REPETITIVE AND RESTRICTED BEHAVIORS AND INTERESTS IN CHILDREN AND ADOLESCENTS WITH AUTISM SPECTRUM DISORDER

by

Beth D. Warsof
A Dissertation
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of
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Committee:

____ Director

____

____

____ Department Chairperson

____ Program Director

____ Dean, College of Humanities and Social Sciences

Date: ___________________________________ Summer Semester 2013
George Mason University
Fairfax, VA

Repetitive and Restricted Behaviors and Interests in Children and Adolescents with Autism Spectrum Disorder

A Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at George Mason University

By

Beth D. Warsof
Master of Education
University of Virginia, 2009

Director: Johannes Rojahn, Professor
Department of Psychology

Summer Semester 2013
George Mason University
Fairfax, VA

DEDICATION

Mom and Dad, this one’s for you.

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LIST OF ABBREVIATIONS AND SYMBOLS

Akaike’s Information Criterion	AIC
Alpha	α
Analysis of Variance	ANOVA
American Psychiatric Association	APA
Autism Diagnostic Interview-Revised	ADI-r
Autism Diagnostic Observation Schedule	ADOS
Autism Spectrum Disorder	ASD
Chi square	r^2
Coefficient of determination	CFA
Confirmatory Factor Analysis	CFA
Comparative Fit Index	CFI
Degrees of freedom	df
Diagnosis	Dx
Diagnostic and Statistical Manual of Mental Disorders	DSM
Exploratory Factor Analysis	EFA
Intellectual disability	ID
Intelligence Quotient	IQ
Kendall’s tau correlation coefficient	τ
Mean	m
Multivariate Analysis of Variance	MANOVA
Pearson’s correlation coefficient	r
Principal Axis Factoring	PAF
Pervasive Developmental Disorder-Not Otherwise Specified	PDD-NOS
Probability	p
Repetitive and Restricted Behaviors and Interests	RRBIs
Root Mean-Square Error of Approximation	RMSEA
Sample size	n
Spearman’s rho correlation coefficient	ρ
Standard deviation	SD

ABSTRACT

REPETITIVE AND RESTRICTED BEHAVIORS AND INTERESTS IN CHILDREN AND ADOLESCENTS WITH AUTISM SPECTRUM DISORDER

Beth D. Warsof, PhD

George Mason University, 2013

Dissertation Director: Dr. Johannes Rojahn

This dissertation examined Repetitive and Restricted Behaviors and Interests (RRBIs) in children and adolescents with Autism Spectrum Disorder (ASD). We looked at RRBI ratings from the respective subscales of the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2000), a clinician observation, and the Autism Diagnostic Interview-Revised (ADI-r; Le Couteur et al., 2003), a parent developmental history report. The purpose was to explore (1) whether RRBIs total scores diminish as individuals with ASD get older, (2) whether RRBIs are a cohesive, unitary construct or whether there are distinct subtypes of RRBIs, and (assuming that there are RRBIs subtypes) whether these subtypes show different trajectories across age and intellectual functioning, and (3) to what extent the ADOS and ADI-r RRBI subscales cross-validate one other. Exploratory and confirmatory factor analyses for the ADOS and ADI-r resulted in two-factor models,

which we labeled as *Cognitive-Restrictive* and *Motor-Sensory*. For total RRBIs, Cognitive-Restrictive RRBIs, and Motor-Sensory RRBIs, adolescents showed significantly lower impairment ratings than younger age groups. Total RRBI ratings were negatively associated with IQ scores for both instruments. However, examining the RRBI subscale scores separately revealed that only Cognitive-Restrictive ratings had a negative association with IQ scores. Ratings for the Motor-Sensory scale were not associated with IQ. On the ADI-r, a significant interaction showed that Cognitive-Restrictive ratings were higher and unchanging for lower-functioning individuals across age groups. Higher-functioning individuals showed lower ratings across each age group. We also found that RRBI items from the ADOS and the ADI-r correlated relatively poorly across the measures. Our study provides evidence for the two-factor model of RRBIs, though distinctions from prior researchers' models are highlighted.

INTRODUCTION

Repetitive and restricted behaviors and interests, known as RRBIs, are a heterogeneous group of behaviors representing a core feature of Autism Spectrum Disorder (ASD). RRBIs make up the second of the two behavioral diagnostic domains in the newly published *Diagnostic and Statistical Manual of Mental Disorders – 5th edition* (DSM-5; APA, 2013). RRBIs are characterized by: a) stereotyped or repetitive speech, motor movements, or use of objects, b) excessive adherence to routines, ritualized patterns of verbal or nonverbal behavior or excessive resistance to change, c) highly restricted, fixated interests that are abnormal in intensity or focus, and d) hyper- or hypo-reactivity to sensory input or unusual interest in sensory aspects of environment. These qualities manifest in a spectrum of behaviors. For example, stereotyped speech can range from echolalia to overly sophisticated and idiosyncratic verbiage. Adherence to routines can involve resisting schedule changes or engaging in obsessive-compulsive rituals. Restricted interests can include both spinning the wheels of a toy car and accumulating excessive factual knowledge on esoteric topics. Motor stereotypies can involve discrete finger-flicking or whole body rocking. Distinct behaviors often demonstrate multiple RRBI qualities, confounding attempts to discern their form and function (Kim & Lord, 2009).

RRBIs significantly impair general functioning and engagement in one's environment. For lower-functioning individuals, rigidity in routines, insistence on sameness, and intense perseverations can disrupt daily schedules and activities, for both the individual and family (Gabriels, Cuccaro, Hill, Ivers, & Goldson, 2005). Even for high-functioning children, parents report that RRBIs, from the inability to adapt to schedule changes to incessant talking about preferred topics, were the most challenging aspects of ASD (South, Ozonoff, & McMahon, 2005). Behaviors can be socially inappropriate and stigmatizing, restricting social interaction and personal relationships (Lee, Odom, & Loftin, 2007). They can prevent formal and incidental learning opportunities (Varni, Lovaas, Koegel, & Everett, 1979). Individuals often become anxious, agitated, or disruptive if behaviors are interrupted. When individuals with ASD cannot inhibit RRBIs behaviors, they can significantly prevent active engagement and participation in daily life.

Though these behaviors were noted in the first descriptions of autism by Kanner (1943) and Asperger (1944/1991), RRBIs remain one of the least examined and understood components of ASD (Seltzer, Shattuck, Abbeduto, & Greenberg, 2004; Turner, 1999). Learning more about these behaviors can inform our understanding of ASD and our ability to design effective interventions. The present study seeks to contribute this understanding by investigating the RRBIs for distinct subtypes and their potentially unique association to age and intellectual functioning for young people with ASD.

RRBI Subtypes

While RRBIs all share the qualities of being unusual, persistent, and stereotyped, experts continue to debate whether these behaviors can be meaningfully considered a cohesive group (Leekam, Prior, & Uljarevic, 2011). To better characterize their heterogeneity, researchers have investigated the possibility of distinct factors of RRBIs. Turner (1999) first introduced the idea of subtypes of RRBIs in ASD. In her review, she suggested that the literature pointed towards two types of RRBIs: *lower-order behaviors* characterized by motor repetition (i.e. stereotyped movements, object manipulation) and *higher-order behaviors* characterized by more complex behaviors (i.e. perseverative interests, inflexible routines). Turner further suggested that the lower-order behaviors were not unique to ASD, but manifestations of co-morbid intellectual disability. The higher-order behaviors alone represented the unique impairment of autism.

A number of studies have since continued to investigate RRBI subtypes. Cuccaro et al. (2003) were the first to empirically examine RRBIs through factor analysis. Looking at 12 items from the Autism Diagnostic Interview-Revised (ADI-r, Le Couteur, Lord, & Rutter, 2003) in a sample of 207 children with ASD, they found a model of two factors they labeled *Repetitive Sensory-Motor Behaviors* and *Resistance-to-Change*. The Repetitive Sensory-Motor Behaviors included hand/finger mannerisms, other complex body movements, repetitive use of objects, and unusual sensory interests, while the Resistance-to-Change behaviors included compulsions/rituals, difficulties with change in routine, and resistance to change in environment. Four items did not load onto either factor: unusual preoccupations, unusual attachments to objects, abnormal responses to sensory stimuli, and sensitivity to noise. Szatmari et al. (2006) looked at 11 items on the ADI-r in a sample of 339 children with ASD and found comparable factors of similar, though not identical, item loadings. Their *Repetitive Sensory and Motor Behaviors* factor included hand/finger mannerisms, other complex body movements, repetitive use of objects, unusual sensory interests, and rocking. Their *Insistence-on-Sameness* factor included compulsions/rituals, difficulties with change in routine, and resistance to change in environment. Unusual preoccupations, unusual attachment to objects, and circumscribed interests again did not load onto either factor.

Lam, Bodfish, and Piven (2008) examined 10 items from the ADI-r in a wider-age sample of 316 children, adolescents, and adults with ASD. They found the two factors of Repetitive Motor Behaviors and Insistence-on-Sameness as well as third factor of *Circumscribed Interests*. The third factor was made up of circumscribed interests, unusual preoccupations, and unusual attachment to objects, which had not fit the previous models with younger children. Examining a younger population, Richler, Bishop, Kleinke, and Lord (2007) explored factors of RRBIs in 165 two-year-olds with ASD. Using 10 items from the toddler version of the ADI-r, they also found a Repetitive Sensory Motor factor (repetitive use of objects, unusual sensory interests, hand/finger mannerisms, and other complex mannerisms) and an Insistence-on-Sameness factor (compulsions and rituals, difficulties with changes in routine, and resistance to trivial changes in the environment). Items of unusual preoccupations, unusual attachment to objects, sensitivity to noise, and abnormal/idiosyncratic response to sensory stimuli did not load onto either factor. A follow up study of the same sample three years later

(Richler, Huerta, Bishop, & Lord, 2010) also supported this model. Importantly, the Repetitive Sensory Motor factor distinguished toddlers with ASD from toddlers with general developmental delays. The Insistence-on-Sameness factor did not. That is, toddlers with ASD showed higher ratings for the sensory and motor behaviors than those with general delays, but the same ratings for insistence-on-sameness behaviors. This refutes the second part of Turner's (1999) hypothesis about the uniqueness of "higher-order" RRBIs to ASD. A comparison of these factor analytic studies of RRBIs can be found below.

