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Behavioral problems in children with autism spectrum disorder with and without co-occurring intellectual disability

Margaret Kurzius-Spencer[a,b,*], Sydney Pettygrove[b], Deborah Christensen[c], Anita L. Pedersen[d], Christopher Cunniff[e], F. John Meaney[a], Gnakub Norbert Soke[c], Rebecca A. Harrington[f], Maureen Durkin[g], Sydney Rice[a]

[a] University of Arizona, College of Medicine, Genetics & Developmental Pediatrics, Tucson, AZ, 85724, USA
[b] University of Arizona, Mel & Enid Zuckerman College of Public Health, Dept. of Epidemiology, Tucson, AZ, 85724, USA
[c] National Center on Birth Defects and Developmental Disabilities, Division of Congenital and Developmental Disorders, Developmental Disabilities Branch, Centers for Disease Control and Prevention, 4770 Buford Hwy, MS E-86, Atlanta, GA, 30341, USA
[d] One University Circle, California State University, Stanislaus, Dept. Psychology & Child Development, Turlock, CA, 95382, USA
[e] Division of Medical Genetics, Department of Pediatrics, Weill Cornell Medical College, New York, NY, USA
[f] Johns Hopkins Bloomberg School of Public Health, Dept. of Epidemiology, Baltimore, MD, 21205, USA
[g] University of Wisconsin School of Medicine and Public Health, Madison, WI, 53726, USA

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ABSTRACT

Background: Autism spectrum disorder (ASD), intellectual disability (ID), and behavioral problems commonly co-occur, leading to increased impairment, diagnostic confusion, and treatment delays. Using data from a large surveillance population of children with ASD, the objectives of the present study were to compare the relative risk of common behavioral problems in children with ASD, with and without co-occurring intellectual disability.

Methods: Data from the Autism and Developmental Disabilities Monitoring (ADDM) Network (2006–2010) on 9378 8-year-old children who met case definition for ASD and had cognitive test scores and information on behavioral problems were analyzed using frequency measures, risk ratios, chi-squared tests, and trend tests.

Results: Children with ASD with and without ID had on average six co-occurring behavioral problems. The relative risk (RR) of self-injurious behaviors, unusual fear responses, and eating abnormalities increased with increasing cognitive impairment among children with ASD and ID (all $p < 0.001$). Conversely, RR of mood ($p < 0.001$) and sleep abnormalities ($p = 0.013$) declined with increasing levels of cognitive impairment.

Conclusions: Children with ASD and ID are at greater risk of some behavioral problems and lower risk of others as compared to children with ASD only. Successful interventions depend on understanding the complex interactions between co-occurring neurodevelopmental and behavioral problems.

1. Introduction

Autism spectrum disorder (ASD) is a developmental disability that encompasses a broad range of symptoms and degrees of impairment (Bennett et al., 2014; Levy et al., 2010; McClintock, Hall, & Oliver, 2003). ASD is characterized by pervasive impairments

* Corresponding author at: University of Arizona, 1656 E Mabel, PO Box 245215, Tucson, AZ, 85724, USA.
E-mail address: mkurzius@email.arizona.edu (M. Kurzius-Spencer).

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in social communication/interaction and by repetitive, stereotyped, and restricted behaviors, interests, or activities, with symptoms present by three years of age (2013, A.P.A., 2000). ASD frequently co-occurs with other developmental, neurological, and speech and language disorders (Levy et al., 2010; Matson, Cooper, Malone, & Moskow, 2008; Salazar et al., 2015; Sell, Giarelli, Blum, Hanlon, & Levy, 2012; Simonoff et al., 2008; Soke et al., 2016). Intellectual disability (ID), which occurs in 38–75% of children with ASD, is defined by significant limitations in intellectual functioning and adaptive behavior (CDC, 2012; Goldin et al., 2014; Matson & Shoemaker, 2009; Rzepecka, McKenzie, McClure, & Murphy, 2011). In addition, behavioral problems, such as inattention/hyperactivity, aggression, tantrums, anxiety, sensory problems, phobias, and sleep difficulties, commonly co-occur with ASD (Goldin, Matson, & Cervantes, 2014; Kogan et al., 2009; Matson & Shoemaker, 2009).

Among children with ASD, those with more severe symptoms and impairments tend to have more behavioral problems (Fodstad, Rojahn, & Matson, 2012; Goldin et al., 2014; Joshi et al., 2010; Leyfer et al., 2006). Although children with ID alone also experience high rates of behavioral comorbidity (Goldin et al., 2014), they appear to have lower overall rates of behavioral problems compared to children with ASD alone (Brereton, Tonge, & Einfeld, 2006). Results of previous studies on the relationship between ID and behavioral comorbidities in children with ASD have been inconsistent. Depending on the sample population, age group, specific behaviors studied, and the severity of ASD, researchers have variously reported: no relationship between ID and problems such as tantrum behaviors, conduct disorders, depression, and eating problems in children with ASD (Goldin et al., 2014; Tureck, Matson, Cervantes, & Konst, 2014); an increased risk of aggression, temper tantrums, and self-injury in children with ASD and ID as compared to those with ASD without co-occurring ID (Estes et al., 2007); a decreased risk of anxiety, depression (Estes, Dawson, Sterling, & Munson, 2007; Mayes, Calhoun, Murray, Ahuja, & Smith, 2011; Mayes, Calhoun, Murray, & Zahid, 2011), and attention deficit/hyperactivity (Brereton et al., 2006) in children with ASD and ID; and increased problems related to social interactions (Brereton et al., 2006) in children with co-occurring ASD and ID as compared to those with ASD only. The co-occurrence of ID and behavioral comorbidities with ASD makes it challenging for clinicians to distinguish between diagnoses of ASD, ID, and psychological or psychiatric conditions. This may result in delayed diagnosis, change in diagnosis over time, and delays in treatment (Close, Lee, Kaufmann, & Zimmerman, 2012; Rieske et al., 2015).

