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Does Gender Moderate Core Deficits in ASD? An Investigation into Restricted and Repetitive Behaviors in Girls and Boys with ASD

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Abstract Due to the uneven gender ratio of autism spectrum disorders (ASD), girls are rarely studied independently from boys. Research focusing on restricted and repetitive behaviors (RRBs) indicates that above the age of six girls have fewer and/or different RRBs than boys with ASD. In this study we investigated whether girls and boys with ASD demonstrated similar rates and types of RRBs in early childhood, using discrete observational coding from a video-taped play interaction. Twenty-nine girls with ASD were matched to 29 boys based on ASD severity. While boys in our sample demonstrated a greater frequency of RRBs, this was not significant and our findings indicate that girls and boys under five are more similar than dissimilar on this core deficit. However our data also revealed a trend toward gender-differential growth trajectories—a finding worthy of further investigation in larger samples.

Keywords Autism · Gender · Restricted and repetitive behaviors

Introduction

One of the most replicated findings in the field of autism spectrum disorder (ASD) is the over representation of boys diagnosed relative to girls (Brugha et al. 2011; Chakrabarti and Fombonne 2005; Developmental Disabilities Monitoring Network Surveillance Year 2010 Principal Investigators 2014; Fombonne 2009; Kim et al. 2011). The gender ratio is consistently reported at around 4–5:1 boys, however this ratio is not evenly distributed across the spectrum. Recent genetic research has begun to shed light on potential gender-specific mutations and female protective factors that may lead to the differential diagnosis rate between sexes (see Jeste and Geschwind 2014; Werling and Geschwind 2013 for recent reviews). Research has also indicated that in order for girls to receive a diagnosis of ASD they require a greater symptom threshold, as well as accompanying behavioral problems or intellectual disability (ID) (Banach et al. 2009; Dworzynski et al. 2012) potentially leading to later detection and diagnosis (Kopp and Gillberg 1992). As a result, the behavioral phenotype and symptom presentation of girls with ASD, especially toddlers and preschoolers, is still widely unknown (Van Wijngaarden-Cremers et al. 2013).

The Female Phenotype in ASD

Research focusing on gender differences in ASD presents an extremely varied picture. For the domain of social-communication, research has indicated both matched (Andersson et al. 2013; Harrop et al. 2015; Lord et al. 1982; Van Wijngaarden-Cremers et al. 2013) and divergent abilities in males and females (Carter et al. 2007; Hartley and Sikora 2009; Holtmann et al. 2007; Kopp and Gillberg 1992; Pilowsky et al. 1998; Tsai and Beisler 1983; Volkmar et al. 1993). One relatively consistent finding is that, when diagnosed, girls often fall within the moderate to severe end of the spectrum where the sex ratio is more evenly distributed (Carter et al. 2007; Fombonne 1999, 2003a, b). However when using matched samples and controlling for IQ differences, research has often failed to

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find differences between girls and boys (Andersson et al. 2013; Harrop et al. 2015; Volkmar et al. 1993) suggestive that developmental abilities (such as IQ) may play a fundamental role in the diagnosis and detection of gender difference in girls with ASD.

Restricted and Repetitive Behaviors (RRBs): The Role of Gender and Developmental Abilities

RRBs are a core symptom of ASD (American Psychiatric Association 2013; World Health Organization 1992). RBBs are defined as the expression of repetitive body mannerisms, overriding preoccupations with objects/parts of objects, sensory behaviors and strict adherence to routines and rituals (Richler et al. 2007). These behaviors are frequently divided into two categories; *lower* and *higher order* behaviors (Turner 1999). *Lower order* behaviors typically characterize repetitive motor actions and physical and/or sensory manipulation of objects, whereas *higher order* behaviors manifest through the presence of routines, an insistence on sameness and circumscribed interests.

RRBs are commonly observed in typically developing infants and toddlers (Barber et al. 2012; Harrop et al. 2014; Leekam et al. 2007; Thelen 1981a, b; Watt et al. 2008). However, it is the increased frequency, persistence over time and interference with learning that distinguishes RRBs in ASD from those observed in typical development and other developmental disorders (Matson et al. 2009). RRBs represent an extremely heterogeneous set of behaviors and even within children with ASD there is vast variability in their frequency and intensity of expression (Harrop et al. 2014; Turner 1999; Walker et al. 2004).

Recent findings indicate lower rates of RRBs in girls with ASD, particularly in the higher-functioning end of the spectrum (Hartley and Sikora 2009; Mandy et al. 2012; Szatmari et al. 2012). Girls are reported to have more appropriate interests or interests less typical of ASD (Hiller et al. 2014; Kopp and Gillberg 1992) whereas boys with ASD present with more atypical motoric behaviors, restricted interests and repetitive and/or abnormal use of objects (Hiller et al. 2014; Lord et al. 1982; Mandy et al. 2012). However when samples are more tightly matched on variables such as chronological age and IQ these differences are less consistently replicated (Holtmann et al. 2007; May et al. 2014; McLennan et al. 1993; Nguyen and Ronald 2014; Pilowsky et al. 1998; Volkmar et al. 1993).