Table 1 Factor Analytic Studies of RRBIs

Study	Sample/Method	Model		
Turner (1999)	Theoretical review	Lower-level (Motor)	Higher-level (ASD)	
Cuccaro et al. (2003)	ADI-r (12 items); 207 children; PCA	Repetitive Sensory Motor	Resistance-to-Change	
Szatmari et al. (2006)	ADI-r (11 items); 339 children; PCA	Repetitive Sensory and Motor	Insistence-on-Sameness	
Richler et al. (2007)	ADI-r (10 items); toddlers; Not specified	Repetitive Sensory Motor	Insistence-on-Sameness	
Lam et al. (2008)	ADI-r (10 items); children – adults; PCA & GLS EFA with target rotation	Repetitive Motor Behaviors	Insistence-on-Sameness	Circum-scribed Interests

However, other researchers came to different conclusions when different methods and instruments were used. South et al. (2005) supported the one-factor model of the traditional RRBI domain, based on the high internal consistencies found across items on the Repetitive Behavior Interview (RBI; Turner, 1997) and the Yale Special Interests Interview (YSII; South, Klin, & Ozonoff, 1999). Lam and Aman (2007) proposed a five-factor structure based on validity assessments of the Repetitive Behaviors Scale-Revised (RBS-r; Bodfish, Symons, Parker, & Lewis, 2000). Anagnostou et al. (2011) proposed a four-factor structure based on reliability analyses of the Yale-Brown Obsessive Compulsive Scale (Y-BOCS; Goodman et al., 1989). Further, factor analyses of items from all three ASD impairment domains (social, communication, and RRBI) did not show the two-factor model found in the studies above. Yet these factor studies also did not consistently find the one-factor RRBI model from the DSM (i.e. Tadevosyan-Leyfer et al., 2003).

On the other hand, studies assessing the association of RRBIs with other characteristics, such as age and intellectual functioning, supported the distinction of the two-factor Motor-Sensory/Insistence-on-Sameness model. These trends are discussed below. Yet in her original paper, Turner (1999) specifically cautioned researchers from relying too heavily on this higher-order/lower-order dichotomous characterization, so as not to obscure other potential groupings of RRBIs. Bishop, Richler, and Lord (2006) also argued for applying the two-factor model with caution, noting that in their sample of 830 children with ASD, the majority of participants demonstrated most, if not all, RRBIs.

RRBIs and Age

RRBIs were not originally considered problematic in very young children with ASD (Lord, 1995). Early first-year-of-life studies found social communication impairments but not RRBIs (Baron-Cohen et al., 1996; Osterling, & Dawson; 1994). It was hypothesized that the RRBIs emerged later as coping mechanisms (Baron-Cohen, 1989) or as secondary behaviors to cognitive impairments (Frith & Happe, 1994). However, newer research has found RRBIs in children with ASD as young as 12-18 months (Fodstad, Rojahn, & Matson, 2012; Morgan, Wetherby, & Barber, 2008; Zwaigenbaum et al., 2005). RRBI ratings at the earliest ages (18-24 months) predict both RRBI and social communication deficits in later childhood (Morgan et al., 2008). This finding, in particular, demonstrates the predictive value of early RRBI severity for later global autism deficits.

In childhood, RRBIs often show constant or increasing rates. From toddlerhood to preschool, Kim and Lord (2010) found RRBI rates stayed constant. Both Lord et al. (2006) and Richler et al. (2010) found that RRBIs remain stable or increase in children ages two to nine. Moore and Goodson (2003) found that some, though not all, RRBIs increase in severity from age two to ages four and five. Using observational measurement on the ADOS, McDonald et al. (2007) also found that RRBIs increase from ages two and three to age four. In retrospective studies, parents report that RRBIs are most impairing to daily functioning during their child's preschool years (South et al., 2005). Yet across childhood, distinct trends can be seen for different types of RRBIs. Very young children often show higher ratings of motor behaviors, while older children show higher ratings of rigidity and restrictive habits (Richler et al., 2007; Richler et al., 2010; South et al., 2005). Militerni, Bravaccio, Falco, Fico, and Palermo (2002) found that young children show more motor and sensory behaviors while older children show more complex repetitive and routine behaviors. In a study of toddlerhood to adolescence, Bishop et al. (2006) found that desire for sameness, restricted interests, and compulsions/rituals were more frequent in older than younger children. These findings emphasize the developmental nature of emergent behaviors in ASD. That is, some behaviors or impairments may only emerge as cognitive abilities and social demands grow.

However, in adolescence and into adulthood, RRBIs decrease in severity among older individuals, suggesting that behaviors abate over the lifespan. In one cross-sectional study, RRBI ratings were twice as high in children ages two to nine than in adults ages 51 and up (Esbensen, Seltzer, Lam, & Bodfish, 2009). Both Seltzer et al. (2003) and Shattuck et al. (2007) compared adolescents to adults and found overall lower ratings in the older age groups. Chowdhury, Benson, and Hillier (2010) examined retrospective age-related changes at the item level and found significant improvement for each behavior. However, specific behaviors varied in their degree of abatement: at the highest end, 75% of the sample improved on compulsive behavior ratings, but at the lowest, only 44% improved on restricted behavior ratings. The Esbensen et al. (2009) study also showed different patterns for specific behaviors, with restricted interests showing the greatest reduction over time, stereotyped behaviors showing the next, and all other subtypes showing lesser reductions. Yet despite these overall improvements, RRBIs do not abate completely. The Seltzer et al. (2003) study found that 87.7% of their sample continued to score above diagnostic cut-offs for RRBIs into later adulthood. Howlin, Good, Hutton, and Rutter (2004) also found the majority of adults continued to engage in RRBIs. Of 68 adolescents and adults, 42% showed mild RRBIs, 35% showed moderate RRBIs, and 11% showed severe RRBIs, while only 12% demonstrated no RRBIs.

While the studies above are helpful, they rely on cross-sectional data. As such, we cannot truly make conclusions about developmental change over time. Only a very limited number of more recent studies have examined longitudinal data of RRBIs. Lord, Guthrie, Luyster, and Pickles (2012) found distinct trajectories of RRBI development for toddlers with ASD. For 78 toddlers assessed every two months from 18 to 36 months, 21% of toddlers showed worsening RRBIs, 21% maintained persistent severe RRBIs, while 19% showed significant improving ratings of RRBIs. In another prospective study, Soke et al. (2011) examined 28 children diagnosed with ASD between ages two and four years old and reassessed on the ADI-r two years later. RRBI ratings stayed generally constant. 26 of the 28 children met the cut-off score for the RRBI domain at both evaluations, though four children showed significant changes at re-evaluation. Two children no longer met the domain score cut-off (improved) while two other children met the cut-off (worsened). Finally, Fountain, Winter, and Bearman (2012) prospectively tracked the three ASD domains for children ages two to 14. They found six different trajectories of development. While the social and communication trajectories were parallel and showed general improvement, the trajectory for RRBI development showed very little change for the majority of children. Only 15% of children showed changing levels of RRBIs as they grew older. Of those children, half showed significant improvement in RRBI ratings, while the other half showed significantly worsening ratings. As autism research moves forward, longitudinal studies past childhood and into adolescence and adulthood will lead to a better understanding of changes across the lifespan.

Thus far, the literature suggests that while RRBIs show decreases in ratings over the lifespan, these changes do not reflect a constant trajectory. Developmental periods often show different rates of abatement. Distinct types of RRBIs show varying patterns of decreases. Further, some studies have shown that during specific developmental periods, certain behaviors may increase in severity. Further, while RRBIs subside over time, there is no evidence to suggest they are ever completely eliminated.

RRBIs and Intellectual Functioning

Intellectual functioning has significant influence on development for individuals with ASD. Individuals with higher IQs consistently demonstrate fewer and less severely impairing ASD behaviors and greater overall developmental gains, while those with lower IQs demonstrate the opposite (McGovern & Sigman, 2005, Nordin & Gillberg, 1998; Seltzer et al., 2004). Intellectual functioning even at the earliest ages is an important predictor of later developmental outcomes for individuals with ASD (Billstedt, Gillberg, & Gillberg, 2007; Venter, Lord, & Schopler, 1992). Ultimately, ASD behaviors both affect and are affected by an individual's functioning ability. Individuals who start out with lower functioning abilities make less significant developmental gains while those who start out with higher functioning abilities make greater developmental gains. (Leekam et al., 2011; Lord & Risi, 2000).

RRBIs also demonstrate these associations with intellectual functioning. Specifically, individuals with lower IQs demonstrate ratings of greater RRBIs that cause greater impairment to daily functioning (Gabriels et al., 2005; Turner, 1999). Even the earliest studies of RRBIs suggested that lower IQ was related to greater severity of RRBIs (Wing & Gould, 1979). This association of IQ continues into adolescence and adulthood (Seltzer et al., 2003). The influence of IQ is most noticeable when comparing RRBI ratings for individuals with and without co-morbid intellectual disability (ID) (Carcani-Rathwell, Rabe-Hasketh, & Santosh, 2006).