Generalizability of most past studies has been limited by small sample sizes and the use of psychiatric or neurodevelopmental clinic populations that tend to include children who have more severe impairments (Hill et al., 2014; Levy et al., 2010). As a result, their findings may not be relevant to the broader population of children with ASD. The dearth of studies using large population samples that include a wide range of ASD presentation and cognitive ability has been noted repeatedly in the literature (Cervantes, Matson, Adams, & Konst, 2014; Close et al., 2012; Estes et al., 2007; Georgiades et al., 2011; Hill et al., 2014; Kanne & Mazurek, 2011; Kogan et al., 2009; Rzepecka et al., 2011; Wiggins et al., 2015). Our objective in conducting this research was to evaluate the relationships between each behavior in children with ASD, with and without co-occurring ID using a large, population-based sample. Based on the literature on co-occurring conditions in ASD, we expected high correlations between behavioral problems, regardless of co-occurring ID. Therefore, we hypothesized that there would be no difference in relative risk of these behaviors in children with ASD + ID as compared to children with ASD only.

2. Methods

2.1. Study population

The Autism and Developmental Disabilities Monitoring (ADDM) Network was established by the Centers for Disease Control and Prevention (CDC) in 2000 to provide estimates of the prevalence of ASDs and other developmental disabilities among 8-year-old children across multiple sites in the United States. ADDM uses information from health and education sources and the methodology for case classification has been described in detail elsewhere (2012, CDC, 2009; Rice et al., 2007; Van Naarden Braun et al., 2007). Briefly, determination of ASD case status involves screening and abstraction of clinical and/or special education records of 8-year-old children residing in a defined catchment area within each site during each survey year. Records are screened for (1) the presence of any social deficits associated with ASD, (2) ASD diagnosis, and (3) receipt of special education services under autism exceptionalities. Records that meet any of these criteria are abstracted for information on diagnostic criteria for ASD, including verbatim descriptions of behaviors recorded in comprehensive developmental evaluations, previous diagnoses of ASD, cognitive and adaptive tests, and associated behaviors and conditions. The abstracted data are then concatenated in a summary record for each child that undergoes subsequent review by trained clinicians to determine whether the child meets ASD surveillance definition using an algorithm based on the Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition-Text Revision (DSM-IV-TR) criteria (A.P.A., 2000; CDC, 2009, 2012; Rice et al., 2007).

Data from three survey years (SY) – 2006, 2008 and 2010 – were used in these analyses. Fourteen study sites (Alabama, Arkansas, Arizona, Colorado, Florida, Georgia, Maryland, Missouri, North Carolina, New Jersey, Pennsylvania, South Carolina, Utah, and Wisconsin) contributed data during one or more survey years (2012, CDC, 2009, 2014). All children who met ADDM surveillance case definition of ASD and who had cognitive test score data and information on associated behavioral problems were included in this study. It should be noted that although our study includes only children with cognitive test score data, seven of the study sites included in the analysis (AL, CO, FL, MD, MO, PA, and WI) did not have access to special education records during some or all of the survey years, and fewer than 70% of children at those sites had IQ data.

2.2. Measures

2.2.1. Surveillance case definition of ASD

Children are determined to have met ADDM surveillance case criteria for ASD if a comprehensive evaluation of the child's summary record by one or more qualified examiners documents behaviors consistent with: (a) the diagnostic criteria for Autistic Disorder in the DSM-IV-TR (A.P.A., 2000), or (b) at least two DSM-IV-TR criteria, including a minimum of one social criterion and one communication or behavioral criterion, and at least one additional behavior (referred to as an autism discriminator) that distinguishes children with ASD from children with other developmental delays or disorders. The presence of an ASD diagnosis, in the absence of having met one of the sets of surveillance case criteria described above, is not sufficient to classify a child as a case for surveillance purposes.

2.2.2. Intellectual disability and cognitive impairment

Various types of assessments (psychological, psychoeducational, developmental, adaptive) were used by educational and clinical sources to determine cognitive ability. In this study, cognitive level was ascertained from the most recent evaluation with intelligence or developmental test scores and categorized as follows: IQ > 85 (average - above average), 71–85 (below average), 50–70 (mild ID), 35–49 (moderate ID), < 35 (severe-profound ID), and cognitive impairment not otherwise specified (NOS). Those children with ASD who had composite/full-scale intelligence test (IQ) scores or developmental tests with cognitive domain scores ≤70 were classified as "ASD + ID", and those with ASD and IQ scores > 70 were classified as "ASD only."

