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Linking ADHD and ASD Symptomatology with Social Impairment: The Role of Emotion Dysregulation

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Abstract

Children with attention-deficit/hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) often experience social impairments. These children also frequently struggle with emotion regulation, and extant literature suggests that emotion dysregulation predicts social impairment in both clinical and neurotypical populations. However, the evidence base linking ADHD/ASD with social impairment comes primarily from samples meeting full diagnostic criteria for ADHD and/or ASD despite evidence that both syndromes reflect extreme ends of natural continuums that are normally distributed across the general population. To our knowledge, the present study is the first to concurrently examine unique and overlapping relations among ADHD/ASD symptoms, emotion regulation, and social difficulties using multi-informant measures (parent, teacher) with a clinically-evaluated sample of 108 children ages 8–13 (40 girls; 66% White/Non-Hispanic) with and without clinically-elevated ASD and ADHD symptoms and other common clinical disorders. Bias-corrected, bootstrapped conditional effects modeling revealed that ADHD-inattentive (β=-0.23) and ASD-social communication (β=-0.20) symptoms predicted social impairment directly, whereas ADHD-hyperactive/impulsive (β=-0.06) and ASD-restricted/repetitive behavior/interests (β=-0.06) symptoms predicted social impairment only via their shared associations with emotion dysregulation. Sensitivity analyses revealed that most relations were robust to control for item overlap across measures. In contrast, only the ADHD-inattention/social impairment link was robust to control for mono-informant bias, highlighting the importance of multi-informant methods and the potential for different determinants of social functioning across settings. Overall, this study implicates emotion regulation skills and all four ADHD/ASD symptom clusters as potential influences on children's social functioning, albeit with a more nuanced and potentially setting-specific pattern than suggested by prior work.

Keywords Autism · ADHD · emotion dysregulation · social competence

Attention-deficit/hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) are strongly associated with emotion regulation difficulties and social impairment (e.g., Bunford et al., 2015; Neuhaus et al., 2019; England-Mason, 2020; Samson et al., 2014; Shaw et al., 2014). Identifying the unique and overlapping mechanisms that link ADHD and ASD with social impairments is imperative given the differences in each disorder's response to evidence-based social skills training regimens (de Boo & Prins 2007; Freitag et al., 2016). Further, replicated evidence emphasizes the need to consider conditions such as ASD (Constantino & Todd, 2003; Robinson et al., 2011) and ADHD (McLennan, 2016) as extreme ends along a natural continuum of characteristics that are normally distributed across the general population, and children who exhibit sub-threshold ADHD and/or ASD symptoms also stand to benefit from targeted social competence training (Kamio et al., 2013; Kirova et al., 2019). Current evidence-based social skills interventions typically involve children practicing prosocial behaviors such as cooperation, conversation basics, perspective

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taking, and group entry techniques during clinic-based social skills groups (Antshel & Remer, 2003; Reichow et al., 2012). Despite their widespread use, the preponderance of evidence indicates that this approach is unsuccessful for children with clinically elevated ADHD symptoms (de Boo & Prins 2007; Storebø et al., 2019) and does not consistently yield lasting effects for children with clinically elevated ASD symptoms (Dekker et al., 2019; Olsson et al., 2017; Soorya et al., 2015). This provides a compelling impetus for basic research aimed at identifying underlying mechanisms/maintaining factors for social difficulties. The current study is the first to test the extent to which emotion regulation difficulties may reflect an underlying mechanism linking ADHD and/or ASD symptoms with social difficulties in a clinically diverse sample of children with and without ADHD, ASD, and/or other common clinical child disorders.

ADHD Symptoms, ASD Symptoms, and Emotion Dysregulation

ADHD symptoms and emotion dysregulation. Emotion regulation refers to an individual's behavioral, physiological, and cognitive experience of emotion and one's skill at modulating the occurrence and intensity of emotional expression and arousal (Berkovits et al., 2017; Bunford et al., 2015; Zelkowitz & Cole, 2016). It is common for children with elevated ADHD symptoms to experience emotion regulation difficulties, with an estimated 48–54% of diagnosed pediatric ADHD cases displaying clinically significant levels of emotion dysregulation (Graziano & Garcia, 2016) that continue into adulthood for an estimated 30–70% of these individuals (Shaw et al., 2014). Extant research indicates that individuals with clinically elevated ADHD symptoms and emotion regulation difficulties are significantly more impaired in peer relationships, family life, occupational attainment, and academic performance than those with clinically elevated ADHD symptoms alone, even when controlling for comorbid disorders (Shaw et al., 2014; Wehmeier et al., 2010). The current study builds on this evidence base by investigating the extent to which emotion dysregulation reflects a potential mechanism linking ADHD symptoms with impairments in social functioning. To further expand upon the literature, the present study examines ADHD symptoms dimensionally rather than categorically (ADHD vs. non-ADHD) to reflect the natural continuum on which ADHD symptoms present in the general population (McLennan, 2016). The study also controls for the ASD symptoms that commonly co-occur in children exhibiting ADHD symptoms, as ASD has been linked with both emotion dysregulation and social problems as described below.

ASD symptoms and emotion dysregulation. It is unclear exactly what percentage of children with clinically elevated ASD symptoms experience emotion regulation difficulties because these difficulties are often overlooked or conflated with core symptoms of the disorder despite being neither necessary nor sufficient for a diagnosis of ASD (Berkovits et al., 2017; England-Mason, 2020; Goldsmith & Kelley, 2018). Impairments related to emotion dysregulation among youth with clinically elevated ASD symptoms are extensive, including increased risk for social anxiety, depression, withdrawal, irritability, aggression, heightened sensory reactivity, psychiatric hospitalization, and increased cost of illness (Croen et al., 2006; Goldsmith & Kelley, 2018; Mazefsky et al., 2013, 2014; Neuhaus et al., 2019; Samson et al., 2014; Swain et al., 2015). In addition, children with clinically elevated ASD symptoms and emotion regulation difficulties are at increased risk for developing more maladaptive coping strategies such as suppression, avoidance, and crying (Jahromi et al., 2012), which increasingly impair functioning across childhood, adolescence, and adulthood (Ballaban-Gil et al., 1996; Samson et al., 2012, 2014). However, less is known about the extent to which the ASD symptoms/emotion dysregulation link is attributable to specific ASD symptom clusters or better explained by the increased incidence of ADHD symptoms in children exhibiting ASD symptomatology, given that ADHD symptoms portend unique risk for emotion regulation difficulties as detailed above. The present study aims to better understand the nature of these relations while examining ASD symptoms dimensionally to reflect the natural continuum on which ASD symptoms present in the general population (Constantino & Todd, 2003; Robinson et al., 2011).