However, examined more closely, it may be that functioning level influences types of RRBIs differently. Bishop et al. (2006) found that repetitive use of objects, unusual sensory interests, and hand/finger mannerisms were more common in children with lower IQ scores while circumscribed interests and compulsions/rituals were more common in children with higher IQ scores. Militerni et al. (2002) found that higher-functioning individuals were rated higher for complex restricted behaviors while lower-functioning individuals were rated higher on motor behaviors. Looking a prevalence of behaviors, Chowdhury et al. (2010) found restricted behavior and ritualistic/sameness behaviors were very common in their high-functioning sample, while a considerable proportion of the sample showed no unusual sensory interests or unusual preoccupations. Szatmari et al. (2006) found that Repetitive Sensory Motor Behaviors subscale negatively correlated with children's functioning scores while Insistence-on-Sameness subscale positively correlated with intellectual functioning scores. Other studies have found that some types of RRBIs showed no association with IQ: Cuccaro et al. (2003) and Lam et al. (2008) both found that their Repetitive Motor and Sensory Behaviors subscales were negatively associated with non-verbal IQ, but the Insistence-on-Sameness subscales were not associated to IQ at all. Esbensen et al. (2009) similarly found that low IQ was associated with higher scores on the Stereotyped Movements subscale of the RSB-r, while no association to IQ was found for the subscales of ritualistic/sameness behaviors, compulsions, or restricted interests.

Significance of the Research

The purpose of this study was to investigate RRBIs for distinct subtypes and their potentially unique associations to age and intellectual functioning for children and adolescents with ASD. The new DSM-5 conceptualizes RRBIs as an even more central feature of ASD than in editions past. RRBIs now represent one of the two core domains, on par with social communication impairments (APA, 2013). Though gains have been made, our understanding of RRBIs in ASD is still limited. Better parsing of the variance of these heterogeneous behaviors may bring to light new understandings of their form and function. Further, a greater understanding of their course across the lifespan will provide clues as to how development both affects and is affected by individual characteristics, particularly intellectual functioning. Greater knowledge of these aspects of RRBIs will inform more appropriate and effective diagnostic and intervention services.

Research Questions

Thus, this study aimed to contribute to our understanding of RRBIs in ASD and their association with age and IQ in a relatively high-functioning sample. We looked first at RRBIs as a unitary construct and then as distinct constructs measured by RRBI subscales. We explored whether these factors, when examined separately, demonstrated distinct associations with age and IQ. We conducted this investigation using the two diagnostic instruments for ASD: the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2000), a clinician observation, and the Autism Diagnostic Interview-Revised (ADI-r; Le Couteur et al., 2003), a parent report. Afterwards, we evaluated how similarly the two instruments measure RRBIs. Specifically, we addressed the following questions:

1) Is the severity of impairment of RRBIs in this population a function of age and/or IQ? That is, do total RRBI scores vary across age and IQ groups? We hypothesized that total RRBI ratings would show decreases across younger to older age groups and lower to higher IQ groups. We also hypothesized that there may be an interaction effect such that RRBI scores may vary across age groups based on the IQ level of the individual.

2) Do RRBIs, as measured by impairment severity, represent a unitary construct or do they represent distinct factors? We hypothesized that distinct factors of RRBIs would be distinguishable in our sample and that they would demonstrate unique associations across age and IQ.

3) How similarly do the ADOS and ADI-r measure the impairment severity of RRBIs? We hypothesized that ratings for RRBI items and scales would correlate well according to conventional standards across the two measures.

METHOD

Participants

The participants for the study were children and adolescents seen for assessment at the Center for Autism Spectrum Disorders (CASD) at Children's National Medical Center (CNMC) in Washington, DC, between the years of 2000 and 2013. All participants received a diagnosis of an autism spectrum disorder as determined by expert clinician evaluation using the criteria from the *Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition, Text Revision* (DSM-IV-TR, APA, 2000) and results from the Autism Diagnostic Observation Schedule (ADOS) and/or the Autism Diagnostic Interview (ADI/ADI-r). Individuals who were evaluated but not given a spectrum diagnosis were not included. Diagnostic evaluations included multidisciplinary team assessment and measures of executive functioning, intellectual functioning, adaptive functioning, speech and language, and parent, teacher, and medical reports of developmental history. Some participants were seen for initial diagnosis while others were evaluated for on-going progress monitoring. While some participants were seen for multiple evaluations, the results from each participant's first evaluation at CASD were used for this study.

The total size of the sample was $n = 432$. Of these, 273 participants had data for the ADOS only, 383 participants had data for the ADI-r only, and 224 participants had data for both. Participants had diagnoses of Asperger syndrome (*n* = 157), High-Functioning Autism (*n* = 111), Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS) (*n* = 84), Autism (*n* = 54), and Autism Spectrum Disorder (*n* = 16). Participants in the pool were between the ages of 3.33 and 23.74 (*m* = 10.45, *SD* = 4.15). IQ scores ranged from 56 to 154 (*m* = 102.53, *SD* = 20.04). About 70% of the sample (*n* = 285) had an IQ within or above average range (above 85) and 25% had an IQ above average (above 115). About 20% (*n* = 67) of the sample had an IQ score below 85 and about 5% (*n* = 18) had an IQ score below 70. The sample characteristics for the individual tests mirrored those of the whole sample. Sample demographics are displayed in the table below.

Table 2 Demographics

	ADOS Sample	ADI-r Sample	Total Sample
n	273	383	432
Gender			
Male	226	265	305
Female	44	53	60
Unknown	3	65	67
Dx			
ASD	12	12	16
Asperger	109	139	157
Autism	21	48	54
HFA	76	105	111
PDD-NOS	53	70	84
Unknown	2	9	10
Race			
African-American	32	35	43
Asian	13	17	18
Caucasian	137	176	200
Other	17	24	27

Unknown	74	131	144
Age			
M	11.43	10.22	10.45
SD	4.52	4.20	4.15
Range	4.07 - 23.74	3.33 - 23.95	3.33 - 23.74
Skew	0.54	0.87	0.84
Kurtosis	-0.54	0.44	0.40
Unknown	3	92	12
IQ			
M	102.65	102.80	102.53
SD	19.60	20.03	20.04
Range	56 - 154	56 - 154	56 - 154
Skew	-0.21	-0.21	-0.17
Kurtosis	-0.49	-0.57	-0.57
Unknown	4	71	79

Informed consent was obtained from parents and caregivers of participants under 18 years of age along with informed assent from participants over 18, following the requirements of the Internal Review Board of Children's National Medical Center. HSRB approval for this study was obtained from George Mason University.

Measures

The Autism Diagnostic Observation Schedule (ADOS).

The Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2000) is a semi-structured, standardized observational measures consisting of interactive play tasks and "social presses" meant to elicit behaviors common to ASD. When combined with the ADI-r (described below), the two assessment measures are considered the "gold standard" for ASD evaluation (Filipek et al., 1999). The ADOS is divided into modules based on the age and verbal fluency of the participant. Thus, the Module 3 test, for verbally fluent children, and the Module 4 test, for verbally fluent adolescents and adults were administered to the participants of our study. Five items measure RRBIs:

1. Stereotyped speech
2. Excessive interest in or references to unusual or highly specific topics or objects or repetitive behaviors
3. Compulsions or rituals
4. Unusual sensory interest in play material/person
5. Hand, finger and other complex mannerisms.

While RRBIs are noted during administration and scored, they are not included in the total diagnostic algorithm, with the exception of the stereotyped speech item, which is part of the communication scale. We included this item in our analyses as an RRBI to model the newer DSM-5 criteria and general convention that communication behaviors, including speech, are better classified as either repetitive behaviors or social behaviors in diagnosis (APA, 2013). Items on the ADOS are scored on a Likert-like scale of 0 – 3 (0 = behavior is absent; 1 = behavior is present but does not interfere with daily functioning; 2 = a definite presence of the behavior that intrudes on general life but not does disrupt it significantly; and 3 = behavior causes substantial interference and intrudes and/or constrains daily functioning for the individual).

The ADOS has strong psychometric properties. The developers reported excellent sensitivity (.95) and specificity (.92). Test-retest correlations ranged from .73 to .78 for the three domains and interrater reliability ranged from .84 to .93. For internal consistency, coefficient α ranged from .74 to .94 for domain scores. Across ages, the

ADOS has been found to reliability distinguish ASD from non-ASD whereby diagnoses of ASD or non-ASD at earlier ages hold true for individuals at later reevaluations (Lord et al., 2000). Independent studies have shown good, though more moderate, psychometric properties. Across modules for verbal children, Gotham, Risi, Pickles, and Lord (2007) found sensitivity ranged from .72 to .84 and specificity from .76 to .83 while de Bildt et al. (2009) found sensitivity ranged from .53 to .86 and specificity from .62 to .63. In a clinical sample, Malloy, Murray, Akers, Mitchell, and Manning-Courtney (2011) found more moderate results with sensitivity ranging from .76 to .98 and specificity from .34 to .60. For internal reliability, Cronbach's α was between .87 and .92 for the social affect domain and .51 to .66 for the RRBI domain (Gotham et al., 2007). In clinical practice, Mazefsky and Oswald (2006) found 77% agreement between ADOS diagnoses and team diagnoses. Similarly, Chawarska, Klin, Paul, and Volkmar (2007) found 95% agreement between ADOS diagnosis and clinician diagnosis for children before age two, though only 79% agreement at follow-up evaluation at age three.

The Autism Diagnostic Interview-Revised (ADI-r).