Clinical and anecdotal evidence indicates potential qualitative differences between girls and boys with ASD particularly in the types/content of interests reported (Attwood 2006) which may be informative in the absence of clear quantitative differences. Hiller et al. (2014) reported qualitatively different interests between high-functioning boys and girls with ASD. Specifically girls were more likely to have interests classified by teachers as "seemingly random" (e.g. rocks, pens, stickers) whereas boys were more likely to have intense interests involving screen time and technology. Girls in this sample were also less likely to have interests involving objects. Focusing on early childhood and diagnosis, Hiller and colleagues further found that repetitive play with wheels distinguished boys from girls (Hiller et al. in press). This reduced frequency and/or different types of RRBs is one mechanism hypothesized to lead to girls being detected later and/or less likely to receive a diagnosis of ASD and may in turn have implications for the trajectory of ASD between girls and boys.

In two recent studies with young children with ASD—one with a tightly matched sample of preschoolers with ASD (Andersson et al. 2013) and another with a large well-defined sample of toddlers with ASD (Reinhardt et al. 2015)—rates of RRBs, as measured through the Autism Diagnostic Observation Schedule (ADOS: Lord et al. 2012), were equivalent between girls and boys with ASD. Further findings of a recent review and meta-analysis also indicate that under the age of six the difference in RRBs between girls and boys is inconsistent with differences only emerging above this age and in behaviors more indicative of *higher* order RRBs—more complex behaviors such as attachment to objects, an insistence on sameness and routine, and in-depth circumscribed interests (Kirkovski et al. 2013; Van Wijngaarden-Cremers et al. 2013). Thus girls and boys with ASD in early development may present with similar behaviors—typically those classified as *lower* order behaviors and frequently observed in early childhood, particularly in children with accompanying developmental delays (Carter et al. 2007). Therefore furthering our understanding of whether gender differences in this core deficit of ASD are apparent in younger children with ASD and exploring the role of development (such as language ability and cognitive functioning) on RRB trajectories has important implications for early detection and diagnosis of ASD.

The association between RRBs and developmental level is well established (Bishop et al. 2006; Carcani-Rathwell et al. 2006; Esbensen et al. 2009; Harrop et al. 2014). Measures of the severity of non-verbal and overall global developmental delay consistently associate with increased repetitive object use, unusual sensory interests/behaviors, self-injury, and repetitive hand and motor mannerisms. The opposite is true for the incidence of behaviors rated as *higher order*, such as restricted and intense interests (Bishop et al. 2006; Carcani-Rathwell et al. 2006; Cuccaro et al. 2003; Esbensen et al. 2009; Harrop et al. 2014; Lam et al. 2008; Militerni et al. 2002; Richler et al. 2007, 2010). However there is some indication that below 36 m these associations are not evident (Bishop et al. 2006).

Frazier et al. (2014) recently raised the question of whether differences in clinical characteristics (social-communication and RRBs) are driven by cognitive abilities in girls and boys with ASD. Their findings indicate that, unlike social-communication impairments, chronological age or IQ did not drive differences in the rates of RRBs between girls and boys. The results suggest that girls, particularly those with an IQ above 70, presented with fewer restricted interests. While providing a comprehensive analysis of RRBs in a large sample of girls and boys with ASD—using the ADOS, Autism Diagnostic Interview-Revised (ADI-R; Le Couteur et al. 2003) and Repetitive Behavior Scales-Revised (RBS-R; Bodfish et al. 1999)—the sample had a wide age range (4–18 years; mean age 9 years) rather than a specific focus on early or later childhood.

As both the diagnosis of girls with ASD and the presence and type of RRBs are two areas that appear to be influenced by IQ and developmental abilities, a logical next step is to explore how these two variables interact with one another in early development. In recent work, we found that girls and boys with ASD matched on symptom severity, chronological age and developmental abilities did not differ on component core deficit behaviors of play, joint attention and behavioral requesting. However associations between developmental variables and behavioral requesting varied by gender (Harrop et al. 2015). As such we were interested in exploring how the other core domain of ASD–RRBs—may associate differentially with developmental characteristics in a well-defined and matched sample of young girls and boys with ASD.