ADHD Symptoms, ASD Symptoms, and Social Impairment

ADHD symptoms and social impairment. Children with ADHD symptoms both above and below clinical thresholds have a high likelihood of experiencing social impairment (Bunford et al., 2015; Hoza, 2007; Kofler et al., 2015), with as many as 80% experiencing some level of peer rejection (Hoza et al., 2005; Pelham & Bender, 1982). Children with clinically elevated ADHD symptoms also have more difficulty performing learned social skills in the moment (Aduen et al., 2018; Kofler et al., 2018), and those exhibiting marked social impairment are rated as significantly more stressful to teach than students not exhibiting social impairment (Greene et al., 2002). Both core symptom clusters of ADHD – inattention and hyperactivity/impulsivity – have been linked with social impairment in children with elevated ADHD symptoms (Bunford et al., 2014; Kofler et

al., 2011). Identifying the mechanisms and processes that underlie social impairment in youth with ADHD symptoms is imperative given its association with both near- and long-term adverse outcomes, including risk for poor social adjustment, lower self-esteem, increased depressive symptoms, and antisocial behavior in childhood, adolescence, and adulthood (Kirova et al., 2019; Robins 1996).

ASD symptoms and social impairments. Social impairments are pervasive in individuals with threshold and subthreshold ASD symptoms (Carter et al., 2014; Kamio et al., 2013; Wagner et al., 2004). Both core symptom clusters of ASD – social communication/interaction deficits and restricted/repetitive behaviors/interests (RRBs) – have been linked to social impairments in children with clinically elevated ASD symptoms (Carter et al., 2014; Goldsmith & Kelley, 2018). For example, social communication deficits, including poor topic management, unusual intonation, and difficulties with paralinguistics associated with ASD may interfere with conversational reciprocity and contribute to difficulties forming age-appropriate friendships in childhood and maintaining friendships beyond middle-childhood (Knott et al., 2006; Paul et al., 2009). Similarly, ASD-related repetitive behaviors such as hand flapping, finger movements, body rocking, and vocal sequences (Rodrigues et al., 2013) are often perceived as unusual by typically developing peers and lead to exclusion from peer groups (Humphrey & Symes, 2010; Zeedyk et al., 2014). These social difficulties do not ameliorate with age; rather, they persist into adolescence and adulthood as the gap between these individuals' social skills and societal expectations widens (Carter et al., 2014; Rosenthal et al., 2013). Although the etiology, phenomenology, qualitative descriptions, and response to treatment of social difficulties in ASD and ADHD are often distinct (Harkins et al., 2021), emotion dysregulation represents a potential shared mechanism linking both ASD and ADHD symptoms with social impairment, given that emotion dysregulation is present in both disorders and has been linked with social competence.

Emotion Dysregulation and Social Impairment

In addition to prior work linking ADHD and ASD symptoms with both emotion dysregulation and social impairment, there is also evidence indicating a direct link between emotion regulation and social competence in children and adolescents (Carlo et al., 2012; Eisenberg et al., 2000; Rydell et al., 2007). For example, greater difficulties self-regulating emotions and attention have been associated with less frequent prosocial behavior with peers and family (Carlo et al., 2012). Similarly, longitudinal studies indicate that emotion regulation difficulties at age five predict underdeveloped social skills at age seven, which in turn predict lower peer acceptance, decreased friendship quality, and fewer emotion regulation skills at age ten (Blair et al., 2015). These studies are consistent with findings indicating that reduced use of developmentally appropriate emotion regulation strategies at age five predicts more social skill difficulties at age seven (Penela et al., 2015). However, less is known about the extent to which emotion regulation difficulties may reflect a mechanism linking ADHD and ASD symptoms with the well-documented social impairment associated with each disorder (e.g., Goldsmith & Kelley 2018).

ASD Symptoms, ADHD Symptoms, Emotion Dysregulation, and Social Impairment

While it is well established that emotion regulation is predictive of social success in typically developing children (Blair et al., 2015; Carlo et al., 2012; Penela et al., 2015), research investigating whether the same is true among children with ADHD and ASD symptoms is less extensive. Mounting evidence suggests that emotion regulation difficulties contribute to much of the social impairment that children diagnosed with ADHD experience (Lee at al., 2018). Indeed, some researchers have proposed that emotion dysregulation may be an underlying mechanism linking ADHD symptoms with social impairment (Bunford et al., 2015; Cleminshaw et al., 2020); however, less is known about the role of emotion dysregulation in the relation between ASD symptoms and social impairment. Further, to our knowledge, no study to date has concurrently examined the role of both ADHD (inattentive, hyperactive/impulsive) and both ASD (social communication/interaction deficits, restrictive/repetitive interests/behaviors/RRBs) symptom clusters when examining relations with emotion dysregulation and social impairment. This limitation is significant considering the moderate intercorrelations among ADHD and ASD symptom clusters (Clark et al., 1999; Stevens et al., 2016; Rodriguez-Seijas et al., 2020), as well as evidence that approximately 37–78% of children with ASD have comorbid ADHD (Stevens et al., 2016) and 22–38% of children with ADHD may have comorbid ASD (Reiersen et al., 2007; Ronald et al., 2008). This gap in the literature makes it difficult to discern whether the mechanistic roles of emotion regulation identified in previous studies are unique to ADHD symptoms, ASD symptoms, or both given the significant associations among ADHD and ASD symptom clusters (Bunford et al., 2015; Goldsmith & Kelley, 2018).