The Autism Diagnostic Interview-Revised (ADI-r; Le Couteur, et al., 2003) and its original form, the Autism Diagnostic Interview (ADI; Le Couteur et al., 1989) are semi-structured standardized interviews administered by a trained clinician to a primary caregiver of a child suspected of ASD. The measures allow clinicians to collect information from parents about the child's developmental history, specifically querying autistic behaviors. Items are based on the ICD-10 and DSM-IV criteria and diagnosis is determined by meeting cut-off scores for the three domains (social, communication, RRBI). As on the ADOS, items are scored on a Likert-like scale of 0 – 3 (0 = behavior is absent; 1 = behavior is present but does not interfere with daily functioning; 2 = a definite presence of the behavior that intrudes on general life but not does disrupt it significantly; and 3 = behavior causes substantial interference and intrudes and/or constrains daily functioning for the individual). Scores are tallied for social abilities, verbal communication, non-verbal communication, and RRBIs and are presented as non-standardized raw scores. Each item receives two scores, one for the "current level of behavior" and the second one for the "most abnormal level of behavior ever." In this study, current levels of behavior were used in order to match the level of behavior with the participant's age. The seven items from the RRBI scale were:

1. Unusual preoccupations
2. Circumscribed interests
3. Repetitive use of objects or interests in parts of objects
4. Compulsions/rituals
5. Unusual sensory interests
6. Hand and finger mannerisms
7. Other complex mannerisms or stereotyped body movements

An eighth item, Verbal rituals, from the communication scale was also included in the RRBI score to reflect the newer DSM-5 criteria and general convention that communication behaviors, including speech, are better classified as either repetitive behaviors or social behaviors for diagnostic purposes (APA, 2013).

The ADI-r has shown sound psychometric properties. Le Couteur et al. (2003) reported overall sensitivity (true positives) and specificity (true negatives) exceeding .90, representing excellent validity according to clinical standards (Cicchetti et al., 2006). Item endorsement agreement for domain scores were considered good to excellent, with weighted kappas of 64-.89 for social interaction, .69-.89 for communication, and .63-.86 for RRBI. Interrater and test-retest reliabilities were good, with weighted kappas of .62-.89. Domain scale scores were found to have strong internal consistencies of $\alpha = .95$ (social), $\alpha = .84$ (communication), and $\alpha = .69$ (RRBI) (Le Couteur et al., 2003). Independent researchers have found slightly lower but acceptable reliability scores (Cox et al., 1999; Lecavalier et al., 2006; Mildenberg, Sitter, Noterdaeme, & Amorosa, 2001). Diagnostic stability has been demonstrated across children assessed at age three and again at age seven (Charman et al., 2005). For reliability, internal consistencies for domain scores ranged from good to excellent, with values of .95 for social interaction, .84 for communication, and .69 for RRBI (Le Couteur et al., 2003). The ADI-r has distinguished ASD from non-ASD well, with sensitivity estimates of .86 to 1.00 and specificity estimates of .75 to .96 (Lord et al., 1997).

General Cognitive Ability.

General cognitive ability was assessed using one of the three Wechsler Intelligence scales. Clinicians administered either the third or fourth edition of the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 1991/WISC-IV; Wechsler, 2003) or the abridged edition, the Wechsler Abbreviated Scale of Intelligence

(WASI; Wechsler, 1999). Test selection was determined by the current edition in use and whether a full battery or abridged version was deemed more appropriate by the clinician. Full-Scale IQ (FSIQ) standard scores (*m* = 100; *SD* = 15) were used as the measure of intellectual functioning for our analyses. The Wechsler scales are the most researched and widely used measures of intellectual and cognitive ability, particularly in ASD populations (Oliveras-Rentas, Kenworthy, Roberson, Martin, & Wallace, 2012). IQ scores for individuals with ASD are consistent across multiple WISC versions (Mayes & Calhoun, 2008). Further, Wechsler IQ scores significantly correlate with adaptive skills (general functioning in every-day life) in multiple ASD studies (Kenworthy, Case, Harms, Martin, & Wallace, 2010; Klin et al., 2007).

Data Analyses

Research Question 1.

Is the impairment severity of RRBIs in ASD a function of age and/or IQ?

For the first research question, we employed 3x3 factorial ANOVAs to examine the differences in total RRBI scores across age groups (early childhood, middle childhood, and adolescence), IQ groups (low, average, and high), and their interaction. We ran separate ANOVAs, first for the ADOS and then for the ADI-r. Total scores for each instrument were calculated by totaling an individual's ratings on the RRBI items. Five items were totaled for the ADOS RRBI score and eight items were totaled for the ADI-r RRBI score. The three age groups were divided based on developmental periods into early childhood (less than seven years old), middle childhood (seven to 12 years old), and adolescence (13 years and older). The IQ groups were divided based on IQ standard deviations for low IQ (below 85), average IQ (85-114), and high IQ (115 and above). We used post-hoc analyses to evaluate within-group differences. The group sizes for the sample are displayed in the table below.

Table 3 Group Sizes

Age Groups	ADOS *n*	ADI-r *n*	IQ Groups	ADOS *n*	ADI-r *n*
Early childhood	62	67	Low IQ	44	44
Middle childhood	83	123	Average IQ	119	123
Adolescence	84	61	High IQ	66	83

Research Question 2.

Do RRBIs, as measured by their level of severity impairment, represent a unitary construct or do they represent distinct factors?

For the second research question, we again ran the analyses first for the ADOS and then for the ADI-r. To start, we split the sample randomly in half. On the first half, we conducted an exploratory factor analysis using Principal Axis Factoring (PAF) with Direct Oblimin rotation. We chose the PAF method for its ability to handle non-parametric data and the Direct Oblimin rotation for its allowance for non-orthogonal factors. The exploratory factor analysis was run on the five RRBI items from the ADOS and then on the eight RRBI items from the ADI-r. On the second half of the sample, we conducted a confirmatory factor analysis using the maximum likelihood. This allowed us to evaluate the fit of the models produced in the exploratory factor analyses. While there are limitations for the maximum likelihood procedure for handling non-parametric data, maximum likelihood is considered to perform best with samples of our size (Gold, Bentler, & Kim, 2003). For the ADOS analysis, the results showed that the size of the split-half sample was not large enough to produce reliable results, so we reran the confirmatory factor analysis using the whole sample. In order to employ AIC (Akaike's Information Criterion), which allows for comparison of fit across models, we ran preliminary analyses of fit for a one-factor model of total RRBIs for both the ADOS and the ADI-r.

Ultimately, we wanted to look at the effects of age and IQ on the separate RRBI factors. From the results of the factor analyses, we created subscale scores by totaling the ratings for the items that loaded onto each factor. We evaluated the reliability of the scales with Cronbach's α. While reliability is also evaluated by the model fit indices of the confirmatory factor analysis, we chose to additionally compute Cronbach's α to allow for comparisons to other studies. Then, we employed 3x3 factorial MANOVAs to examine the differences in the subscale scores across the age and IQ groups and their interaction. We ran separate analyses for the ADOS and the ADI-r and used post-hoc analyses to evaluate within-group differences.

Research Question 3.

How similarly do the ADOS and ADI-r measure the impairment severity of RRBIs?

For the third research question, we first ran correlation analyses to compare similar items across the ADOS and ADI-r. As the instruments do not have identical items, we matched items from across the two instruments that are intended to measure the same behavior. In some cases, multiple items from one test matched up to a more inclusive item on the other. The table below shows the matched items from the two tests.

Table 4 Corresponding RRBI Items from the ADOS and the ADI-r

ADOS	ADI-r
A4. Stereotyped/Idiosyncratic use of words or phrases	39c. Verbal rituals
D4. Excessive interest in/references to unusual or highly specific topics, objects, or repetitive behaviors	67c. Unusual preoccupations; 68c. Circumscribed interests 69c. Repetitive use of objects or interests in parts of objects
D5. Compulsions or rituals	70c. Compulsions/Rituals
D1. Unusual sensory interest in play material/person	71c. Unusual sensory interests
D2. Hand, finger, and other complex mannerisms	78c. Hand and finger mannerisms; 79c. Other complex mannerisms or stereotyped body movement

Note: Item A4 is part of the ADOS communication scale; Items D1-D5 are part of the ADOS RRBI scale; Items 39c.-79c. denote the "current" ratings for the ADI-r

We used Kendall's τ (tau) to evaluate the correlations of the matched items. τ is the most appropriate statistic for evaluating ordinal variables when many scores are ranked the same value (Howell, 1997), which is the case in this study. τ is a better measure than the more commonly used Spearman's ρ as it is based on number of inversions in rankings, instead of sample covariance, and it approaches a normal distribution as sample size increases (Gilpin, 1993). We used the conversation tables from Gilpin (1993) to convert τ to the more common statistics of ρ, r, and r^2 to better interpret the obtained values. We then analyzed the correlations of the RRBI total and subscale scores across the two instruments using the same procedure.

RESULTS

Research Question 1

Is the impairment severity of RRBIs in ASD a function of age and/or IQ?

ADOS.

To answer this first question, we ran an ANOVA to examine RRBI total scores across age and IQ groups for the ADOS. Levene's test was not significant and homogeneity of variance was assumed. There was no age by IQ interaction effect. The main effect was significant for age, F (2, 220) = 11.05, $p < .001$, partial $\eta^2 = .09$. That is, individuals across age groups showed different mean RRBI total scores. The main effect for IQ was also significant, F (2, 220) = 3.01, $p = .048$, partial $\eta^2 = .03$. Thus, individuals belonging to different IQ groups showed different mean RRBI total scores.

We evaluated pairwise differences using LSD post-hoc tests for age effect. The RRBI ratings were not different across the childhood groups. The ratings for adolescents, however, were significantly lower than those for both the middle childhood participants (mean difference = 1.30, $SD = .31$, $p < .001$) and the early childhood participants (mean difference =1.42, $SD = .33$, $p < .001$). We evaluated pairwise differences for the IQ effect using Gabriel's post-hoc tests to account for different group sizes. Individuals with low IQs were rated significantly higher on total RRBI scores than those with average IQs (mean difference = 1.00, *SD* = .35, $p < .01$). There was no difference between the high IQ group and either of the low or average IQ groups. The table and figure below show the results for the univariate analysis and the mean differences across age groups and IQ groups. The figure illustrates the higher severity ratings for the low IQ group (left-box) compared to the average IQ group (middle box) as well as the lower scores in all three groups for the adolescent participants (across the three boxes).