To date few studies have examined gender differences in RRBs in early development. In studies using the gold-standard diagnostic measures (ADOS and ADI-R) gender differences in RRBs have not been consistently found (Andersson et al. 2013; Carter et al. 2007; Kirkovski et al. 2013; Reinhardt et al. 2015; Van Wijngaarden-Cremers et al. 2013). Given that these behaviors are some of the very first to flag a child as at risk for ASD (Elison et al. 2014; Ozonoff et al. 2008; Wolff et al. 2014) and the fact that boys are identified at a rate of 4–5 to 1, it is possible that girls may not be as impaired in these behaviors as boys, thus accounting for their infrequent and potentially later identification. To our knowledge, a fine-grained observational analysis of RRBs focused on specific subcategories of RRBs typically used within early detection and diagnosis in girls and boys has not been conducted, with most investigations into potential differences reliant upon caregiver report and diagnostic tools, which are frequently used for sample characterization and sample inclusion. Given that in early childhood overlap between caregiver report of these behaviors and researcher rated observational data is inconsistent or weaker than expected, even in high risk populations (Chawarska et al. 2007; Harrop et al. 2014; Le Couteur et al. 2008; Ventola et al. 2006) standardized observational coding may be more informative in detecting early gender differences in this core deficit of ASD.

Using a well-defined matched sample of girls and boys with ASD, we asked whether gender differences in RRBs were evident in early development and whether associations with developmental variables and chronological age differed between girls and boys. It is possible that if girls present with fewer RRBs in early childhood this could potentially lead to later detection or diagnosis, especially without the presence of accompanying ID and be indicative of gender-differential trajectories in girls with ASD.

Our aims were threefold;

1. Explore potential differences in the overall frequency of observer coded RRBs between girls and boys with ASD.
2. Explore potential differences in the categories of RRBs between girls and boys with ASD.
3. Determine if the associations between developmental variables (non-verbal and verbal) and chronological age and RRBs differ by gender

Method

Ethical approval for this research was obtained through our Institutional Review Board and caregivers gave written consent for their child to participate.

Participants

Two groups of participants were sampled for this study; (1) a group of girls (N = 29) with a clinical diagnosis of ASD and (2) a group of boys (N = 29) with a clinical diagnosis of ASD (Table 1). Boys were individually matched to a girl with ASD based on Autism Diagnostic Observation Schedule (ADOS-2; Lord et al. 2012) module and algorithm score. The ADOS-2 was used to verify the community clinical diagnosis of the sample upon entry into the study and as an index of ASD severity for sample characterization and matching (see "Matching Procedure"). The 29 girls represented all female participants recruited into three studies at UCLA who completed a videotaped caregiver–child interaction (CCX)—required for coding of RRBs.

Recruitment and Corresponding Studies

Participants were recruited from three studies that included a videotaped CCX with the same standardized set of toys all conducted at the University of California, Los Angeles (UCLA). Study one was a randomized controlled trial (RCT)

Table 1 Sample characteristics

	ASD girls (n = 29)	ASD boys (n = 29)	t	*df*	*p*
ADOS-2 module (1:2)	26:2 (1 missing)	27:2	–	–	–
ADOS-2 algorithm score	15.46 (4.81)	15.55 (4.55)	.07	55	.94
Restricted and repetitive behavior score	3.46 (1.93)	3.58 (1.92)	.24	55	.81
Chronological age (months)	38.81 (8.71)	35.83 (6.49)	−1.23	56	.22
Developmental quotient	61.62 (21.55)	61.39 (21.93)	−.04	56	.40
Non-verbal age equivalent	32.29 (11.86)	30.20 (6.49)	−.71	56	.48
Expressive language age equivalent	18.96 (9.04)	17.51 (9.37)	−.60	56	.55
Receptive language age equivalent	20.10 (12.16)	19.58 (9.58)	−.18	56	.86
Ethnicity					
African-American	3	1			
Caucasian	12	11			
Hispanic	2	5			
Asian	7	7			
Other/multi-racial	5	5			

Mean (SD)

for children aged between 36 and 48 months with a clinical diagnosis of ASD comparing two different treatment approaches across multiple sites. This study was targeted to families with low resources. Five girls with ASD were recruited from the UCLA site of the study and included in this sample. Study two was a lab-based RCT for children with a clinical diagnosis of ASD aged between 22 and 36 months. Sixteen girls were recruited into study two and all sixteen were included in the current study. Study three was an ongoing school and home based intervention project for children aged between 33 and 54 months of age with minimal expressive language abilities. Eight girls were recruited at the UCLA site and included in this sample. Child characteristics and data were included from the baseline assessments for each child (Table 2).

Matching Procedure

Each girl with ASD was individually matched to a boy with ASD from the same study (1 to 3) based on the following criteria; (1) same ADOS-2 module (1 or 2); and (2) within one point match on the ADOS-2 algorithm total score. When multiple boys were potential matches, we purposefully selected the participant with the closest developmental quotient (DQ) on the Mullen Scales of Early Learning (MSEL; Mullen 1995) and/or chronological age. One girl was missing her ADOS due to a community clinical administration being completed within a month of study entry. This girl was matched to an ASD boy on MSEL DQ and chronological age.