2.2.3. Associated behavioral problems

The presence or absence in the abstracted evaluations of any mention of ASD-associated behavioral problems was also documented as part of clinician review (Sell et al., 2012; Wiggins, Rice, & Baio, 2009). Clinician reviewers followed a standardized protocol in coding behavioral problems. Behaviors that could either be coded as behavioral problems or as DSM-IV-TR criteria for autistic disorder were coded as criteria only. The following ten behavioral problems were analyzed in this study: inattention/hyperactivity; physical aggression toward others; argumentative; oppositional; and destructive behaviors; temper tantrums; self-injurious behaviors; unusual or odd responses to sensory stimuli; abnormalities of mood or affect; lack of fear or excessive fearfulness; sleeping abnormalities or problems sleeping; and abnormalities in eating or drinking. These are described in greater detail in Table 1.

2.2.4. Sociodemographic and other factors

Age at earliest known comprehensive evaluation, age at earliest known ASD diagnosis, total number of comprehensive evaluations, sex, and race/ethnicity were abstracted from school or clinic records. The following race/ethnicity categories were used: non-Hispanic white; non-Hispanic black; Hispanic, any race; other (includes other race/ethnicity or missing). Census data on the percentage of families with children < 18 years old living below the poverty level within census block groups were used as an area-level proxy measure for socioeconomic status (SES) (Durkin et al., 2010).

2.3. Statistical analyses

Stata/SE version 11.2 was used for all statistical analyses (Stata, 2012). Descriptive statistics were used to evaluate the distribution, central tendency and frequencies of variables. For variables that were not normally distributed, geometric means were calculated. Spearman rank correlation was used to estimate the correlation between pairs of behaviors in children with and without co-occurring ID and in the whole population. Fisher's r to z transformation and z test statistic were used to transform and compare correlation coefficients (rho values) in the stratified analysis. To test for differences in mean values of normally distributed variables by ASD/ID status (ASD + ID vs. ASD only), we used one-way analysis of variance (ANOVA), and to evaluate rank-based differences in

Table 1
Behavioral problems addressed in this study.[1].

Abbreviation	Description of Behavioral Problems
ADH	Short attention span; inattentive; hyperactivity; impulsivity (includes being fidgety and general attention problems)
AGGR	Physical aggression toward others (such as hitting, biting, kicking, etc.)
ARGU	Argumentative, oppositional, defiant, destructive (includes acting out, talking back, rude or foul language or actions, refusals, "uncooperative" behavior, destructive or violent play or use of objects)
TT	Temper tantrums; excessive or problem tantrum behavior
SIB	Self-injurious behavior (any self-directed behavior that could cause physical harm or a sign or bodily mark of the act, such as picking fingers until bleeding, sucking fingers until chapped, slapping self in the face, etc.)
SENS	Unusual or odd responses to sensory stimuli (hyper or hypo-responsive), such as sounds, smells, or vestibular movement (includes preoccupation with sensory input); unresponsiveness to pain
MOOD	Abnormalities of mood or affect (extreme presence or absence of emotions or mood, such as excessive distress, frustration, anxiety, depression)
FEAR	Lack of fear in response to real dangers or excessive fearfulness in response to harmless objects or events; abnormal or unusual fear response
SLEEP	Abnormalities in sleeping; problems or difficulties sleeping
EAT	Abnormalities in eating or drinking (includes pica and being a "picky eater")

[1] Based on ADDM Study Year 2008 ASD Surveillance Clinician Reviewer Guidelines (CDC, 2009a).

Table 2
Characteristics of 9378 8-year olds identified as meeting surveillance case status for ASD during study years 2006, 2008 and 2010 in the multi-site Autism and Developmental Disabilities Monitoring (ADDM) Network. ASD cases are stratified by IQ > 70 (ASD only) vs. IQ ≤ 70 (ASD + ID).

	ASD only	ASD + ID	*P*	*Cohen's d*
N (% total study population)	6083 (64.9)	3295 (35.1)	—	
Sex, N (%)				
Females	944 (15.5)	654 (19.8)		
Males	5139 (84.5)	2641 (80.2)		
Male:Female ratio	5.44	4.04	< 0.001	
Race/ethnicity, N (%)	< 0.001			
White, non-Hispanic	3904 (64.2)	1501 (45.6)		
Black, non-Hispanic	889 (14.6)	998 (30.3)		
Hispanic, any race	744 (12.2)	532 (16.1)		
Other, non-Hispanic[1] or missing	546 (9.0)	264 (8.0)		
% families < poverty level[2], GM (95% CI)	8.5 (8.3-8.8)	10.8 (10.4-11.2)	< 0.001	
Cognitive test score, N (%)				
IQ > 85 (average-above average IQ)	3892 (64.0)			
IQ 71-85 (below average IQ)	2191 (36.0)			
IQ 50-70 (mild ID)		1703 (51.7)		
IQ 35-49 (moderate ID)		624 (19.0)		
IQ < 35 (severe-profound ID)		301 (9.1)		
Cognitive impairment-NOS		667 (20.2)	—	
N comprehensive evaluations, GM (95% CI)	5.0 (4.9-5.1)	5.6 (5.5-5.8)	< 0.001	0.18
N (%) with prior ASD diagnosis	3928 (64.6)	2423 (73.5)	< 0.001	
Age in mos., earliest evaluation, GM (95% CI)	43.8 (43.3-44.4)	34.4 (33.8-35.1)	< 0.001	0.50
Age in mos., earliest ASD diagnosis, GM (95% CI)	55.7 (54.9-56.4)	45.7 (44.9-46.5)	< 0.001	0.47
N problem behaviors (0-10), mean (95% CI)	6.0 (5.9-6.0)	6.1 (6.0-6.2)	0.045	0.04