Table 5 ADOS Total RRBI Scores: Effects of Age and IQ

	F (df)	Mean diff. (*SD*)	*p*	Partial η^2
Age	11.05 (2)	-	.000	0.09
Adolescence vs. Early childhood	-	1.42 (0.33)	.000	-
Adolescence vs. Middle childhood	-	1.3 (0.31)	.000	-
IQ	3.01 (2)	-	.048	0.03
Low IQ vs. Average IQ	-	1.00 (0.35)	.005	-

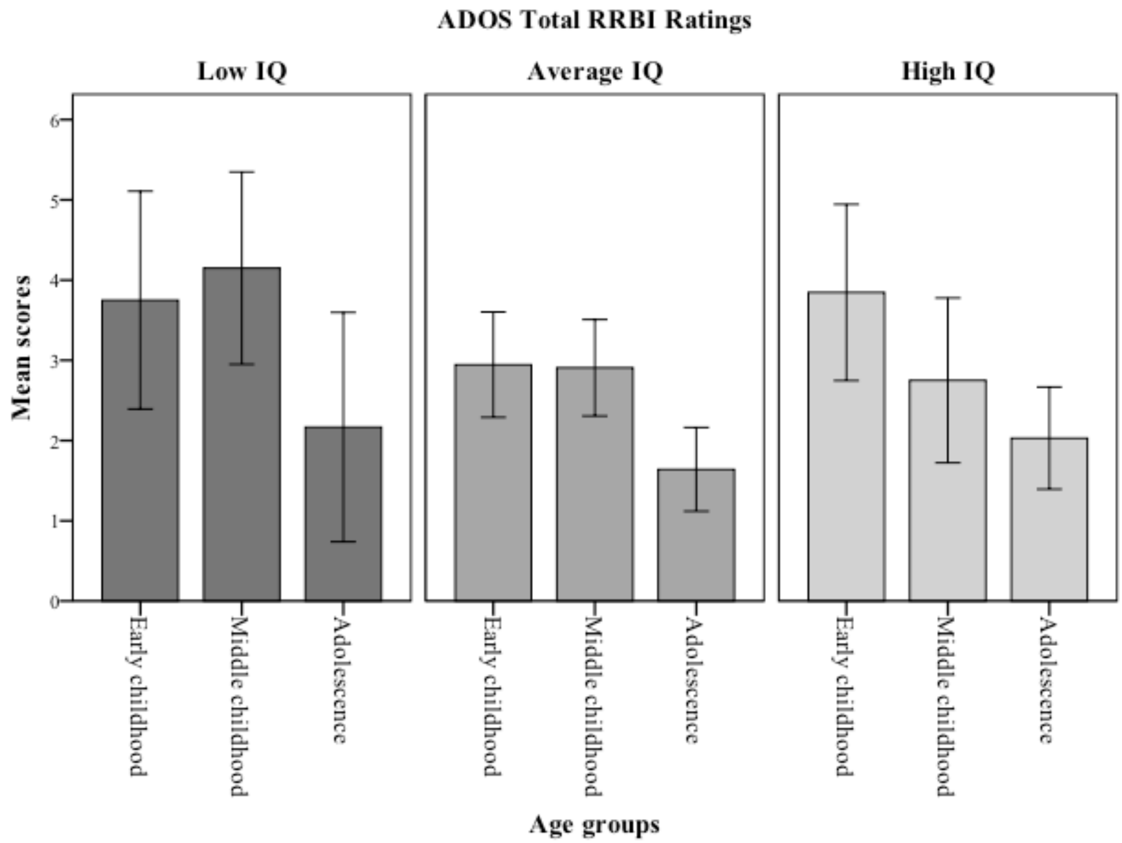

Figure 1 ADOS Total RRBI Ratings by Age and IQ

ADI-r.

Next, we ran the ANOVA using the total RRBI scores from the ADI-r. Levene's test was not significant at the .001 level, F (8, 242) = 3.40, $p > .001$. The interaction of age and IQ was significant, F (4, 242) = 3.39, $p < .001$, partial $\eta^2 = .05$. That is, mean RRBI total scores for age groups varied based on the intellectual functioning level of the participants. Noting that the significant interaction takes precedence over interpreting main effects, the main effect for age was significant, F (2, 242) = 6.35, $p < .01$, partial η^2 = .05. That is, individuals across age groups showed different total mean RRBI scores. The main effect for IQ was not significant.

For age, mean differences in total RRBI total scores were seen across all groups. That is, the ratings for adolescence were lower than the ratings for middle childhood (mean difference = 2.04, *SD* = .55, $p < .001$), middle childhood ratings were lower early childhood ratings (mean difference = 1.44, *SD* = .53, $p < .01$), and adolescent ratings were lower than early childhood ratings (mean difference = 3.47, *SD* = .62, $p < .001$). Though the main effect for IQ was not significant, between the groups, the ratings for the low IQ group were significantly higher than the ratings for the high IQ group (mean difference = 1.65, *SD* = .65, $p < .05$). The table below shows the significant results for the univariate analysis and the mean differences across age groups and IQ groups.

Table 6 ADI-r Total RRBI Scores: Effects of Age and IQ

Items	*F (df)*	Mean diff. (*SD*)	*p*	Partial η^2
Age*IQ	3.39 (4)	-	0.01	0.05
Age	6.35 (2)	-	0.002	0.05
Adolescence vs. Early childhood	-	3.47 (0.62)	<.001	-
Adolescence vs. Middle childhood	-	2.04 (0.55)	<.001	-
Middle childhood vs. Early childhood	-	1.44 (0.53)	.007	-
IQ	1.61 (2)	-	>.05	0.01
Low IQ vs. High IQ	-	1.65 (0.65)	.032	-

On the ADI-r, the average and high IQ groups had lower RRBI ratings in the adolescence. However, the low IQ group, when examined separately, did not show this pattern. The low IQ participants had unchanging higher ratings across all age groups. The figure below displays the interaction of age and IQ on RRBI total item ratings. The low IQ group (shown in the left-most box) did not show the same lower severity scores across age groups as the average or high IQ groups (shown in the middle and right boxes).

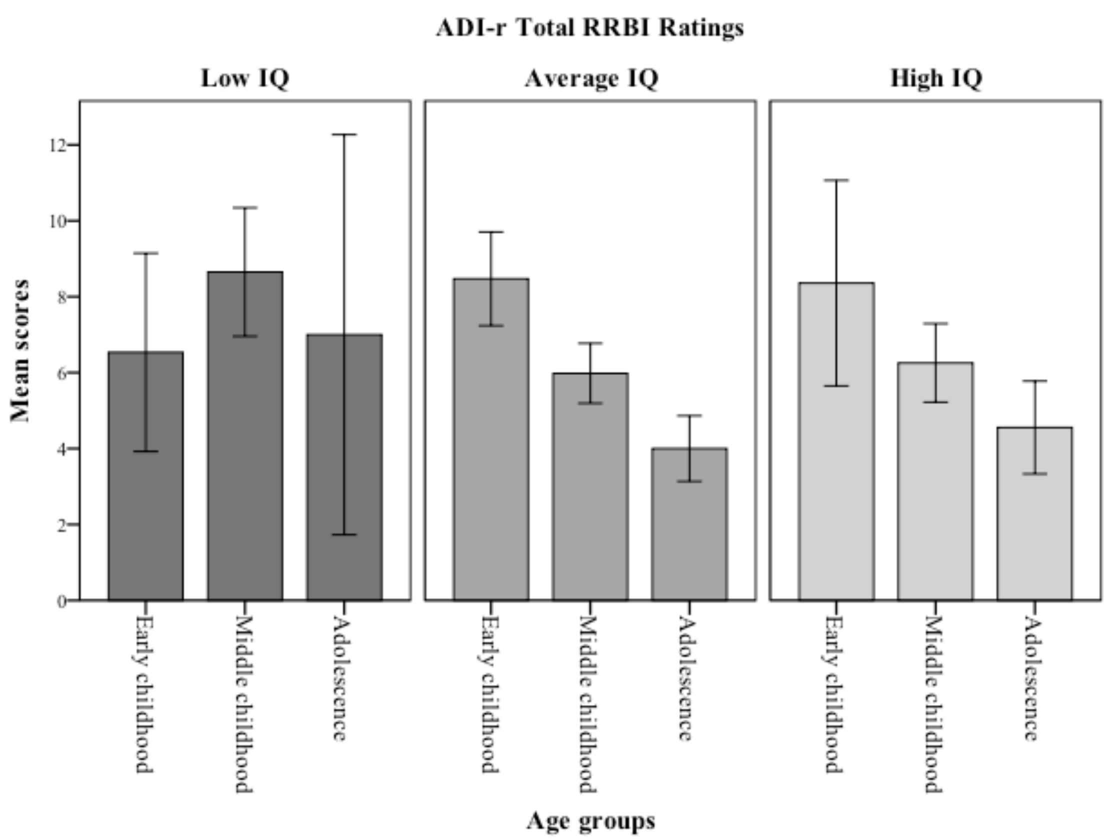

Figure 2 ADI-r Total RRBI Ratings by Age and IQ

Research Question 2

Do RRBIs, as measured by their level of severity impairment, represent a unitary construct or do they represent distinct factors?

ADOS.

For the second question, we asked whether distinct factors of RRBIs could be discerned in our sample. We began with an exploratory factor analysis of the ADOS items. We used principal axis factoring (PAF) with non-orthogonal (Direct Oblimin) rotation on the split-half sample of n = 136. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO = .58, which was above the acceptable cutoff of .5 (Kaiser, 1974). Bartlett's test of sphericity, χ^2 (10) = 54.70, p < .001, indicated that the correlations between items were sufficiently large for the PAF. An initial analysis was run to obtain eigenvalues for each factor. Two factors had eigenvalues over Kaiser's criterion of 1 and combined explained 57.66% of the variance of the items. The scree plot showed inflexions that justified retaining factors 1 and 2. The table below shows the factor loadings after rotation.