Measures

Eligible children were screened using the ADOS-2 upon entry to each of the three studies as a means of confirming community clinical diagnosis of ASD. If children met the cut off for an ASD, they completed the MSEL and a videotaped caregiver–child interaction (CCX) with a standardized set of toys. The MSEL is a standardized experimenter administered measure of early development commonly used with young children with ASD (Bishop et al. 2011; Lord et al. 2006). It has good convergent validity with other measures of developmental abilities (Bishop et al. 2011). The MSEL is suitable from infancy through to 68 months. Four scales were used in this study (fine motor, visual reception, expressive language and receptive language) to ascertain a DQ, language and non-verbal development scores. In addition, two measures of RRBs were available—clinician rated algorithm scores from the ADOS-2 and researcher rated frequencies from the CCX.

Caregiver–Child Interaction (CCX)

Child RRBs were coded from the CCX. The CCX was designed to represent a naturalistic play interaction between the child and their primary caregiver. CCXs were filmed either at home (Boys: 8; Girls: 8) or in an observation room (Boys: 21; Girls: 21). Research has indicated that play at home is comparable to that observed within more standardized settings (Bornstein et al. 1997) thus we did not control for CCX location. Caregivers were provided with a standardized set of toys selected for developmental appropriateness and variety in both the home and the lab (Blocks; Peg Bus; Dump Truck; Animal Blocks; Small Figurines; Furniture; Bike and Ramp; 2× Phone; Ball; Dinosaurs; Pop-Up; Utensils; Shape Sorter). Caregivers were instructed to play as they normally would and to use as many or as few toys as they wished. Interactions were videotaped and later coded.

Table 2 Sample characteristics by study

	Study 1		Study 2		Study 3	
	Boys	Girls	Boys	Girls	Boys	Girls
N	5	5	16	16	8	8
ADOS-2 module (1:2)	4:1	4:1	15:1	14:1[a]	8:0	8:0
ADOS-2 algorithm score	14.00 (3.39)	14.20 (3.03)	15.75 (4.96)	15.93 (5.05)	16.13 (4.61)	15.38 (5.60)
Restricted and repetitive behavior score	2.20 (1.79)	2.80 (2.83)	3.50 (2.10)	3.33 (2.19)	4.62 (0.91)	4.12 (1.72)
Chronological age (months)	37.00 (3.53)	49.60 (7.30)	31.56 (0.69)	31.81 (3.10)	43.63 (5.75)	44.25 (4.98)
Developmental quotient	70.07 (27.11)	65.61 (15.63)	64.39 (23.23)	64.81 (25.23)	49.95 (11.16)	52.76 (15.14)
MSEL age equivalent	26.00 (10.68)	31.45 (7.04)	20.12 (7.02)	20.92 (8.27)	21.87 (5.98)	23.28 (7.10)
Ethnicity						
African-American	1	2	0	0	0	1
Caucasian	0	0	11	10	0	2
Hispanic	3	1	1	1	1	0
Asian	0	1	1	2	6	4
Other/multi-racial	1	1	3	3	1	1

Mean (SD)

[a] One ADOS missing

Ratings of Restricted and Repetitive Behaviors (RRBs)

Coding of child RRBs was based on the scheme developed by Harrop et al. (2014). This scheme was developed based on previously validated caregiver report and observer rated measures of RRBs used within a range of published studies (Boyd et al. 2011; Lam et al. 2008; Leekam et al. 2002, 2007; Watt et al. 2008). While ADOS-2 *Restricted and Repetitive Behavior* algorithm scores have been used in a number of studies exploring gender differences (Frazier et al. 2014; Hartley and Sikora 2009; Reinhardt et al. 2015) this measure was used for study inclusion and to define and match our samples, therefore we did not want to rely solely upon this measure to explore potential differences between boys and girls with ASD. Additionally the ADOS-2 was developed as a diagnostic tool and thus does not provide a fine-grained analysis of individual behaviors or a large range of scores which may be informative when exploring potential differences between girls and boys with ASD particularly in younger children (Carter et al. 2007).

The coding scheme (Harrop et al. 2014) focuses on behaviors classed as *lower order* RRBs due to their likelihood of being observed within a short free play session and in young children with ASD. However routinized play sequences/scripts are captured within this coding scheme and can span both categories of *higher* and *lower order* RRBs. Operational definitions of behaviors coded are reported in Table 3. While all 11 behaviors were coded individually, these were collapsed into six corresponding categories for the purpose of the analysis and to increase statistical power given our sample size.