Current Study

Taken together, the evidence base at this time indicates that emotion regulation plays an important role in predicting social success in children and adolescents both with and without psychopathology (e.g., Blair et al., 2015, Greenberg et al., 1995; Zeman et al., 2006). This link may be especially pronounced in children with clinically elevated ADHD and ASD symptoms, as these children are predisposed to emotion regulation and social interaction difficulties (Barkley, 2010; Samson et al., 2014; Bunford et al., 2015; Goldsmith & Kelley, 2018). However, to our knowledge no study has concurrently examined the relations among ADHD symptoms, ASD symptoms, emotion dysregulation, and social impairment using a dimensional approach to capture the full spectrum of ADHD/ASD symptoms exhibited in the general population (McLennan, 2016; Robinson et al., 2011). We hypothesized that both ADHD (inattentive, hyperactive/impulsive) and both ASD (social communication, RRBs) symptom clusters would be associated with greater emotion regulation difficulties (Berkovits et al., 2017; Shaw et al., 2014) and reduced social competence (Carter et al., 2014; Kofler et al., 2018). We also hypothesized that emotion regulation difficulties would predict lower social competence even after controlling for ADHD and ASD symptoms (Eisenberg et al., 2000). Finally, we predicted that emotion regulation difficulties would reflect an intermediate effect linking ADHD/ASD symptoms with reduced social competence – i.e., that the relations between ADHD/ASD symptom clusters and social difficulties would be attributable, in part, to their shared interrelations with emotion regulation difficulties.

Method

Participants

The sample comprised 108 children aged 8 to 13 years ($M = 10.51$, $SD = 1.52$; 40 females) from the Southeastern United States, recruited by or referred to a university-based children's learning clinic through community resources (e.g., pediatricians, community mental health clinics, school system personnel, self-referral) from 2015 to 2018. All parents and children gave informed consent/assent. IRB approval was obtained/maintained. Sample ethnicity was mixed with 72 White (66.7%), 15 Black (13.9%), 10 Hispanic/Latino (9.3%), 10 multiracial children (9.3%), and 1 Asian child (0.9%).

All children and caregivers completed a comprehensive evaluation that included detailed, semi-structured clinical interviewing and multiple norm-referenced parent and teacher questionnaires. A detailed account of the comprehensive psychoeducational evaluation, differential diagnosis process, and study procedures can be found in the larger study's preregistration: [https://osf.io/nvfer]. The final sample included 55 children with either ADHD only (19) or ADHD and a common comorbidity other than ASD (36; 14 anxiety, 2 depression, 8 oppositional-defiant disorder/ODD, and 14 specific learning disorders). It also included 9 children with either ASD only (6) or ASD and a common comorbidity other than ADHD (3; 2 anxiety, 2 specific learning disorder). Lastly, the final sample included 2 children with comorbid ADHD/ASD; 18 children with one or more common clinical disorders but not ADHD or ASD (13 anxiety, 3 depression, 4 specific learning disorders); and 24 neurotypical children with no clinical diagnoses. Parents and teachers were instructed to rate children's behavior when the child was not taking psychostimulant medication, if applicable (29.0% of participants with ADHD were prescribed psychostimulants)[1]. Psychoeducational evaluations were provided to caregivers. Children were excluded from the larger study if they presented with gross neurological, sensory, or motor impairment; non-stimulant medications that could not be withheld for testing; or history of seizure disorder, psychosis, or intellectual disability.

Measures

ADHD Symptoms. ADHD symptoms were assessed using parent-reported raw scores from the ADHD Rating Scale for DSM-IV or -5 (ADHD-RS-4/5; DuPaul et al., 2016). The ADHD-RS-4/5 includes 18 items assessed on a 4-point scale (*never/rarely, sometimes, often, very often*). Psychometric support for the ADHD-RS-4/5 includes high internal consistency ($\alpha = 0.94$-0.97) and 6-week test-retest reliability ($r = 0.66$-0.93). Internal consistency in the current sample was $\alpha = 0.87$. Higher scores reflect greater quantity/frequency of ADHD symptoms.

ASD Symptoms. ASD symptoms were assessed using parent-reported raw scores from the Child Symptom Inventory (CSI-IV; Gadow et al., 2008). The CSI-IV includes 12 items assessed on a 4-point scale (*never, sometimes, often, very often)*. Psychometric support for the CSI-IV includes high internal consistency ($\alpha = 0.74$-0.94) and 4-week test-retest reliability ($r = 0.46$-0.87; Gadow & Sprafkin 2002).

[1] Results of the primary model reported below were unchanged when medication status (N/Y) was explored as an additional covariate, with one exception: The indirect effect of ASD RRB symptoms on social competence via emotion dysregulation was no longer significant (95%CI includes 0.0) despite the point estimate changing minimally (Beta = – 0.061 vs. – 0.055). Medication status did not uniquely predict social competence or emotion regulation (95%CIs include 0.0). This sensitivity analysis was added during the peer review process and thus should be considered exploratory.

Internal consistency in the current sample was $\alpha = 0.85$. Higher scores reflect greater quantity/frequency of ASD symptoms.

Emotion Dysregulation. Emotion dysregulation was assessed using parent-reported raw scores from the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000) Emotional Control subscale, which contains 9 items rated on a three-point Likert scale (*never a problem, sometimes a problem, often a problem*). Psychometric support for the BRIEF includes high internal consistency (α = 0.89-0.93), 3-week test-retest reliability ($r = 0.79$-0.92) and expected relations with other parent- and teacher-reports of emotion regulation (e.g., Reynolds & Kamphaus 2015). Internal consistency in the current sample was $\alpha = 0.76$. Higher scores indicate more difficulty with emotion regulation.