Abbreviations: GM, geometric mean; NOS, not otherwise specified; 95% CI, 95% confidence interval; mos., months. P-values based on Pearson $\chi 2$, ANOVA or Kruskal-Wallis chi-squared rank test. Cohen's d is an estimate of effect size (0.02 is considered a small effect size, 0.05 is medium, 0.08 is large, and 1.3 is very large (Sullivan & Feinn, 2012). 1 "Other" includes Asian/Pacific Islanders and American Indian/Alaska Natives; 2% of families with children < 18 living below the poverty level (by census block group, year 2000 census).

non-normally distributed variables, Kruskal-Wallis chi-squared tests were used. Differences in the proportion of children with specific behaviors by ASD/ID status were evaluated using Pearson's chi-squared test. Cohen's *d*, an indicator of effect size, was estimated as the difference in arithmetic means between the two groups, divided by the larger of the standard deviations. Using Cohen's *d*, 0.2 is considered a small effect size, 0.5 is medium, 0.8 is large, and 1.3 is very large) (Sullivan & Feinn, 2012). Risk ratios (point estimates and 95% confidence intervals) for problem behaviors were calculated using epidemiological tables and generalized linear models for the binomial family. Children whose cognitive impairment was NOS were excluded from the models stratified by cognitive level. Non-parametric tests for trend were used to evaluate trends by level of cognitive impairment, with IQ > 85 (average - above average) as the reference group. Sensitivity analysis was performed using the same statistical tests on the subgroup of ASD cases from study sites that had access to school records and had cognitive test information for at least 70% of cases.

3. Results

3.1. Characteristics of the population

During survey years 2006, 2008, and 2010, a total of 12,240 8-year-old children were identified across sites in the ADDM Network as ASD cases. Of these, 9378 children (77%) had complete records on cognitive testing (Table 2). Approximately one third of ASD cases had co-occurring ID, and of those with ID, 52% had mild cognitive impairment (IQ 50-70), 19% were moderately impaired, 9% severely or profoundly impaired, and 20% had cognitive impairments NOS. Of the children without co-occurring ID, 64% had average - above average IQ scores (IQ > 85) and 36% had below average IQ scores (IQ 71-85).

The ratio of males to females was higher among children with ASD only (5.4:1.0) as compared to children with ASD + ID (4.0:1.0, $p < 0.001$). Significant differences by race/ethnicity were also observed: 64% of children with ASD only vs. 46% with ASD + ID were non-Hispanic white, 15% of children with ASD only vs. 30% with ASD + ID were non-Hispanic black, and 12% and 16%, respectively, were Hispanic, any race ($p < 0.001$). The age at earliest comprehensive evaluation was significantly younger for children with ASD + ID (34 months) as compared to those with ASD only (44 months), a medium effect size (Cohen's $d = 0.5$). Children with ASD + ID also had more evaluations in their records than those without (5.6 vs. 5.0) and an earlier age at first ASD diagnosis (46 vs. 56 months) (Cohen's $d = 0.18$ and 0.47, respectively; p-values < 0.001). Approximately 65% of children with ASD only had a prior clinical diagnosis of ASD, while 74.5% of children with ASD + ID had a prior ASD diagnosis.

Almost all children in the study had at least one co-occurring behavioral problem and a majority (60%) had six or more regardless of co-occurring ID (Cohen's d = 0.04). Inattention/hyperactivity, argumentative/oppositional behaviors, mood problems, and unusual sensory responses were reported in > 70% of children. Between 45 and 65% of children were reported to have temper tantrums, aggression, abnormal fear responses and abnormal eating behaviors, and > 25% had problems sleeping and exhibited self-