All CCXs were coded by a graduate research assistant—trained by the first author—who was blind to study purpose. Intraclass correlation coefficients (ICCs) were established on 30 % of the total sample for total RRBs frequency and for the six RRBs categories (Table 3). The ICC for total RRBs was 0.88. The collapsed categories ranged between 0.76 and 0.94 (object: $\alpha = 0.88$; motor/mannerisms: $\alpha = 0.86$; sensory seeking: $\alpha = 0.78$; sensory–visual: $\alpha = 0.76$; verbal: $\alpha = 0.87$). An ICC was not obtained for sensory aversion due to zero variance in this coding between raters.

Statistical Analysis

Statistical analysis was conducted using SPSS 20. Between group differences were explored by gender for total RRBs and each of the individual subcategories using MANOVAs. Effect sizes were calculated for each of these analyses. In the second stage of the analysis, we conducted correlations within gender to explore the association between total RRBs, chronological age and the developmental variables of non-verbal development and language. Language age equivalent scores were established through the receptive and expressive scales of the MSEL. Non-verbal age equivalent scores were comprised of the MSEL fine motor and visual reception scales. If the pattern of correlation was different between girls and boys (i.e., if an correlation was positive in girls, but negative in boys, or if there was a significant correlation with developmental variables in boys, but not in girls) we conducted Z-tests to determine if these correlations were significantly different by gender.

We used a Bonferroni-adjusted significance level of 0.007 to account for the seven types of measurement within our data set. These included six collapsed categories of RRBs (total RRBs was not included as total frequencies

Table 3 Operational definitions and examples of RRBs coded during the CCX

Category	Individual item	Item description	Examples
Object	Grouping	Arranges objects in rows/patterns/stacks or hoards objects	Lining up toys Arranging toys by size Retaining/hoarding objects
	Repetitive object use	Fiddles with objects Uses in repetitive and non-functional way Non-functional and/or repetitive/scripted routines with objects	Pushes one button on a pop-up toys over and over (without any engagement with a play partner) Only using two shapes in a shape sorter repeatedly
	Object manipulations	Bangs/taps/shakes/throws objects	Taps toys with finger repeatedly Bangs toys together Shakes toys
Motor/mannerisms	Whole body movements	Spins/rocks/paces/jumps/toe walking	Walks on toes Paces room back and forth Spinning
	Complex and unusual mannerisms	Unusual hand/finger mannerisms Flapping	Flapping Flicks fingers Hand posturing
Sensory seeking	Sensory seeking	Unusual interest in smell, texture and/or sound	Rubs toy on face Brings toys to ears to hear sounds Smells toys
	Sensory seeking–self/other	Touches part of body repetitively Touches part of body in unusual way	Touches part of foot repeatedly Hold foot throughout interaction Rubs caregivers hair repeatedly
	Oral	Mouthing/chewing/biting/licking objects	Indiscriminate mouthing of objects
Sensory aversion	Sensory aversion	Sensitive to sounds or touch	Covers ears in response to sounds Clear reaction to caregiver rolling car on their leg
Sensory–visual	Visual	Visual inspection Looking at objects from certain angles Brings objects close to eyes Visual stimulatory behaviors	Rests head on floor at looks at car wheels Brings objects close to eyes Squints at objects and looks at from an angle
Verbal	Verbal	Echolalia Scripted language Atypical vocalizations Atypical rhythm/intonation	Child echoes caregivers language “Sing-song” rhythm

stem from the six corresponding categories) and one from the Mullen (verbal and non-verbal were classified as one measurement type as stem from the same measure and are highly correlated). Tests that passed the Bonferroni adjustment are denoted with an asterisk in the text.

Results

Sample Characteristics

Sample characteristics are reported in Table 1 for the full sample [$n = 58$] and Table 2 by study. Girls with ASD were matched to boys with ASD on ADOS module and score. This score did not differ between the two groups [$t(55) = 0.07$, $p = .94$] indicating well-matched groups. The groups also did not differ on the chronological age [$t(56) = -1.23$, $p = .22$] or developmental quotient [$t(56) = -.04$, $p = .40$]. All variables were matched within each individual study with the exception of chronological age in Study One where the girls were chronologically older than the boys [$t(4) = -3.47$, $p < .01$].