Table 7 EFA Factor Loadings for the ADOS

Items	Cognitive-Restrictive	Motor-Sensory
Stereotyped/Idiosyncratic use of words or phrases	**.81**	.02
Unusual sensory interest in play material/person	.03	**.63**
Hand and finger and other complex mannerisms	-.04	**.42**
Excessive interest in unusual/highly specific topics, objects, or repetitive behaviors	**.56**	-.06
Compulsions or rituals	**.23**	.21

We concluded that the items that loaded onto first factor represented a *Cognitive Restrictive* factor, made up of items of stereotyped speech, excessive interest in unusual/highly specific topics, objects, or repetitive behaviors, and compulsions/rituals. The items that loaded onto the second factor represented of a *Motor-Sensory* factor, made up of items of hand, finger, and other complex mannerisms and unusual sensory interest in play material/person. We did note that the compulsions/rituals item had cross-loadings that weren't particularly high for either factor. Yet, this item had important clinical value as part of the RRBI scale, so we chose to retain it in the model. The structure matrix, which allows for shared variance, supported the pattern matrix shown above. The factors were moderately correlated, $r = .31$.

Next, we ran a maximum likelihood confirmatory factor analysis (CFA) to evaluate how well the two-factor Cognitive-Restrictive/Motor-Sensory model fit the data. We used the second half of the split-half sample for the analysis (n=136). The two-factor structure model yielded a test statistic of χ^2 (4) = 2.73, p > .05. The non-significant result for the χ^2 test indicated good model fit, as the null hypothesis of similar observed and expected covariance was not rejected. In other words, the observed model approached the perfect fit model of explained variance. Additional analyses of model fit, however, yielded inappropriate results that suggested a perfect fit model (RMSEA = 0.00, CFI = 1.00). We concluded that split-half sample size might have been too small to produce meaningful results. However, as the χ^2 test indicated a potentially well-fitting model, we decided to re-run the CFA on the total ADOS sample.

Using the total ADOS sample (*n*=273), multiple indices of fit supported the two-factor model. The χ^2 statistic was non-significant, χ^2 (4) = 4.40, $p > .05$, suggesting non-significant differences between the observed and the expected covariance matrix and indicating a well-fitting model. The Comparative Fit Index (CFI), for which a value over .95 indicates good fit (Hu & Bentler, 1999), yielded a test statistic of .99. The Root Mean Square Error of Approximation (RMSEA), for which a value less than .05 indicates good fit (Browne & Cudeck, 1993), yielded a test statistic of .02. Finally, the AIC (Akaike's Information Criterion) compares goodness-of-fit across models, where smaller values indicate better fit (Hu & Bentler, 1999). The two-factor model produced a lower AIC value (36.40) than a preliminary analysis of the one-factor model (42.64). This suggested that our two-factor model was a better fit for the RRBI items than the unitary construct model.

The figure below shows the CFA model with standardized factor loadings. The two factors correlated relatively strongly, $r = .47$. This indicated that while they were not independent, they were not redundant. For the Cognitive-Restrictive factor, stereotyped speech loaded very heavily (.73), while the highly specific/restricted interests (.48) and compulsion/rituals (.38) loaded more equally. For the Motor-Sensory factor, unusual sensory interests (.69) loaded more heavily than hand/finger/other mannerisms (.37). The values mirrored the factor loadings from the EFA.

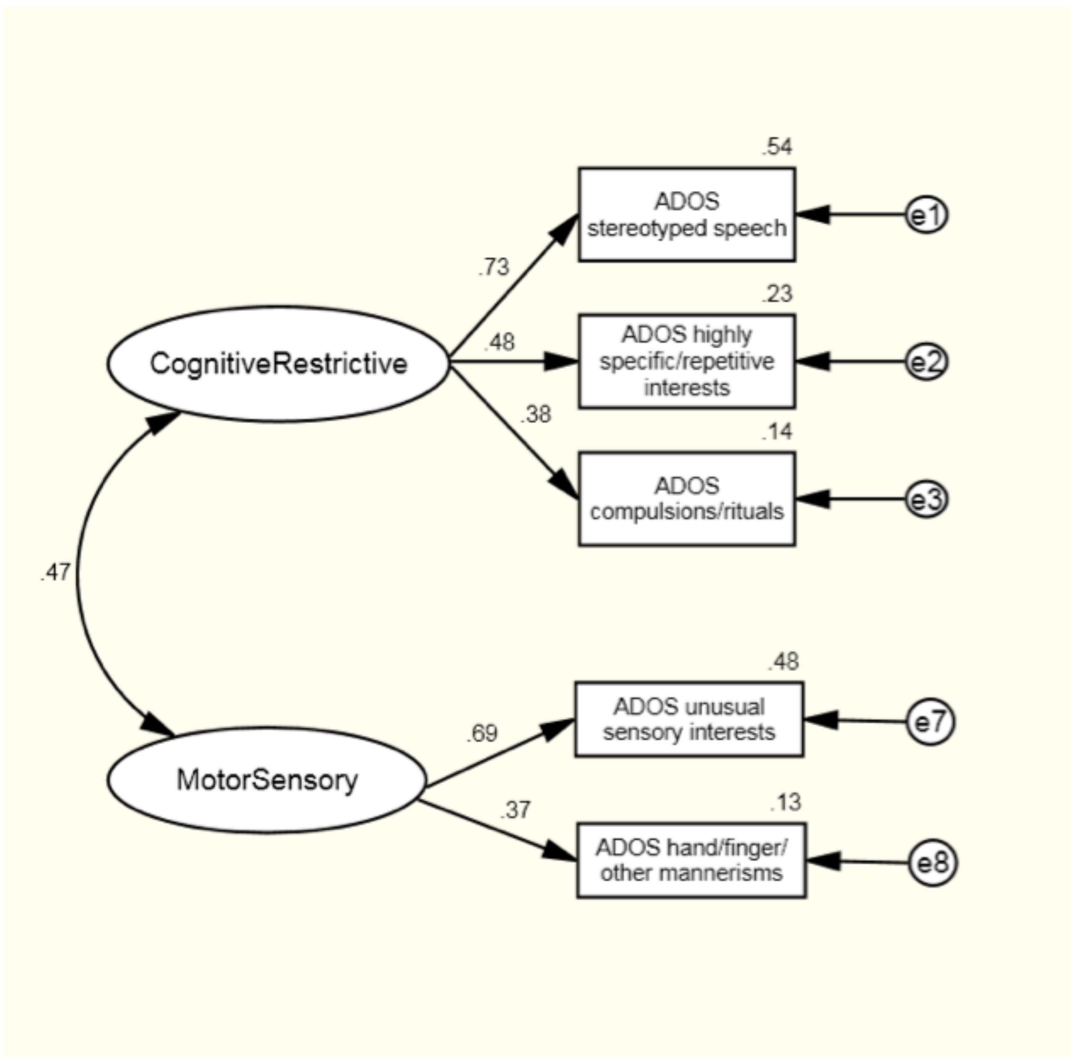

Figure 3 CFA Model for the ADOS

ADI-r.

Next, we looked the ADI-r. We ran an exploratory factor analysis using principal axis factoring (PAF) with non-orthogonal (Direct Oblimin) rotation on the split-half sample of $n = 178$. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO = .65, which was above the acceptable cutoff of .5 (Kaiser, 1974). Bartlett's test of sphericity, χ^2 (28) = 158.16, $p < .001$, indicated that the correlations between items were sufficiently large for the PAF. An initial analysis was run to obtain eigenvalues for each factor. Two factors had eigenvalues over Kaiser's criterion of 1 and, combined, explained 45.19% of the variance of the items. The scree plot showed inflexions that justified retaining factors 1 and 2. The table below shows the factor loadings after rotation.

Table 8 EFA Factor Loadings for the ADI-r

Items	Cognitive-Restrictive	Motor-Sensory
Verbal rituals	**.39**	.16
Unusual preoccupations	**.46**	-.17
Circumscribed interests	**.55**	-.13
Repetitive use of objects/interests in parts of objects	**.72**	.04
Compulsions/rituals	**.37**	.14
Unusual sensory interests	**.23**	.13
Hand/finger mannerisms	.02	**.56**
Other complex mannerisms/stereotyped body movements	-.01	**.73**

We concluded that the items that loaded onto first factor represented a *Cognitive Restrictive* factor, made up verbal rituals, unusual preoccupations, circumscribed interests, repetitive use/interest in objects, and compulsions/rituals**.** The items that loaded onto the second factor represented a *Motor-Sensory* factor, made up of hand and finger mannerisms, and other complex mannerisms/stereotyped body movements. The unusual sensory interests item did not load heavily (>.3) on either factor. As the item did not load definitively onto either factor nor did it warrant its own factor, and because the literature and our own prior findings with the ADOS suggest a relationship with the motor items, we decided that the item most likely belonged to the Motor-Sensory factor. The structure matrix, which allows for shared variance, supported the pattern matrix shown above. The factors were somewhat correlated, r = .21

Next, we ran the maximum likelihood confirmatory factor analysis (CFA) to evaluate how well the two-factor Cognitive-Restrictive/Motor-Sensory model fit the data. We used the second half of the split-half sample for the analysis (n=178). Multiple indices of fit supported the two-factor model. The χ^2 statistic was non-significant, χ^2 (19) = 27.15, p > .05, suggesting non-significant differences between the observed and expected covariance matrices and ultimately, a good-fit model. The Comparative Fit Index, for which a value over .90 indicates good fit (Hu & Bentler, 1999), yielded a statistic of .95. The Root Mean Square Error of Approximation (RMSEA), for which a value of .05 or lower indicates good fit (Browne & Cudeck, 1993), yielded a statistic of .05. Finally, the AIC (Akaike's Information Criterion) compares goodness-of-fit across models, where smaller values indicate better fit (Hu & Bentler, 1999). The two-factor model of this study produced a lower AIC value (77.15) than a preliminary analysis of the one-factor model (80.52). This suggested that the two-factor model was a better fit than the unitary construct model.