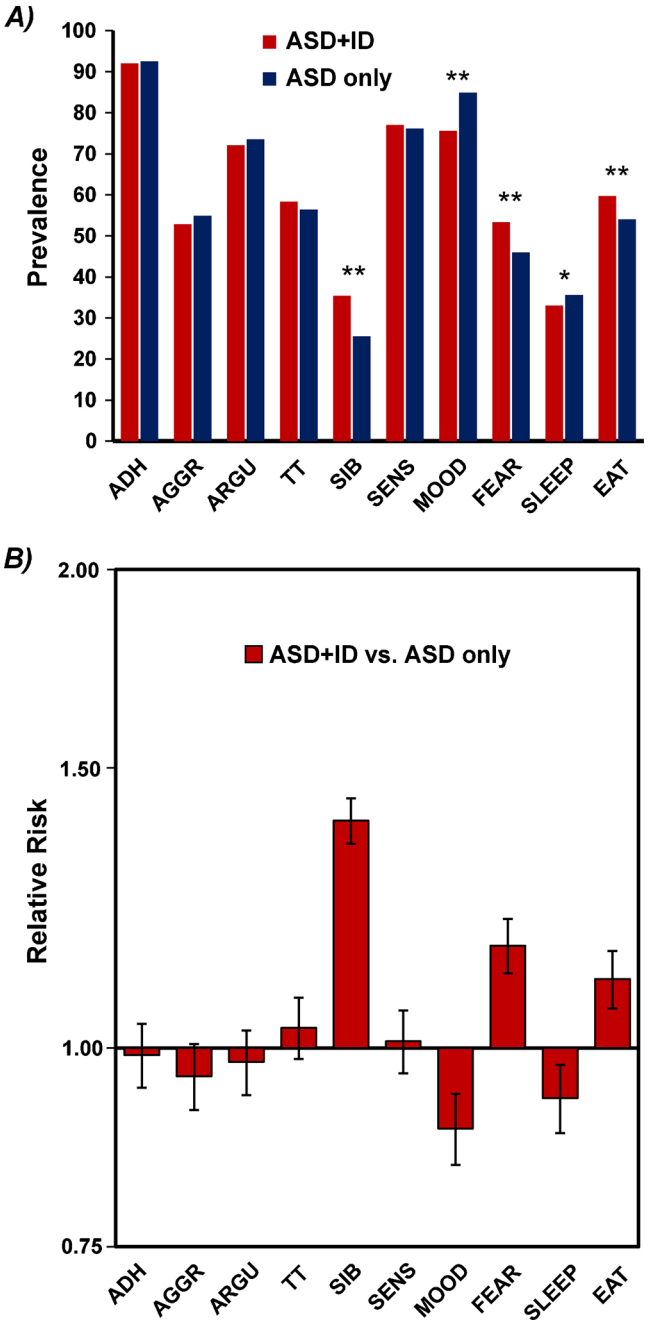


Fig. 1. A) Prevalence of problem behaviors by ASD/ID status, and **B)** relative risk (and 95% confidence intervals) of problem behaviors in children with ASD + ID as compared to children with ASD only (reference group). Pearson's chi-squared test: ** $p < 0.001$; * $p = 0.002$. Abbreviations: ADH, inattention/hyperactivity; AGGR, aggression; ARGU, argumentative/oppositional; EAT, abnormalities in eating or drinking; FEAR, lack of or excessive fearfulness; MOOD, abnormalities of mood or affect; SENS, unusual responses to sensory stimuli; SIB, self-injurious behaviors; SLEEP, sleeping abnormalities; TT, temper tantrums.

injurious behaviors (Fig. 1a).

3.2. Correlated behaviors

All behaviors assessed in this study showed statistically significant – albeit negligible to low – correlations with other problem behaviors ($p < 0.001$), regardless of stratification by ASD/ID status (Table 3). Slightly higher rho values were observed between aggression, argumentative/oppositional behaviors, temper tantrums and self-injurious behaviors, and between eating, sleeping and

Table 3
Spearman rank correlations between pairs of behaviors. All rho values are statistically significant at p < 0.001. Superscript indicates those correlations that showed statistically significant differences in children with ASD + ID as compared with children with ASD only.

	ADH	AGGR	ARGU	TT	FEAR	SENS	SIB	EAT	SLEEP	MOOD
ADH	—									
AGGR	0.1305	—								
ARGU	0.1811	0.3409[a]	—							
TT	0.1216	0.2852	0.2484	—						
FEAR	0.1210	0.1735	0.1572[a]	0.1645	—					
SENS	0.1273	0.0947	0.1219	0.1026[a]	0.2022	—				
SIB	0.0876	0.2629[b]	0.1598	0.2366	0.1771	0.1069	—			
EAT	0.0795	0.1417	0.1336	0.1532	0.2107	0.2408	0.1682	—		
SLEEP	0.1013	0.2120	0.1569	0.1823	0.1842	0.1591	0.1998	0.2453	—	
MOOD	0.1832	0.2102	0.2174	0.1933	0.1547	0.1375	0.1193	0.1132	0.1500	—

[a] Significantly higher correlation in children with ASD only as compared with children with ASD + ID.
[b] Significantly higher correlation in children with ASD + ID as compared with children with ASD only.

sensory problems, as compared with other behaviors. These correlations were not significantly different in children with and without co-occurring ID (not shown), with a few exceptions. Aggression and self-injurious behaviors showed a significantly higher correlation in children with ASD + ID as compared with those with ASD only ($p = 0.034$). Conversely, argumentative behavior and aggression, argumentative behavior and unusual fear response, and temper tantrums and sensory problems were more highly correlated in children with ASD only (all $p < 0.05$).

3.3. Relative risk of behavioral problems

The relative risk for each behavior was compared by ASD/ID status (Fig. 1b). Children with ASD + ID had lower risk of mood abnormalities (RR 0.89, $p < 0.001$) and sleep abnormalities (RR 0.93, $p = 0.013$) than children with ASD only. Table 4 shows a steep stepwise decline in mood problems with increasing severity of cognitive impairment. In contrast, the relative risk of self-injury, unusual fear responses and eating problems were all greater in children with ASD + ID than in children with ASD only (all $p < 0.001$), and the risk ratios increased significantly with greater severity of cognitive impairment. For example, the relative risk of SIB was 1.84 (95% CI, 1.60–2.11) times greater in children with severe-profound ID as compared to those with average - above average IQ. There were no consistent trends in relative risk of inattention/hyperactivity, aggression, argumentative behavior, temper tantrums, or sensory problems by cognitive level.

3.4. Sensitivity analysis: differences among sites and survey years

There was variability among sites and within sites by survey year in the proportion of children classified as ASD + ID vs. ASD only, regardless of a site's access to special education records. For example, in Utah, which had access to both education and clinical records, < 18% of cases had co-occurring ID, while in both South Carolina and Florida, one site with and one without access to

Table 4
Relative risk (95% confidence interval) of problem behaviors by cognitive level among children with ASD (based on generalized linear models, binomial family).