Social Competence. Social competence was assessed using parent-reported raw scores from the Social Skills Improvement System (SSIS; Gresham et al., 2010). Teacher-reported raw scores were included in the sensitivity analyses to assess the impact of mono-informant bias as described below. The SSIS includes 46 items assessing social skills across 7 domains (communication, cooperation, assertion, responsibility, empathy, engagement, and self-control) on a 4-point scale *(never, seldom, often, almost always*). The SSIS exhibits high internal consistency (α = 0.95-0.97) and 6- to 8-week test-retest reliability ($r = 0.82$–0.84; Gresham & Elliott 2008). Internal consistency in the current sample was $\alpha = 0.95$. Higher scores reflect greater social competence.

Data Analysis Plan

The study's primary analyses used conditional effects modeling (Hayes, 2017) with 5,000 bootstrapped samples using the R package lavaan (Rosseel, 2012) as implemented in JASP v.0.14.1 (JASP Team, 2021) to analyze the bias-corrected relations among ADHD (inattentive, hyperactive/impulsive) and ASD (social communication/interaction deficits, RRBs) symptom clusters, emotion dysregulation, and social competence. ADHD and ASD symptoms were modeled as predictors of emotion dysregulation rather than vice versa given empirical evidence and DSM-5 conceptualizations of emotion regulation difficulties as secondary outcomes of ADHD/ASD (Berkovits et al., 2017; Samson et al., 2014; Shaw et al., 2014). In addition, emotion dysregulation was modeled to predict reduced social competence based on prior experimental evidence (Rydell et al., 2007) as well as longitudinal studies demonstrating that early emotion regulation skills predict social competence later in life (Blair et al., 2015; Penela et al., 2015). Finally, ADHD and ASD symptoms were modeled as predictors of reduced social competence, rather than vice versa, given that the preponderance of evidence supports effects in this direction (Bunford et al., 2015; Carter et al., 2014; Kofler et al., 2015). ADHD inattention, ADHD hyperactivity/impulsivity, ASD social communication/interaction deficits, and ASD RRBs were included separately based on evidence that they differentially predict emotion dysregulation and social competence (Samson et al., 2014; Shaw et al., 2014; Wheeler Maedgen & Carlson, 2000). Age and sex were covaried in all models. Effects are considered statistically significant if their 95% confidence intervals (CIs) do not contain zero. Effect ratios (ER) for significant indirect effects indicate the proportion of the total effect (c pathway) that is conveyed via the indirect pathway (ab; i.e., ER = ab/c).

Results

Preliminary Analyses

Studentized residuals were used to identify outliers based on influence on the outcome variable. This process identified one case with SDBETA values exceeding the acceptable range of -1.0–1.0, and this case was excluded from the final dataset ($N = 107$). Missing values were imputed using expectation maximization based on all available data. This process affected 0.9% of data points. Data were determined to be missing completely at random (Little's MCAR test: $\chi^2 = 5.93$, $p = .82$). Data from the ADHD-RS-5 and BRIEF Emotional Control subscales have been reported for subsets of the current sample in previous studies for the purposes of characterizing the sample and/or investigating conceptually distinct research questions (Groves et al., 2020). Data for the study's primary outcome measures (parent and teacher reported SSIS social competence) and all ASD-related measures (CSI-IV social communication and RRB subscales) have not been reported previously for any children in the current sample. All measure inclusion/exclusion decisions and analytic plans were made *a priori*, prior to accessing the data. Demographic characteristics are shown in Table 1.

Power Analysis

A Monte Carlo simulation using the conditional effect power analysis app developed by Schoemann and colleagues (2017) indicated that for $\alpha = 0.05$, one predictor, and one conditional effect, our $N = 107$ is expected to detect significant effects at power = 0.99, assuming large associations between ADHD/ASD symptoms and social competence, large associations between emotion regulation and social competence, and conservatively assuming partial mediation (i.e., small/medium associations between ADHD/ASD symptoms and reduced social competence remaining after

Table 1 Sample and demographic variables

	M	*SD*	*Min*	*Max*	*Skew*	*Kurtosis*
Sex (Boys/Girls)	67/40		--	--	--	--
Ethnicity (A/B/H/M/W)	1/15/10/10/71		--	--	--	--
Medication Status (Y/N)	31/76		--	--	--	--
Age	10.52	1.51	8.30	13.37	0.37	-1.18
SES	49.20	11.75	20	66	-0.63	-0.32
IQ (Standard Scores)	105.51	14.20	73	151	0.03	0.38
ADHD HI Symptom Raw Scores	12.63	7.98	0	27	0.24	-0.99
ADHD I Symptom Raw Scores	16.40	7.38	0	27	-0.30	-0.84
ASD SCI Symptom Raw Scores	1.89	2.74	0	14	1.95	4.34
ASD RRB Symptom Raw Scores	1.16	1.89	0	9	2.04	4.33
Emotion Dysregulation Raw Scores	18.95	5.06	10	29	0.26	-0.79
Social Competence Raw Scores	84.95	18.93	34	133	0.27	0.02

Note. A = Asian, B = Black, H = Hispanic/Latino, HI = Hyperactive/Impulsive, I = Inattentive, IQ = WISC-V Intelligence Quotient, M = Multiracial, RRB = restrictive/repetitive interests/behaviors, SCI = Social Communication/Interaction, SES = Socioeconomic Status, W = White

accounting for emotion regulation difficulties). Effects of this magnitude were considered reasonable given previous evidence of (a) large magnitude relations between ADHD symptoms and reduced social competence ($r = 0.50$-0.59; Bunford et al., 2014; Kofler et al., 2011) and between ASD symptoms and reduced social competence ($r = 0.71$-0.84; Gillespie-Lynch et al., 2012); (b) large magnitude relations between ADHD symptoms and emotion regulation difficulties ($d = 0.80$–0.95; Graziano & Garcia 2016) and between ASD symptoms and emotion regulation difficulties ($r = 0.48$-0.54; Berkovits et al., 2017); and (c) moderate-to-large magnitude relations between emotion regulation difficulties and reduced social competence ($r = 0.29$-0.41; Blair et al., 2015).