RRBs by Gender

As shown in Tables 1 and 2, girls and boys did not differ on ADOS-2 RRB algorithm scores in the whole sample ($n = 58$) or by individual study (Table 2). While boys

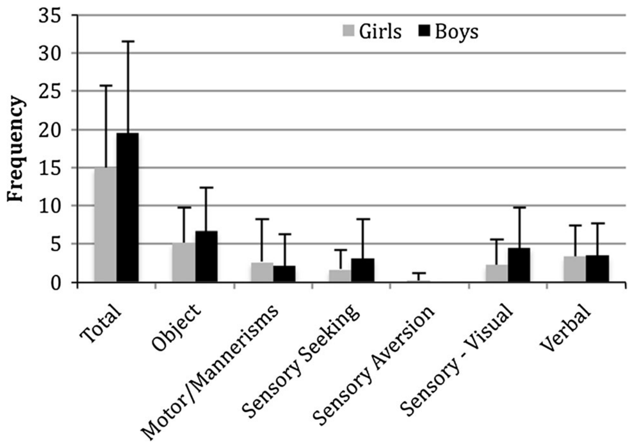

Fig. 1 Restricted and repetitive behaviors by gender: total frequencies and subcategories

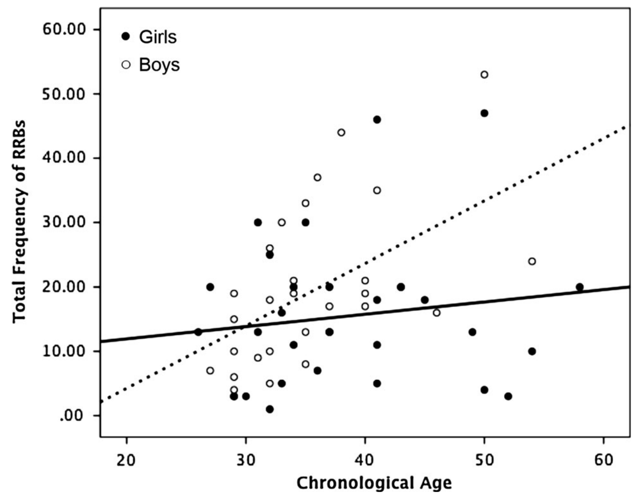

Fig. 2 Association between chronological age and total frequency of RRBs by gender

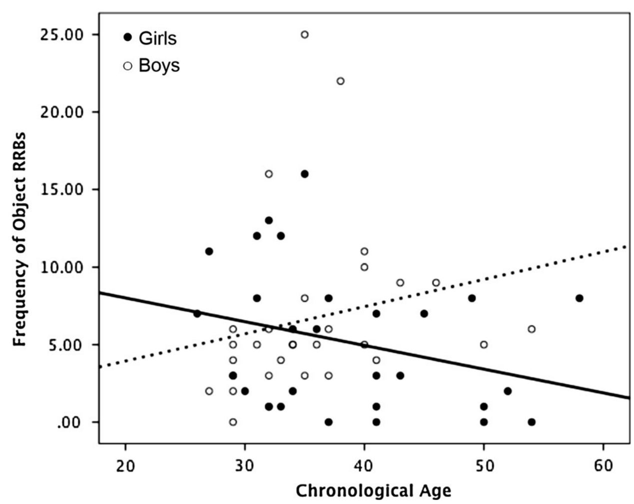

Fig. 3 Association between chronological age and object RRBs by gender

demonstrated higher frequencies of RRBs than girls within the CCX (Fig. 1) this difference was not significant [$F(1, 56) = 2.37$, $p = .13$, $\eta_2 = .04$]. Boys demonstrated a trend toward higher frequencies of *visual* RRBs [$F(1, 56) = 3.89$, $p = .05$, $\eta_2 = .06$]. While boys displayed more *object* and *sensory seeking* RRBs (Fig. 1), these differences were not significant [object: $F(1, 56) = 1.62$, $p = .21$, $\eta_2 = .02$; sensory seeking: $F(1, 56)$: 1.72; $p = .19$, $\eta_2 = .03$]. The remaining categories of *sensory aversion*, *motor/mannerisms* and *verbal* were not significantly different between girls and boys (Fig. 1).

Associations with Development by Gender

Higher frequencies of RRBs were associated with lower non-verbal abilities in both boys and girls [Boys: $r(29) = -.39$, $p = .03$; Girls: $r(29) = -.54$, $p < .01$*]. These associations were not different between girls and boys [$z(56) = .69$, $p = .49$]. While lower language abilities associated with total RRBs in girls [$r(29) = -.36$, $p = .05$], this was not found in boys with ASD [$r(29) = -.19$, $p = .32$]. This pattern of association was not statistically different [$z(56) = -.67$, $p = .25$]. Age associated positively with total RRBs in boys [$r(29) = .53$, $p < .01$*]—older boys in our sample displayed higher frequencies (Fig. 2). This association was not found in girls [$r(29) = .15$, $p = .44$], however there was no statistically significant difference between these associations [$z(56) = 1.58$, $p = .11$].

To preserve statistical power, associations between age and developmental variables were only run with the categories of *object* and *visual* RRBs. This was due to *object* RRBs being the most common RRB observed during the CCX and *visual* RRBs revealing a marginal between group difference.