	ADH	AGGR	ARGU	TT	SIB
Cognitive Level					
IQ > 85 (average-above average IQ)	(ref)	(ref)	(ref)	(ref)	(ref)
IQ 71-85 (below average IQ)	1.00 (0.98-1.01)	1.00 (0.95-1.05)	1.02 (0.99-1.05)	1.02 (0.98-1.07)	1.21 (1.11-1.32)
IQ 50-70 (mild ID)	1.00 (0.98-1.02)	0.94 (0.89-0.99)	1.00 (0.97-1.03)	1.06 (1.01-1.12)	1.29 (1.18-1.41)
IQ 35-49 (moderate ID)	1.00 (0.98-1.03)	1.04 (0.97-1.12)	1.04 (0.99-1.09)	1.10 (1.02-1.17)	1.75 (1.57-1.95)
IQ < 35 (severe-profound ID)	0.98 (0.94-1.01)	0.99 (0.89-1.10)	0.96 (0.89-1.04)	0.89 (0.79-1.00)	1.84 (1.60-2.11)
Test for trend[1]	0.469	0.447	0.745	0.175	< 0.001
	SENS	**MOOD**	**FEAR**	**SLEEP**	**EAT**
Cognitive Level					
IQ > 85 (average-above average IQ)	(ref)	(ref)	(ref)	(ref)	(ref)
IQ 71-85 (below average IQ)	0.95 (0.92-0.98)	0.96 (0.94-0.98)	1.05 (0.99-1.11)	0.92 (0.85-0.98)	1.02 (0.97-1.07)
IQ 50-70 (mild ID)	0.96 (0.93-1.00)	0.90 (0.87-0.93)	1.14 (1.08-1.21)	0.86 (0.79-0.93)	1.06 (1.01-1.11)
IQ 35-49 (moderate ID)	1.05 (1.00-1.09)	0.88 (0.84-0.92)	1.22 (1.13-1.32)	0.93 (0.83-1.05)	1.19 (1.12-1.27)
IQ < 35 (severe-profound ID)	1.04 (0.98-1.10)	0.81 (0.75-0.87)	1.34 (1.22-1.48)	0.90 (0.76-1.06)	1.20 (1.09-1.31)
Test for trend[1]	0.525	< 0.001	< 0.001	0.002	< 0.001

[1] Non-parametric test for trend across ordered group.

education records, > 50% of ASD cases had co-occurring ID. Arizona and Missouri were the only sites that showed statistically significant differences within site by study year. Arizona, which had access to education records during all three study years, saw a decrease in the proportion of cases with co-occurring ID, from 40 to 29% between 2006 and 2010. Missouri, which did not have access to education records, saw an increase from 15 to 30% during that same time period. In a sensitivity analysis of only those sites and those study years in which IQ data were collected on ≥70% of all children, the risk ratios for behavioral problems in children with and without co-occurring ID were nearly identical to those calculated for the total population sample (see Supplement 1).

4. Discussion and implications

In a large population-based surveillance sample of 8-year-old children exhibiting a wide range of ASD symptomatology and cognitive ability, 60% of children with ASD, with and without co-occurring ID, had six or more behavioral problems. There were several differences in the predominant behavioral problems observed in children with ASD and ID as compared to children with ASD and average intelligence. Most notably, children with ASD and ID were at significantly increased risk of self-injurious behavior, abnormal fear responses and eating problems, and decreased risk of mood abnormalities and sleep-related problems as IQ declined. Degree of cognitive impairment was unrelated to the risk of inattention/hyperactivity, aggression, argumentative/oppositional behavior, temper tantrums, or unusual sensory responses in children with ASD. These findings have potentially important implications for diagnosis and intervention, given that children with co-occurring ASD and ID were evaluated and diagnosed nearly a year earlier and thus have a wider window of opportunity for early intervention.

Previous studies also reported very high rates of behavioral problems (including anxiety, depression, attention-deficit/hyperactivity, and sleep problems) in children with ASD compared to neurotypical children and children with other disorders (Mayes, Calhoun, Murray, Ahuja et al., 2011; Mayes, Calhoun, Murray, Zahid et al., 2011; Tureck et al., 2014). Although most of these studies did not account for differences in intellectual disability among children with ASD, the few that did showed markedly inconsistent findings. In a comparison of children with high vs. low functioning autism, Mayes, Calhoun, Murray, Ahuja et al. (2011); Mayes, Calhoun, Murray, Zahid et al. (2011) found that a higher percentage of the children with IQ ≥ 80 as compared to children with IQ < 80 suffered from anxiety (79 vs. 67%), depression (54 vs. 42%), and irritable/angry behaviors (88 vs. 84%, respectively) (Mayes, Calhoun, Murray, Ahuja et al., 2011; Mayes, Calhoun, Murray, Zahid et al., 2011). In contrast, Estes et al. (2007) reported an increased risk of internalizing behaviors, such as mood problems, depression and anxiety, in children with ASD and IQ ≥ 70, and an increased risk of externalizing behaviors, such as attention deficit/hyperactivity, aggression and temper tantrums, in children with ASD and IQ < 70 (Estes et al., 2007). Several other studies found that children with ASD and ID had more tantrums, depression, eating problems, and challenging behaviors in general (Matson & Shoemaker, 2009; Tureck et al., 2014), or reported no relationship between these behaviors and co-occurring ID (Goldin et al., 2014).