Notably, however, this power analysis assumes a single predictor, whereas our model includes four predictors that are expected to be moderately interrelated (Goldsmith & Kelley, 2018; Harkins et al., 2021; Lee at al., 2018) and thus potentially attenuate each others' unique relations with emotion regulation and social competence. To our knowledge, power analysis for conditional effect models with multiple predictors is not yet available. We therefore reran the power analysis, this time conceptualizing the additional predictors as covariates that would moderately attenuate the relation between any given predictor and the conditional effect and outcome. Conservatively assuming that detected relations would be half the magnitude expected based on prior work (i.e., small-to-medium instead of large), and that there would be no significant relation between a given predictor and outcome after accounting for the other predictors and the conditional effect, our $N = 107$ is expected to detect significant effects at power = 0.80. Thus, the study is powered to detect clinically meaningful effects of the expected magnitude.

Primary Analyses

Inspection of the zero-order and partial correlation matrices (Supplementary Table 1) indicates that all four ADHD/ASD symptom clusters were significantly associated with both emotion regulation difficulties ($r = 0.21$-0.38, $p < .05$) and reduced social competence ($r = -0.39$ to -0.46, $p < .01$), and that emotion regulation difficulties were also associated with reduced social competence ($r = -0.43$ to -0.44, $p < .01$), both with and without control for age and sex. However, a somewhat different pattern emerged based on the bias-corrected, bootstrapped conditional effects model that controlled for the interrelations among ADHD and ASD symptoms (Table 2). Interestingly, all four ADHD and ASD symptom clusters predicted reduced social competence, but in somewhat different ways. Specifically, ADHD inattentive (c and c' pathways; $\beta = -0.23$ to -0.25) and ASD social communication/interaction symptoms (both $\beta = -0.20$) both exerted significant total and direct effects on reduced social competence (95%CIs exclude zero), but did not exert additional indirect effects via the emotion dysregulation pathway (ab pathways; 95%CIs include 0.0). In contrast, ADHD hyperactive/impulsive symptoms ($\beta = -0.06$; ER = 0.90) and ASD RRBs ($\beta = -0.06$; ER = 0.38) both exerted significant indirect effects on reduced social competence through their association with increased emotion regulation difficulties (ab pathways; 95%CIs exclude 0.0), but did not demonstrate significant total or direct effects (c and c' pathways; both 95%CIs include 0.0). Interestingly, emotion dysregulation continued to predict lower social competence even when controlling for the ADHD and ASD symptom clusters (b pathway; $\beta = -0.25$; 95%CI excludes 0.0).

In sum, emotion regulation difficulties were associated with reduced social competence, both independently and via the additional risk for emotion regulation difficulties conveyed by elevated ADHD hyperactive/impulsive and ASD

Table 2 Primary Analysis: Bias-corrected bootstrapped conditional effects model of parent-reported ADHD and ASD symptom clusters, emotion regulation difficulties, and social competence

Effects	B	SE	Lower 95%CI	Upper 95%CI	β	
Total effects (c pathways)						
ADHD Inattentive Symptoms --> Social Competence	-0.64	0.27	-1.17	-0.12	-0.25	*
ADHD Hyperactive/Impulsive Symptoms --> Social Competence	-0.29	0.25	-0.79	0.21	-0.12	
ASD Restricted Interests/Repetitive Behaviors --> Social Competence	-1.51	1.09	-3.64	0.62	-0.15	
ASD Social Communication Symptoms --> Social Competence	-1.40	0.68	-2.73	-0.07	-0.20	*
Direct effects (a pathways)						
ADHD Inattentive Symptoms --> Emotion Dysregulation	0.05	0.09	-0.12	0.21	0.08	
ADHD Hyperactive/Impulsive Symptoms --> Emotion Dysregulation	0.14	0.08	-0.01	0.30	0.23	
ASD Restricted Interests/Repetitive Behaviors --> Emotion Dysregulation	0.61	0.36	-0.08	1.38	0.22	
ASD Social Communication Symptoms --> Emotion Dysregulation	0.02	0.21	-0.38	0.45	0.01	
Direct effects (b pathway)						
Emotion Dysregulation --> Social Competence	-0.95	0.34	-1.61	-0.29	-0.25	*
Indirect effects (ab pathways)						
ADHD Inattentive Symptoms --> Emotion Dysregulation ◊ Social Competence	-0.05	0.10	-0.27	0.10	-0.02	
ADHD Hyperactive/Impulsive Symptoms --> Emotion Dysregulation --> Social Competence	-0.14	0.09	-0.37	-0.01	-0.06	*
ASD Restricted Interests/Repetitive Behaviors --> Emotion Dysregulation --> Social Competence	-0.58	0.42	-1.75	-0.001	-0.06	*
ASD Social Communication Symptoms --> Emotion Dysregulation --> Social Competence	-0.01	0.21	-0.46	0.40	-0.002	
Direct effects (c' pathways)						
ADHD Inattentive Symptoms --> Social Competence	-0.59	0.27	-1.12	-0.07	-0.23	*
ADHD Hyperactive/Impulsive Symptoms --> Social Competence	-0.15	0.25	-0.67	0.29	-0.06	
ASD Restricted Interests/Repetitive Behaviors --> Social Competence	-0.93	1.19	-2.93	1.67	-0.09	
ASD Social Communication Symptoms --> Social Competence	-1.39	0.68	-2.71	-0.02	-0.20	*
Covariate pathways						
Age --> Emotion Dysregulation --> Social Competence	0.28	0.39	-0.30	1.28	0.02	
Sex --> Emotion Dysregulation --> Social Competence	-0.05	1.07	-2.26	2.11	-0.001	
Age --> Emotion Dysregulation	-0.29	0.35	-0.97	0.41	-0.09	
Sex --> Emotion Dysregulation	0.05	1.06	-2.05	2.06	0.01	
Age --> Social Competence	-0.85	0.98	-2.85	1.04	-0.07	
Sex --> Social Competence	-5.63	2.95	-11.60	0.16	-0.14	

* significant pathways (95%CIs exclude 0.0)

RRB symptoms. In addition, ADHD inattentive and ASD social communication/interaction difficulties both conveyed unique risk for reduced social competence. Altogether, the model accounted for 41% of the variance in children's social competence ($R^2 = 0.41$).