The figure below shows the CFA model with standardized factor loadings. The two factors were very strongly correlated, $r = .94$. This could indicate that the factors were not all that different from each other and should be noted when interpreting the results. However, a preliminary analysis of the items loading onto one factor resulted in poor model fit statistics. Thus, we decided to retain this model. For the Cognitive-Restrictive factor, the items loaded relatively equally onto the factor. Verbal rituals loaded most heavily (.60) and circumscribed interests loaded the least heavily (.38). For the Motor-Sensory factor, the items also loaded relatively equally. Unusual sensory interests loaded most heavily (.51) and hand/finger mannerisms loaded least heavily (.35). These loadings were somewhat different than those from the EFA. In the EFA, verbal rituals loaded moderately (.39) onto the Cognitive-Restrictive factor, while repetitive use of objects loaded most heavily (.73). Also, unusual sensory interests did not load heavily onto either factor.

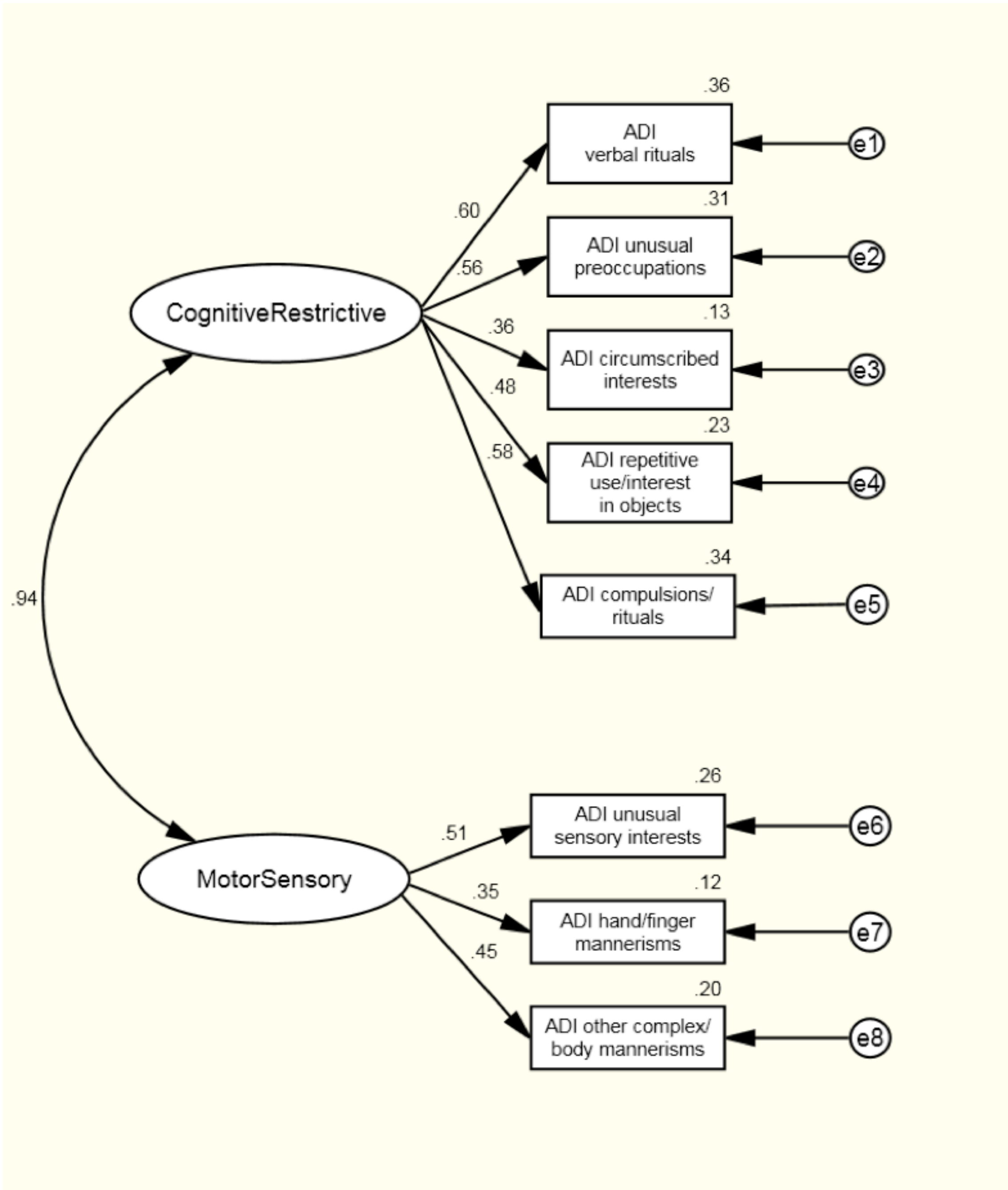

Figure 4 CFA Model for the ADI-r

RRBI Subscales.

With the results from the factor analyses, we wanted to examine the associations of age and IQ to the individual factors. To do this, we created subscale scores by totaling the ratings for the items that loaded onto each factor. That is, we totaled the ratings for the Cognitive-Restrictive factor items to create a Cognitive-Restrictive subscale score and the ratings for the Motor-Sensory factor items to create a Motor-Sensory subscale score. The descriptive statistics for the scales are presented in the table below.

Table 9 RRBI Total and Subscales Scores

		Total RRBI	Cognitive-Restrictive	Motor-Sensory
ADOS	Potential range	0 - 15	0 - 9	0 - 6
	Actual range	0 - 11	0 - 7	0 - 4
	M	2.77	1.99	0.78
	SD	2.14	1.63	1.02
	Skew	0.73	0.73	1.28
	Kurtosis	0.28	-0.04	1.04
	α	**.54**	**.51**	**.40**
ADI-r	Potential range	0 - 24	0 - 15	0 - 9
	Actual range	0 - 18	0 - 13	0 -7
	M	5.95	4.17	1.82
	SD	3.60	2.79	1.49
	Skew	.69	.84	.63
	Kurtosis	-.07	.22	-.28
	α	**.65**	**.62**	**.45**

To assess the reliability of the scales, we ran a reliability analysis using Cronbach's α. Values of $\alpha > .70$ generally represent good reliability (Cohen, 1992), though lower values may be more realistically expected and considered reliable when measuring psychological constructs (Kline, 1999). Given that *α* coefficients are also influenced by the size of the scale, such that scales with fewer items will produce lower *α* coefficients (Cortina, 1993), we expected our scales to produce lower-than-ideal *α* coefficients.

For the ADOS, the total RRBI scale had relatively low reliability, α = .54. Four of the items were found to have Corrected-Item Total Correlations equal to or greater than .3, suggesting the items correlated reasonably well with the overall score. The hand, finger, and body mannerisms item had a low correlation of .21, suggesting it did not correlate well with the overall scale (and supporting our hypothesis of a distinct motor factor). Dropping this item did not change the overall *α*. The overall *α* was also not increased by dropping any of the other items. The Cognitive-Restrictive scale had relatively low reliability, α = .51. The compulsions/rituals item did not correlate well with the overall scale (< .30), but dropping it (or any of the other items) would not increase the overall α. The Motor-Sensory scale had a low reliability, α = .40. The two items on this scale demonstrated Corrected-Item Total Correlations of less than .3. No items could be dropped to improve the scale as there were only two items. The table above includes the α reliability coefficients.

For the ADI-r, the total RRBI scale had higher reliability, *α* = .65, which approached the standard for good reliability. Six of the items had Corrected-Item Total Correlations of equal to or greater than .30, suggesting the items correlated reasonably well with the overall score. However, like on the ADOS, hand and finger mannerisms had a lower correlation of .25, suggesting it did not correlate well with the overall scale. Dropping it did not increase the overall α, however. The overall α was also not increased by dropping any of the other items. The table above includes the α reliability coefficients. The Cognitive-Restrictive scale had lower reliability, $\alpha = .62$, but still approached the standard for good reliability. All item correlations were greater that .30 and the α was not improved by dropping any item. The Motor-Sensory scale had a low reliability, $\alpha = .45$. Unusual sensory interests had a very low correlation of .19, much less than the acceptable cutoff of .30. The α coefficient could be raised a small amount, from .45 to .49 if the sensory interests item was dropped. With this in mind, the analysis was rerun with the sensory interests item loading onto the Cognitive-Restrictive factor instead. In this model, the overall α was raised a negligible amount, to $\alpha = .64$, and the sensory interests item was still under the cutoff of acceptable correlation of .30. These findings were not noticeably different, thus justifying the original inclusion of the sensory interests item on the Motor-Sensory subscale.

ADOS Subscales.

Next, we wanted to look at the subscales separately to address the question of whether they demonstrated unique associations to age and/or IQ. We began with the ADOS. We conducted a 3x3 MANOVA to examine Cognitive-Restrictive scores and Motor-Sensory scores across the age and IQ groups. Box's test for equal covariance matrices was non-significant, F (24, 28921.29) = .95, $p > .05$, meeting the assumption for homogeneity of covariance for the outcome variables. Levene's test indicated homogeneity of variance was assumed for both the Cognitive-Restrictive subscale, F (8, 218) = .79, $p > .05$, and the Motor-Sensory subscale, F (8, 218) = 1.80, $p > .05$.