While the association did not reach the pre-specified level of significance, boys with lower language abilities demonstrated more *object* RRBs [$r(29) = -.45$, $p = .01$]. This was not found in the girls with ASD [$r(29) = -.30$, $p = .12$], however there was no difference between these associations [$z(56) = -.63$, $p = .53$]. Similarly boys with lower non-verbal abilities produced a greater number of *object* RRBs [$r(29) = -.43$, $p = .02$]. This was not found in girls with ASD [$r(29) = -.22$, $p = .24$], however there was no difference between these associations [$z(56) = -.85$, $p = .39$]. While age did not associate significantly with *object* RRBs for either gender [boys: $r(29) = .20$, $p = .29$; girls: $r(29) = -.29$, $p = .12$], the direction of these two associations were in opposing directions (Fig. 3) though not significantly [$z(56) = 1.81$, $p = .07$].

Total frequency of visual RRBs did not associate with chronological age in either boys or girls [boys: $r(29) = .22$,

$p = .25$; girls: $r(29)$: .27, $p = .15$]. Similarly there was no association between visual RRBs and non-verbal [boys: $r(29) = -.05$, $p = .78$; girls: $r(29) = -.25$, $p = .19$] or language abilities [boys: $r(29) = .07$, $p = .71$; girls: $r(29) = .10$, $p = .61$].

Discussion

This study attempts to characterize in-depth RRBs displayed within a free play session in girls and boys with ASD. Our aims were threefold; first we explored potential gender differences in overall frequency of RRBs and by different subclasses of these behaviors. Second, based on the findings of our previous study (Harrop et al. 2015) we explored whether associations between developmental variables and RRBs varied between girls and boys with ASD. Additionally we explored the associations between RRBs and age, stemming from research that indicates that, older girls with ASD demonstrate fewer RRBs than their male counterparts (Hartley and Sikora 2009; Kirkovski et al. 2013; Lord et al. 1982; Van Wijngaarden-Cremers et al. 2013). While boys in our sample demonstrated a greater frequency of RRBs than girls, this was not significant and overall our findings indicate that girls and boys before the age of five are more similar than dissimilar on this core deficit, consistent with recent published findings in the field (Andersson et al. 2013; Frazier et al. 2014).

While on average boys displayed five more RRBs than girls during a 10-min free play session, only *visual* RRBs emerged as producing a between gender difference with boys displaying double the frequency (though this did not pass the Bonferroni adjustment). Overall girls and boys with ASD aged between 2 and 5 years demonstrated equivocal rates of RRBs across the remaining categories and also had similar distributions of total and individual RRB frequencies, replicating a number of studies indicating matched incidences of RRBs in girls and boys with ASD (Holtmann et al. 2007; May et al. 2014; McLennan et al. 1993; Pilowsky et al. 1998; Volkmar et al. 1993). This could represent a sampling *bias* within our data set, with more severe individuals (both boys and girls) entering our studies at this young age. As research indicates that within the more severe end of the spectrum gender differences between girls and boys are reduced (Carter et al. 2007; Fombonne 1999, 2003b), the age of our sample may indicate that these girls represent those more severely impacted thus obscuring any potential gender differences in RRBs.

Research with children older than six has suggested higher rates of RRBs in boys with ASD (Hartley and Sikora 2009; Kirkovski et al. 2013; Van Wijngaarden-Cremers et al. 2013), therefore in the absence of clear gender differences in these behaviors we were interested in exploring potential associations between age and RRBs. While the associations were not significantly different from one another, our data suggests that the older boys within our sample demonstrated greater rates of RRBs whereas older girls had fewer RRBs. This trend aligns with the literature that indicates that within older samples, girls demonstrate fewer RRBs than boys. This trend appeared to be driven by the differing directions in which chronological age associated (albeit non-significantly) with *object* RRBs, suggesting that as girls get older they demonstrate fewer RRBs with objects—partially replicating the recent findings of Hiller et al. (2014). One hypothesized explanation for this may relate to an overall reduction with age in object interest in girls or conversely an increased interest in toys that may preclude repetitive play. Using parental report data, Knickmeyer et al. (2008) found that 5-year old girls had preserved pretend play relative to boys and more gender-typical toy choices. Further Hiller et al. (in press) also reported that repetitive spinning of wheels distinguished boys with ASD from girls in early childhood. Therefore it could be that with development, girls with ASD advance from object-based play to pretend play showing a preference for toys that do not possess as many repetitive qualities. This possibility is worthy of further investigation.

Our results suggest that *object* RRBs associate with non-verbal development and chronological age in boys, but less so in girls. This, in part, replicates our previous findings for social-communication variables (Harrop et al. 2015) and suggests developmental variables and age may differentially relate to core domains of ASD in girls and boys with ASD. Further girls and boys may demonstrate differential growth trajectories which change over the course of the lifespan, as previously suggested in the cross-sectional findings of Frazier et al. (2014). While our results suggest a trend in this area, these findings have both clinical and developmental implications for girls with ASD and longitudinal repeated measures designs are required to explore how the ASD phenotype may evolve overtime in both girls and boys.