Sensitivity Analyses

Taken together, the primary analyses were generally consistent with prior studies, and implicated all four ADHD/ASD symptom clusters and emotion regulation difficulties as risk factors for reduced social competence in our clinically evaluated sample – albeit with a somewhat more nuanced pattern than suggested by the zero-order correlation matrix. Next, we explored the extent to which this pattern was attributable to methodological artifacts and/or our *a priori* decision to base our analyses on parent perceptions of their child's social functioning.

First, we considered the extent to which the primary findings may be an artifact of item overlap across the measures. To this end, three judges (EMJ, NBG, KEB) independently evaluated the items on each measure for significant overlap with item(s) on any of the other measures. There was 100% agreement that none of the ADHD or emotion regulation items overlapped significantly with each other or any of the ASD or social competence items. In contrast, all three judges identified SSIS social competence items that overlapped significantly with, or were worded nearly identically to, items on the CSI-IV ASD social communication subscale. Fleiss' kappa for inter-judge reliability was excellent ($\kappa = .92$, $p < .001$); a single discrepancy among judges was resolved by the principal investigator. This process led to the exclusion of five items from the SSIS social competence subscale. As shown in Supplementary Tables 2, the pattern of results with the revised parent SSIS social competence scale (internal consistency: $\alpha = .95$) was highly consistent with the primary analyses reported above, with two minor

exceptions. Despite the point estimates changing minimally, the indirect effect of ASD RRBs (ab pathway; $\beta = -.061$ vs. $-.057$) and the direct effect of ASD social communication/interaction difficulties (c' pathway; $\beta = -0.19$ vs. -0.20) on reduced social competence no longer reached significance (both 95% CIs included 0.0). All other findings were highly consistent with the primary analyses reported above, including total effects of ADHD inattentive and ASD social communication/interaction symptoms on social competence (c pathways; $\beta = -0.26$ and $\beta = -0.20$, respectively), direct effects of emotion dysregulation on social competence (b pathway; $\beta = -0.27$), and indirect effects of ADHD hyperactive/impulsive symptoms on social competence (ab pathway; $\beta = -0.06$).

Next, we probed the extent to which the findings were robust to control for mono-informant bias by substituting teacher-reported social competence ($\alpha = 0.97$ based on the current sample) for the parent-reported social competence scores included in the primary analyses (i.e., parent-reported ADHD, ASD, and emotion dysregulation predicting teacher-reported social competence). This model was added based on observations made during our literature review indicating that most if not all prior work on this topic has relied on the same informant for all analyzed measures. As expected (Frey et al., 2011), parent- and teacher-perceived social competence correlated only moderately ($r = 0.34$, $r_{partial} = 0.32$, $p < .001$), highlighting variations in child behavior across contexts and the importance of collecting data from multiple informants.

Examination of the zero-order and partial correlations indicated a pattern that was similar, albeit somewhat attenuated, to that found based on parent-reported social competence, including significant associations between teacher-perceived social competence and parent-perceived ADHD inattentive (both $r = -0.32$), ADHD hyperactive/impulsive ($r = -0.23$ to -0.25), ASD social communication (both $r = -0.23$), and emotion dysregulation symptoms ($r = -0.23$ to -0.24; all $p < .01$). The teacher social competence/parent RRB association did not reach significance ($r = -0.15$ to -0.17, $p \geq .07$). Despite this high degree of similarity, inspection of Supplementary Table 3 indicates that most relations detected in the primary bootstrapped path model were no longer significant when teacher-reported social competence was the outcome: only ADHD inattentive symptoms predicted social competence (c and c' pathways; $\beta = -0.29$ to -0.30; 95% CIs exclude 0.0), with standardized β-weights similar to or modestly larger than those detected in the primary analyses. In contrast, there were no detectable direct or indirect effects of parent-reported ADHD hyperactive/impulsive, ASD social communication/interaction, ASD RRBs, or emotion dysregulation on teacher-reported social competence (95% CI include 0.0).

Taken together, results of the primary and sensitivity analyses provided consistent evidence linking ADHD inattentive symptoms with reduced social competence ($\beta = -0.23$ to -0.30) even after accounting for ADHD hyperactive/impulsive symptoms, both ASD symptom clusters, and emotion regulation difficulties. Evidence for all other associations was more nuanced: (a) ADHD hyperactive/impulsive symptoms demonstrated significant indirect effects via the emotion dysregulation pathway in the primary model that were robust to control for item overlap (both $\beta = -0.06$) but not detectable in the cross-informant model ($\beta = -0.03$); (b) ASD social communication/interaction ($\beta = -0.20$ vs. -0.19 and -0.14) and RRB ($\beta = -0.06$ vs. -0.06 and -0.03) symptoms demonstrated significant direct and indirect effects, respectively, in the primary model that were no longer detectable when controlling for item overlap across measures or mono-informant effects; and (c) direct effects of emotion dysregulation on reduced social competence were found in the primary and item-non-overlap models ($\beta = -0.26$ to -0.27), but not detectable in the cross-informant model.

Discussion

The current study was the first to concurrently examine the relations among ADHD symptoms, ASD symptoms, emotion dysregulation, and social impairment in a carefully phenotyped sample of children with and without neurodevelopmental disorders. Consistent with our hypotheses and extant literature, all four ADHD and ASD symptom clusters were positively related to emotion dysregulation and negatively related to social competence – albeit with a somewhat more nuanced pattern than suggested by the zero-order correlation matrix. Specifically, ADHD hyperactive/impulsive symptoms and ASD RRBs were related to social competence indirectly through emotion dysregulation, whereas ADHD inattentive symptoms, ASD social communication/interaction symptoms, and emotion dysregulation directly predicted social competence even when controlling for the effects of the other symptom clusters. These findings partially supported our hypotheses and suggest that emotion regulation may be an important mechanistic target associated with better-developed social competence for children with clinically elevated ADHD and ASD symptomatology (e.g., Goldsmith & Kelley 2018; Lee at al., 2018). Thinking ahead to intervention development, these results suggest that interventions targeting inattentive symptoms, social communication symptoms, and emotion regulation skills

may have the strongest potential to reduce social impairment for children with elevated ADHD and/or ASD symptoms. This hypothesis is of course speculative because the current study was not an intervention trial, but it is generally consistent with previous evidence that emotion regulation training may produce improvements in social functioning in both clinical (Reyes et al., 2019; Senior et al., 2020) and community samples (Greenberg et al., 1995; Zeman et al., 2006).