Increased risk of self-injurious behaviors among children with comorbid ASD and ID is consistent with previously published studies (Baghdadli, Pascal, Grisi, & Aussilloux, 2003; McTiernan, Leader, Healey, & Mannion, 2011; Minshawi et al., 2014; Soke et al., 2016). In several of these studies, self-injurious behavior is associated with greater severity of ASD symptomatology, high frequency of repetitive or stereotyped behaviors, lower developmental and adaptive scores, lower speech skills, and a wide variety of problem behaviors (Baghdadli et al., 2003; Carroll et al., 2014; Minshawi et al., 2014; Oliver, Petty, Ruddick, & Bacarese-Hamilton, 2012; Soke et al., 2017).

In this study, children with co-occurring ID were less likely to have mood abnormalities than those without ID and the risk decreased with increasing severity of cognitive impairment. In the ADDM Network data, the presence of mood abnormalities was determined by review of descriptions of excessive distress, frustration, anxiety, or depression or a lack of mood or affect in developmental evaluations for children with ASD. Other researchers have similarly reported that children with ASD and ID have a lower risk of anxiety and depression than children with ASD only (Estes et al., 2007; Hallett et al., 2013; Mayes, Calhoun, Murray, Ahuja et al., 2011; Mayes, Calhoun, Murray, Zahid et al., 2011; Salazar et al., 2015).

We observed an inverse relationship between IQ and abnormal fear responses, though several previous studies found no association (Mayes et al., 2013; Salazar et al., 2015; Simonoff et al., 2008). Interestingly, one study noted that maternal ratings of “fearful, anxious or worried” behaviors in children with ASD were higher for children who had higher, not lower, IQs (Mayes et al., 2013). Inconsistencies among studies may be a result of differences in the age of the children studied, sampling methodology, assessment tools, or possibly due to the limited ability of children with severe ID to communicate or understand fear.

We found no other studies on the role of ID on eating abnormalities among children with ASD. In a small prospective study comparing children with a diagnosis of ASD to those with a diagnosis of ID, eating problems were more prevalent and more severe in children with ASD (Crasta et al., 2014). Another study found that children with ASD who exhibited atypical eating behaviors tended to have higher rates of ASD symptomatology (Postorino et al., 2015). In the present study, abnormalities in eating or drinking were more prevalent in children with co-occurring ID.

Although we report that relative risk of sleep abnormalities is lower in children with ASD who have slight cognitive impairment (IQ 50-70 or 71-85), as compared to children with IQ > 85, sleep problems occur across all cognitive levels in children with ASD (Souders et al., 2017). Difficulty falling asleep, night wakings, and other sleep difficulties are frequently reported in children with ASD and are strongly associated with behavioral problems, such as aggression, inattention, hyperactivity, and hostility (Mazurek & Sohl, 2016) and with family stress (Souders et al., 2017). Several studies have reported that children with ASD and ID have a greater propensity to chronic sleep disturbances than children without ID (Elrod & Hood, 2015; Taylor, Schreck, & Mulick, 2012; Cohen, Conduit, Lockley, Rajaratnam, & Cornish, 2014). Other researchers have reported an inverse association between IQ and scores for several types of sleep disorders in the overall population, but found no association in children with a diagnosis of ASD (Krakowiak,

Goodlin-Jones, Hertz-Picciotto, Croen, & Hansen, 2008). In that (1) children with sleep problems and ASD tend to have more severe autistic symptoms, (2) sleep difficulties appear to exacerbate ASD symptoms, and (3) sleep problems are linked to other behavioral problems (Cohen et al., 2014; Sikora, Johnson, Clemons, & Katz, 2012), it may be especially difficult to disentangle associations between ID and sleep abnormalities.

As mentioned above, there were no differences in inattention/hyperactivity, aggression, temper tantrums, argumentative/oppositional/defiant behavior, or unusual sensory responses in children with and without co-occurring ID. Attention deficit/hyperactivity disorder (ADHD) is common in children with ASD and/or ID (Lamanna et al., 2017; Yerys et al., 2009). Several studies report that children with a dual diagnosis of ASD and ADHD show a more severe ASD phenotype, with lower IQ, higher autistic symptom severity and more problems with oppositional, anxiety and conduct disorders, as compared to children with ASD without ADHD (Cooper, Martin, Langley, Hamshere, & Thapar, 2014; Craig et al., 2015; Lamanna et al., 2017; Mansour, Dovi, Lane, Loveland, & Pearson, 2017). In a multi-site European study, Charman et al. (2017) observed statistically significant but weak negative correlations between parent-reported inattention and IQ and between hyperactivity/impulsivity and IQ in children with ASD. Several studies report high rates of aggression in ASD and in ID separately (Visser, Berger, Prins, Van Schrojenstein Lantman-De Valk, & Teunisse, 2014), but there appears to be no consensus regarding prevalence of aggression in those with ASD and ID (Mazurek, Kanne, & Wodka, 2013; Visser et al., 2014). A higher rate of tantrums and conduct problems have been reported among children with ASD without accompanying cognitive problems (Cervantes et al., 2014). Unusual or atypical responses to sensory stimuli, such as negative reactions to noisy or busy surroundings or to being touached, commonly occur with ASD and are now included in the DSM-5 diagnostic criteria for ASD (one of four possible elements of which two must be met) (A.P.A., 2013; Green, Chandler, Charman, Simonoff, & Baird, 2016). Sensory problems have been linked to anxiety (Green & Ben-Sasson, 2010), increased social and communication impairments (Green et al., 2016), restricted, repetitive behaviors, and insistence on sameness in children with ASD (Uljarevic & Evans, 2017), and other problem behaviors (Canfield, 2008). In several studies sensory dysfunction appears to be independent of IQ in children with a diagnosis of ASD or considered at risk of ASD (Boyd et al., 2010; Green et al., 2016), though Baranek, Boyd, Poe, David, and Watson, (2007) report a decrease in sensory aversion with increased mental (and chronological) age.