A number of points are worthy of discussion stemming from our data and the wider field of gender differences research in ASD. While our findings indicate that at this young age girls and boys do not differ on *lower* order RRBs, their profile of RRBs may change across the lifespan and gender differences may be observed in older, higher-functioning children with ASD (Frazier et al. 2014; Hiller et al. 2014). Thus while in early detection and early childhood girls and boys may display similar types and rates of behaviors, their profiles may diverge with development and as they transition to behaviors classified as *higher* order with the interests displayed by girls and boys differing.

While we matched our samples on ADOS severity scores, there is speculation that our current diagnostic tools are inherently biased as they are based on our male-conceived views of ASD (Lai et al. 2015). This gender bias is hypothesized to impact research and clinical practice due to a male-biased view of ASD (Lai et al. 2015). As a result, our understanding of RRBs—a core deficit of ASD—may potentially be biased. However our results indicate that, in terms of both behavioral coding and scoring within the ADOS, equivocal types and rates of RRBs are being detected in both girls and boys at this young age and it may be that this *bias* impacts higher-functioning individuals when behaviors are less concrete and based more on subjective interpretations of interests.

Strengths

This study has a number of notable strengths. Firstly this represents one of the first attempts to explore the core deficit of RRBs in such detail using in-depth observational coding rather than rely upon standardized measures with limited variability (Reinhardt et al. 2015). Additionally, while most previous studies have focused on gender differences in older children, we purposefully focused on an age range close to diagnosis in order to capture *lower* order RRBs and a different developmental window.

Limitations

There are a number of limitations within the current study that are worthy of discussion. Firstly our small sample size limits our statistical power and ability to draw inference from the data. An unavoidable trade-off of our well-matched and defined sample is our limited ability to generalize our findings which may be possible with a larger sample. While our modest sample size shows trends toward significance both in individual categories of RRBs and potential differential associations with age and developmental abilities, with a larger sample these may reach conventional significance levels. As girls with ASD are difficult to recruit in large samples, pooling of data across data sets and institutions or utilizing large database resources would be beneficial to explore potential gender-differential trajectories (as exampled by Frazier et al. 2014). Additionally while our sample represents the diversity of the recruitment area, our diverse sample (with regards to ethnicity) may introduce further confounds that are worthy of further study.

Our study also focused on one context (the CCX) to assess RRBs. While this context is frequently used within ASD research and for coding RRBs (e.g. Harrop et al. 2014), research does indicate that the expression of RRBs may vary dependent on the context in which they are observed (Stronach and Wetherby 2014). Additionally, the use of a play based CCX may preclude higher rates of object RRBs, therefore *higher order* behaviors, such as circumscribed interests, may not be readily apparent within this context.

Within the typically developing literature, little is known about the distribution and potential gender differences in RRBs. While many studies have explored RRBs in early normative development only a handful have explored potential gender effects on RRBs. Evans et al. (1997) reported no main effects of gender in typically developing children's routines. However Leekam et al. (2007) reported higher total scores on the Repetitive Behavior Questionnaire (Leekam et al. 2007) for 2 year old typically developing boys, driven by elevated scores on the preoccupation and restricted interests subscales, mirroring what has been found with boys with ASD (Frazier et al. 2014; Hiller et al. 2014). Therefore the inclusion of matched typically developing controls will further enhance the study of gender differences in ASD.

Our study was not a longitudinal investigation into RRB trajectories therefore we cannot track potential emergence of gender differences over time. Our data revealed a trend towards fewer RRBs in older girls within our sample, in keeping with findings in the field. However there is a clear absence of longitudinal data to study the potential complexity and change in gender differences in core deficits over the lifespan.

Given that we matched on ADOS-2 algorithm scores—a metric that includes items relating to RRBs—this method of matching may have automatically reduced the likelihood of finding a difference using observational coding, especially given the fact that the groups did not differ in the RRB algorithm scores. While subtle differences emerged on subtypes of behaviors in our data set, these were not statistically significant and thus matching on ASD severity, rather than chronological or mental age, may have obscured our differences. However, recent studies with matched samples also failed to find similar differences on other measures of RRBs within young age groups of girls and boys with ASD (Andersson et al. 2013).

Conclusions

Our findings suggest that at this young age, girls and boys are presenting with similar rates and types of RRBs that are detected by both global ASD measures and more discrete observational coding. There was a trend toward a gender difference in overall frequency of RRBs and *visual* RRBs, with greater rates found in boys with ASD. In terms of *lower* order RRBs, the overall pattern and distribution of these behaviors does not appear to differ greatly between girls and boys with ASD however differential associations with development and chronological age may be potentially informative and are worthy of further longitudinal investigation.

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