The present findings were consistent with prior evidence suggesting that emotion regulation is linked more strongly with hyperactivity/impulsivity than inattention (Groves et al., 2020; Wheeler Maedgen & Carlson, 2000), and extends prior work by demonstrating that this link, in turn, predicts social impairment. This conclusion is based on the relatively stronger effects of hyperactivity/impulsivity relative to inattention for predicting emotion regulation ($\beta = 0.23$ vs. 0.08), as well as the finding that shared variance between hyperactivity/impulsivity and emotion regulation predicted social competence (i.e., a significant indirect effect), whereas this was not the case for the inattention/emotion regulation association. Similarly, we found that ASD-related RRB symptoms were more strongly linked with emotion regulation difficulties than were ASD-related social communication difficulties ($\beta = 0.22$ vs. 0.01). This finding is consistent with prior work (Mazefsky et al., 2012; Samson et al., 2014), and extends this line of inquiry by demonstrating that the intersection between RRBs and emotion regulation difficulties – rather than RRBs in and of themselves – may be important for understanding the reduced social competence associated with ASD symptomatology.

Interestingly, emotion regulation independently predicted social competence even after accounting for ADHD and ASD symptoms. Combined with the direct and indirect effects noted above, this finding suggests at least six unique pathways to reduced social competence in children: (a) social difficulties related directly to ADHD inattentive behaviors (Bunford et al., 2018; Kofler et al., 2018); (b) social difficulties related directly to ASD social communication symptoms (Patriquin, 2019); (c) social difficulties related directly to underdeveloped emotion regulation skills independent of ADHD and ASD (Blair et al., 2015; Carlo et al., 2012); (d) social difficulties related to additional components of emotion regulation linked with ADHD hyperactive/impulsive behaviors (Kofler et al., 2018); (e) social difficulties related to additional components of emotion regulation linked with ASD RRB symptoms (Samson et al., 2014); and (f) social difficulties unrelated to ADHD, ASD, and emotion regulation difficulties, as evidenced by the model not fully explaining the variance in social competence ($R^2 = 0.41$). Future work is needed to confirm these links and identify additional affective, behavioral, and cognitive factors that impact social competence for children at risk for social difficulties due to ADHD symptoms, ASD symptoms, and/or emotion regulation difficulties.

Finally, we conducted a series of sensitivity analyses to probe the extent to which the primary findings were robust to our *a priori* methodological decisions and/or artifacts of validity threats such as overlapping item content and mono-informant bias that, to our knowledge, have not been adequately considered in prior work on this topic. In terms of item overlap across measures, the indirect effect of hyperactive/impulsive symptoms on social competence via emotion dysregulation, the direct effect of inattention on social competence, and the direct effect of emotion regulation on social competence were robust to control for item overlap across measures. While perhaps unsurprising given that none of the ADHD symptom or emotion regulation items overlapped significantly with any of the social competence items, these results are consistent with the well-documented social difficulties experienced by children with clinically elevated ADHD symptoms (Kofler et al., 2018), as well as with previous evidence for emotion regulation as an intermediate effect between clinically elevated ADHD symptoms and social difficulties (Bunford et al., 2015; Lee et al., 2018). These findings extend the evidence base by explicitly examining item-level content to rule out item-overlap as an explanation for these relations.

In contrast, 5 of the 46 SSIS social competence items were worded, in most cases, nearly identically to ASD social communication items, and removal of these redundant items resulted in most ASD/social competence relations becoming nonsignificant. Only the total effect of ASD social communication on social competence remained significant, but this effect was no longer detectable after controlling for ADHD and emotion regulation symptoms. Notably, however, the point estimates were remarkably similar to the significant effects found in the primary model, suggesting the need for additional inquiry into the nature of the ASD/social competence relation and the extent to which it may be better explained by (a) co-occurring ADHD symptoms; (b) inclusion of social competence-related behaviors in the DSM criteria that obfuscates attempts to disentangle causes and effects of social difficulties for these children; and/or (c) additional factors not assessed herein. Taken together, our primary and sensitivity analyses were consistent with previous evidence linking ASD symptoms with emotion dysregulation (Mazefsky et al., 2012) which, in turn, predicts social impairment (Aduen et al., 2014), while suggesting that statistical and methodological artifacts may warrant additional consideration as this line of inquiry progresses.

Interestingly, only the direct effect of inattentive symptoms on social competence was robust to control for mono-informant bias – parent-perceived ASD symptoms, ADHD

hyperactive/impulsive symptoms, and emotion regulation skills each failed to predict teacher-perceived social competence in our clinically evaluated sample of children with and without ADHD and ASD. This finding reflects an important extension to extant literature that relies primarily on same-informant reports of study predictors and outcomes (Cleminshaw et al., 2020; Neuhaus et al., 2019). The consistency across the mono-informant and cross-informant models in terms of ADHD inattentive symptoms and social functioning underscores the importance of attention in the successful performance of social skills. It also appears consistent with conceptual models suggesting that social difficulties in children with clinically elevated ADHD symptoms may be due to interfering behaviors (e.g., inattention) rather than to reduced social knowledge per se (Aduen et al., 2018). In contrast, no indirect pathways were detected in the cross-informant model; although unexpected, this pattern was consistent with studies in both neurotypical (Winsler & Wallace, 2002) and neurodevelopmental (Azad et al., 2016; Locke et al., 2014) samples demonstrating only modest agreement between parent and teacher perceptions of children's social skills.