According to the literature, behavioral problems tend to cluster together. Sleep problems often co-occur with inattention, hyperactivity, aggression, disruption, irritability, anxiety, mood variability, and self-injury (Cohen et al., 2014; Sikora et al., 2012), while self-injury has been linked with aggression, tantrums, disruptive/destructive behavior, anxiety, and mood problems (Baghdadli et al., 2003; Carroll et al., 2014; Minshawi et al., 2014; Oliver et al., 2012; Soke et al., 2017). We also found that certain problem behaviors, such as argumentative behavior and aggression, argumentative behavior and abnormal fear response, and sensory issues and temper tantrums, were more highly correlated among children without ID, while aggression and self-injury were more highly correlated in children with ASD + ID.

Consistent with an earlier ADDM Network study (Shattuck et al., 2009), we report that children with co-occurring ASD and ID tend to be evaluated and diagnosed with ASD earlier (mean age, 3.8 years) than children without co-occurring ID (mean age, 4.6 years). This is not surprising given that diagnosis of ASD in higher functioning children averages between 4 and 5 years of age and closer to 2 years of age in children who experience developmental regression or severe cognitive impairment (Shattuck et al., 2009). Early identification, however, is critically important in maximizing adaptive functioning and minimizing behavioral and mental health problems (Myers & Johnson, 2007).

A major strength is the utilization of data from a large surveillance population and all of the children are evaluated at the same age. It has been noted that most prior research on co-occurring developmental and behavioral disorders has been conducted on small, clinic-based patient populations predisposed to selection and reporting biases and thus not necessarily generalizable to the population of children with ASD at large (Lecavalier, 2006; Matson & Cervantes, 2014; Wiggins et al., 2009). Platt and colleagues specifically stated that many of the associations reported in clinical samples have not been corroborated in population-based samples (Platt, Keyes, McLaughlin, & Kaufman, 2018).

ADDM Network methods entail meticulous review of comprehensive evaluations from a diverse population of 8-year-old children and collation of extensive data on ASD-related behaviors, diagnostic criteria and cognitive impairment. Although our population sample is not considered representative of all 8-year-old children in the United States who have ASD, study sites attempt to define surveillance areas that approximate the demographic characteristics of the resident population. Several ADDM surveillance sites did not have access to education records which could lead to larger numbers of children being misclassified as ASD only. However, the site-to-site and year-to-year variations observed in the proportion of children classified as ASD only vs. ASD + ID were not related to differences in access to special education records, and sensitivity analysis suggests that this did not bias the results. Furthermore, since cognitive test score data was an inclusion criterion for this study, children who did not have scores were not included in any analyses.

Our study has several potential limitations. The population was not systematically assessed using a common instrument, as might be the case in other studies. Therefore, appropriate classification of these children was dependent on the documentation in their records of ID, ASD criteria, and behaviors. Underreporting could be a problem when not all of the clinical and educational records were accessible. The behavioral problems assessed in the ADDM study are coded as “present” or “absent,” with no objective tests or detailed information on the frequency, intensity, persistence, or specific nature of these behaviors.

Another consideration is that our definition of ID was based only on IQ scores and did not include an assessment of adaptive functioning and the implications of low cognitive scores and low adaptive scores are not necessarily the same in relation to ASD and psychopathology (Platt et al., 2018). Hence, children classified as having ID did not necessarily meet all of the criteria needed for a diagnosis (2013, A.P.A., 2000). Differences in scores on tests on adaptive functioning suggest a complex relationship with ASD and IQ (Kenworthy, Case, Harms, Martin, & Wallace, 2010). The additional information captured by tests of adaptive skills such as

[conceptual, social, and practical] communication, daily living, motor, and socialization skills might better explain behavioral problems than IQ tests alone (Kenworthy et al., 2010) and provide a better framework for intervention (Tasse et al., 2012).

Successful strategies for intervention and treatment in ASD depend in part on differentiation and understanding of the underlying developmental problems and their complex interactions with co-occurring behavioral problems. ID in children with ASD is associated with increased risk of self-injury, abnormal fear responses, and eating problems and decreased risk of mood and sleep abnormalities. These and other behavioral problems tend to be associated with greater severity of ASD core symptoms and greater impairment in socialization, communication and adaptive skills (Minshawi et al., 2014). Further clarification of the interaction of co-occurring symptoms and behaviors associated with ASD, including ID, can inform diagnostic and intervention strategies, with the potential to reduce the frequency and severity of these behaviors.

Conflict of interest

The authors confirm that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.rasd.2018.09.002.

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