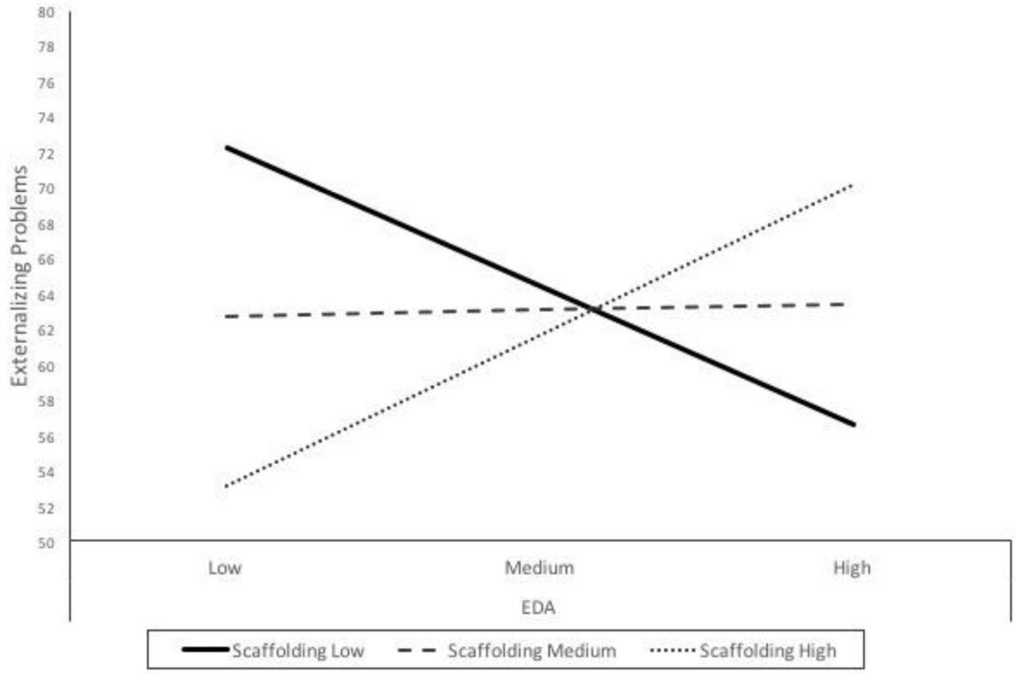

Figure 1.
Scaffolding as a moderator for the association between electrodermal activity (EDA) during problem-solving tasks and children's externalizing problems.

Table 1

Sample Demographic Information.

Variable	
Child	
Mean age	6.40 (2.00)
Mean estimated IQ	84.69 (23.41)
Range estimated IQ	47 – 139
Male (percent)	80 %
Race/Ethnicity	
Caucasian, not Hispanic	46 %
Caucasian, Hispanic	26 %
Asian American	13 %
African American	8 %
“Other”	8 %
ASD symptom level	7.18 (2.17)
Primary caregiver	
Married (percent)	85 %
Father was primary caregiver (percent)	5 %
Median annual family income	US $50,000 – $70,000

Table 2

Descriptive Statistics and Correlations among Variables of Interest.

	Valid *n*	1	2	3	4	5	Mean (*SD*)
1. Child Age	40	--					6.40 (2.00)
2. EDA Free Play	34	−.33*	--				4.46 (8.42)
3. EDA Compliance	37	−.31+	.87***	--			−.01 (.84)[a]
4. EDA Problem-Solving	39	−.12	.78***	.80***	--		.02 (.95)[a]
5. Scaffolding	39	.03	−.19	−.02	−.17	--	3.30 (1.15)
6. Externalizing Problems	39	−.27+	−.22	−.33*	−.12	−.09	62.92 (11.97)

Note: EDA = Electrodermal activity

[a]These EDA composites were constructed by averaging standardized scores.

*** $p<.001$,

* $p<.05$,

+ p =.10

Table 3

Hierarchical Linear Regressions Predicting Externalizing Problems from Electrodermal Activity (EDA) and Scaffolding (pooled estimates).

	B	*SE*	β^{a}	*t*	*p*	$R^{2\,a}$
Free Play						
Step 1:						
Child Age	−2.15	0.98	−.36	-2.20^{*}	.03	.17
EDA Free Play	−3.98	2.11	−.31	1.89+	.06	
Scaffolding	−1.53	1.93	−.12	−0.79	.43	
Step 2:						
Child Age	−2.01	0.97	−.34	-2.07^{*}	.02	.23
EDA Free Play	−3.11	2.17	−.24	−1.44+	.15	
Scaffolding	−0.62	2.02	−.04	−0.31	.76	
EDA x Scaffolding	3.54	2.78	.25	1.27	.21	
Compliance Tasks						
Step 1:						
Child Age	−2.31	0.94	−.39	-2.45^{*}	.01	.19
EDA Compliance Tasks	−5.52	2.03	−.43	-2.73^{**}	.01	
Scaffolding	−0.48	2.03	−.04	−0.23	.82	
Step 2:						
Child Age	−2.19	0.93	−.37	-2.35^{*}	.02	.22
EDA Compliance Tasks	−5.67	1.99	−.44	-2.86^{**}	.00	
Scaffolding	−0.14	1.94	−.01	−0.07	.94	
EDA x Scaffolding	2.74	2.18	.21	1.25	.21	
Problem-Solving Tasks						
Step 1:						
Child Age	−1.67	0.98	−.28	-1.71^{+}	.09	.10
EDA Problem-Solving	−1.77	2.07	−.14	−0.85	.39	
Scaffolding	−0.51	1.97	−.05	−0.26	.80	
Step 2:						
Child Age	−1.66	0.93	−.28	-1.78^{+}	.07	.25

	B	SE	β^{a}	t	p	$R^{2\,a}$
EDA Problem-Solving	−1.42	1.93	−.10	−0.73	.46	
Scaffolding	1.03	1.93	.07	0.53	.60	
EDA x Scaffolding	7.63	3.36	.40	2.27*	.02	

[a]These scores were derived from averages across all imputed data.

** $p < .01$,

* $p < .05$,

+ $p < .10$