Finally, it is worth commenting that parent and teacher perceptions of children's social competence correlated only modestly ($r = 0.32$). This may reflect children adapting their behavior in the classroom to meet the expectations of their teacher (Dinnebeil et al., 2013; Kuklinski & Weinstein, 2001), parents and teachers having different reference groups and expectations for appropriate social behavior (Aduen et al., 2018), and/or teachers reporting social impairment at a lower base rate than parents (Murray et al., 2009). Alternatively, it may be that different child behaviors are important for adaptive social functioning in different settings (Heyman & Hauser-Cram, 2019). Future work that objectively measures social behaviors, ideally while experimentally manipulating emotion regulation demands (e.g., Walcott & Landau 2004), will be important as this line of inquiry moves forward. Overall, the present study provides evidence for emotion dysregulation as a possible mechanism linking hyperactive/impulsive symptoms and RRBs with reduced social competence per parent report, while highlighting measurement and methodological issues that will need to be addressed to clarify the relations reported herein.

Limitations and Future Directions

The current study has several strengths, including the carefully evaluated, clinically diverse, and relatively large sample of children with and without ADHD and ASD; conditional effects path modeling approach that allowed shared variance among predictors to be parsed according to theory and previous research; concurrent examination of, and control for, both ADHD and both ASD symptom clusters; and sensitivity analyses that examined methodological concerns often overlooked in the extant literature. However, the following limitations should be considered when interpreting results. First, the use of both parent and teacher informants to measure social competence was useful in that it (a) allowed us to probe the extent to which the relations detected in the parent-report model were robust to control for mono-informant bias; and (b) captured a more complete picture of children's social behavior that may present differently across contexts (Azad et al., 2016; Murray et al., 2009). Self-report measures were not used given that children with clinically elevated ADHD symptoms (Owens et al., 2007) and ASD symptoms (Lerner et al., 2012) frequently underreport their own social impairment, and teacher report was not available for all constructs of interest, which precluded us from testing fully cross-informant models. At the same time, parent/teacher agreement is modest for all of the constructs assessed herein, and future work would benefit from the use of multiple informants for all assessed constructs to test the extent to which different aspects of ADHD symptoms, ASD symptoms, and emotion dysregulation predict different aspects of social impairment across different settings/contexts for these children.

Additionally, the present study examined symptoms continuously and included children with and without ADHD and ASD and common comorbidities, favoring the generalizability of findings to the broader population of children who present for evaluation of neurodevelopmental concerns (Reale et al., 2017) as well as children who may exhibit sub-threshold symptomatology (Christ et al., 2010). However, this may reduce specificity of the findings to children with only ADHD or ASD, despite evidence that both syndromes reflect extreme ends of characteristics that are normally distributed in the population (e.g., Robinson et al., 2011). Similarly, the larger study from which this sample was drawn oversampled for children with ADHD, and children with ASD diagnoses in the sample consisted primarily of children needing Level 1 or 2 support (APA, 2013). It is possible that ASD symptoms would have continued to predict social functioning in the cross-informant model had our sample also included children with more severe ASD symptom scores, although restricted range is likely not a viable explanation given that we obtained nearly the full range of possible symptom scores (Table 1) and also found robust associations between ASD symptoms and social functioning in the parent model that were consistent with prior work in this area (Carter et al., 2014; Goldsmith & Kelley, 2018). Related to this point, a key assumption of this study – and the literature on these topics more broadly – is that the

scales/items are measuring the same constructs in different populations. Future work assessing for differential item functioning and/or measurement invariance will be important as this line of inquiry progresses . The cross-sectional design also prevents conclusions regarding causality. For example, while most studies model ADHD and ASD symptoms as predictors of emotion dysregulation and conceptualize emotion regulation difficulties as a secondary outcome of these syndromes (Cleminshaw et al., 2020; Goldsmith & Kelley, 2018), others have suggested that emotion dysregulation may reflect a core symptom of these disorders (Barkley, 2010; England-Mason, 2020). Future work implementing experimental or longitudinal study designs would allow causal claims to be made regarding the directionality of pathways linking ADHD and ASD symptoms, emotion dysregulation, and social impairment.

Lastly, the benefits of using the CSI-IV to assess ASD symptoms were twofold. First, the specificity of the items decreases the likelihood of endorsement if ASD symptoms are not exhibited (Gadow et al., 2008). In turn, this increases the likelihood that symptoms are truly present if endorsed, even if the child does not fully meet diagnostic criteria for ASD. This is particularly attractive given the present study's goal of examining ASD (and ADHD) symptoms continuously given that symptoms of both are normally distributed in the general population (e.g. Robinson et al., 2011). Nevertheless, the CSI-IV was designed around diagnostic criteria for ASD in the DSM-IV rather than the DSM-5, and future work may benefit from using measures of ASD symptoms more aligned with the DSM-5.

Clinical Implications

The current findings raise important questions about the extent to which most previously documented ADHD- and ASD-related associations with social functioning may be highly setting specific, artifacts of item overlap across measures, or both. Interestingly, in the primary parent-report model, emotion dysregulation uniquely predicted social impairment and also served as an intermediary linking ADHD hyperactive/impulsive and ASD RRB symptoms with social impairment. ADHD inattentive symptoms and ASD social communication/interaction symptoms, on the other hand, were directly related to social impairment and less related to emotion regulation. These findings suggest that different ADHD and ASD symptom domains may impair social functioning via different pathways and provides evidence that emotion dysregulation may reflect a transdiagnostic mechanism associated with social impairment across neurodevelopmental disorders, as well as in typically developing youth. To that end, it stands to reason that teaching effective emotion regulation strategies may facilitate social success in most children, regardless of if they meet criteria for a neurodevelopmental or other psychiatric disorder. Results of the current study provide a promising target for future investigation; incorporating interventions that target emotion dysregulation with first-line treatments for ADHD and/or ASD may result in incremental improvement in social functioning for these children.

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Compliance with Ethical Standards

Conflict of Interest The authors have no conflicts of interest to report.

Ethical Approval 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.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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