There was no age by IQ interaction effect. The multivariate effect was significant for age, Wilks' $\Lambda = .91$, F (4, 434) = 5.50, p < .001, partial $\eta^2 = .05$. Pillai-Bartlett's trace, Hotelling's T^2, and Roy's Largest Root also supported the significant multivariate effect. This indicated that mean scores on both scales differed for age groups. The multivariate effect for IQ was not significant based on the Wilks' Λ calculation; however, it was significant according Roy's Largest Root, $\theta = .03$, F (2, 218) = 3.02, $p < .05$. This calculation produces the maximum possible between-group difference based on the data and thus, was a more liberal test.

Given the significance of the multivariate test, the univariate main effect for age was examined. A significant univariate main effect for age was obtained for both the Cognitive-Restrictive subscale, F (2, 218) = 7.88, $p < .01$, partial $\eta^2 = .07$ and for the Motor-Sensory subscale F (2, 218) = 5.53, $p < .01$, partial $\eta^2 = .05$. For the Cognitive-Restrictive subscale, we evaluated pairwise differences using LSD post-hoc tests. The adolescent group had significantly lower ratings than both the middle childhood group (mean difference = .78, $SD = .24$, $p < .01$) and the early childhood group (mean difference = .97, $SD = .27$, $p < .001$). The difference between early childhood and middle childhood was not significant. For the Motor-Sensory subscale, we evaluated pairwise differences using Gabriel's post hoc tests to account for group size differences. The Motor-Sensory subscale had the same pattern of age group differences as the Cognitive-Restrictive subscale. That is, the adolescent group had significantly lower ratings than the middle childhood group (mean difference = .52, *SD* = .14, $p < .001$) and the early childhood group (mean difference = .45, *SD* = .16, $p < .01$). The difference between early childhood and middle childhood was not significant.

Following the significant multivariate effect, there was significant univariate effect for IQ for the Cognitive-Restrictive subscale, F (2, 218) = 3.14, $p < .05$, partial η^2 = .03. Gabriel's post-hoc tests showed that the low IQ group had higher ratings than the average IQ group (mean difference = .79, *SD* = .28, $p < .05$). The table below displays the results from the MANOVA. The figures below show the age group differences for the Cognitive-Restrictive subscale and the Motor-Sensory subscale, respectively. The first figure shows the lower Cognitive-Restrictive scores for the adolescent group compared with the early and middle childhood groups (across the three boxes) and the lower scores for the average IQ group (middle box) compared to the low IQ group (left box). The second figure illustrates how there was the same trend for age for the Motor-Sensory subscale, but that there were no differences across the IQ groups.

Table 10 ADOS Subscales: Effects of Age and IQ

		F	Mean diff. (*SD*)	*p*	Partial η^2
Age	Cognitive-Restrictive	7.88 (2)	-	.000	0.07
	Adolescence vs. Early childhood	-	0.97 (0.27)	<.001	-
	Adolescence vs. Middle childhood	-	0.78 (0.24)	.002	-
	Motor-Sensory	5.53 (2)	-	.005	0.05
	Adolescence vs. Early childhood	-	0.45 (0.16)	.005	-
	Adolescence vs. Middle childhood	-	0.52 (0.14)	<.001	-
IQ	Cognitive-Restrictive[a]	3.14 (2)	-	.045	0.03
	Low IQ vs. Average IQ	-	0.79 (0.28)	.012	-

[a] Multivariate effect achieved significance by Roy's Largest Root statistic

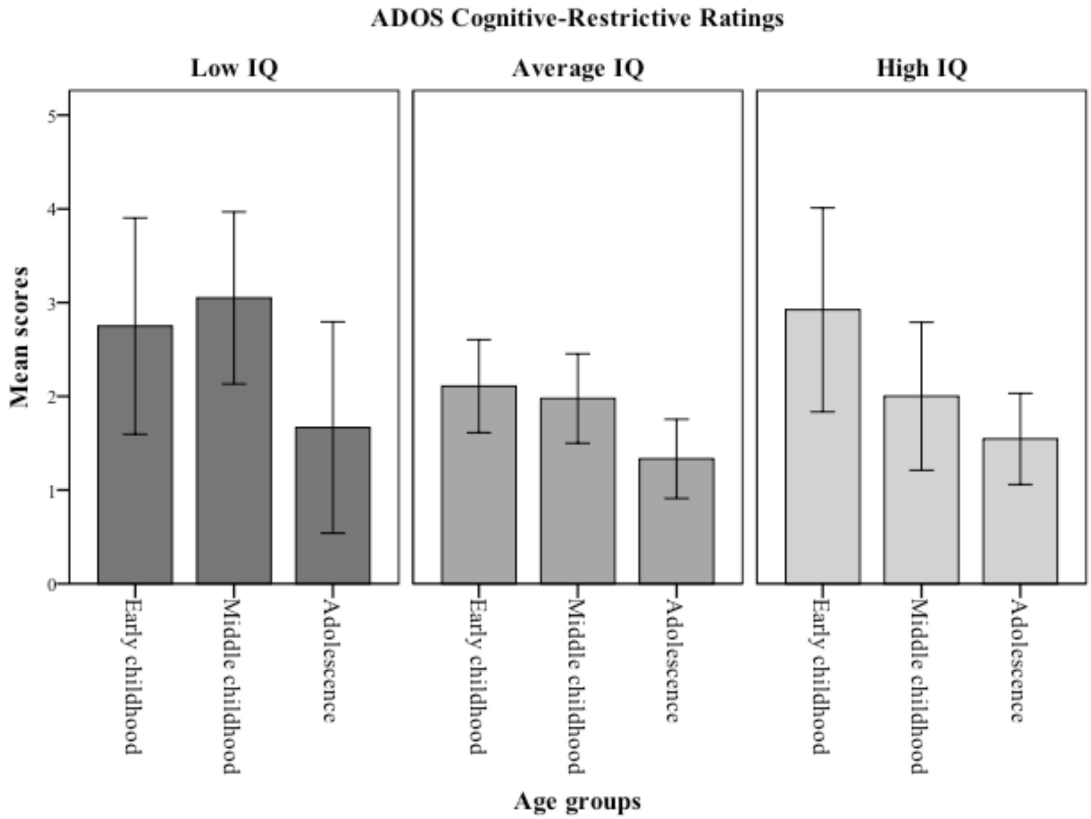

Figure 5 ADOS Cognitive-Restrictive Ratings by Age and IQ

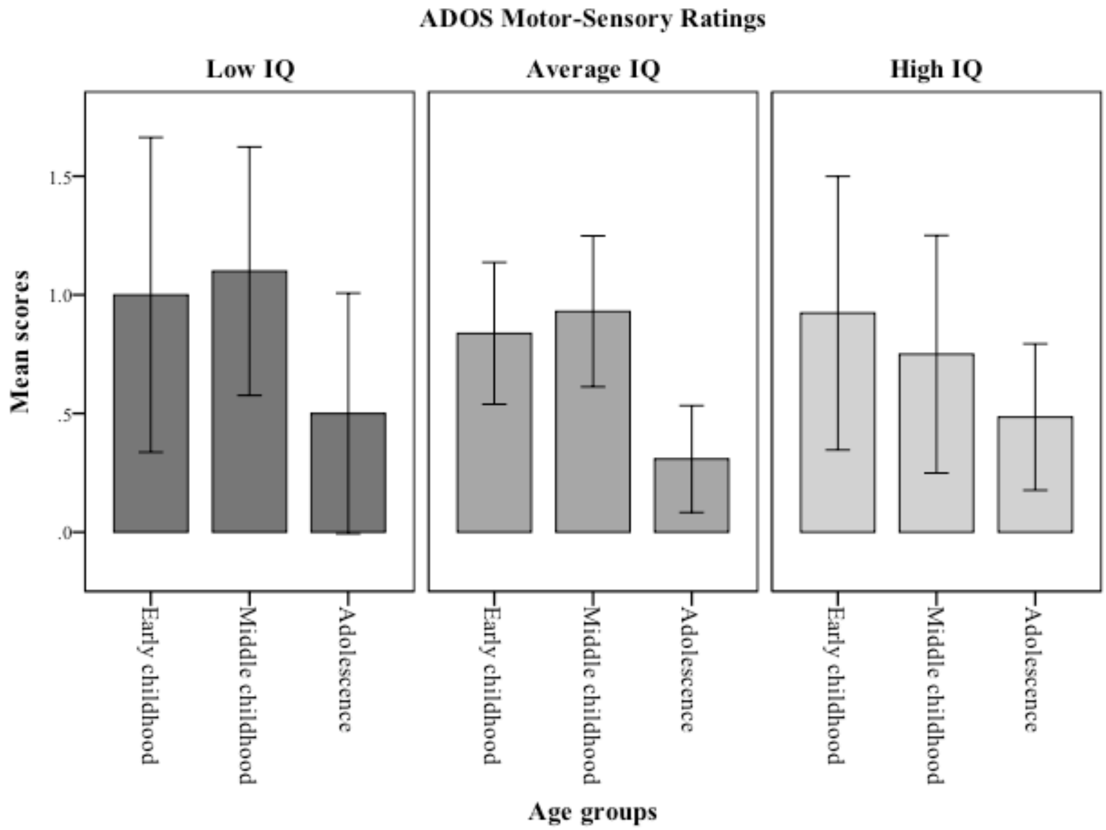

Figure 6 ADOS Motor-Sensory Scores Ratings by Age and IQ

ADI-r Subscales.

Next, we ran the MANOVA on the ADI-r subscales. Box's test for equal covariance matrices was non-significant at the .01 level, F (24, 10433.06) = 1.752, $p > .01$. Levene's test was non-significant at the .001 level for the Cognitive-Restrictive scale, F (8, 228) = 3.43, $p > .001$ and non-significant at the .01 level for the Motor-Sensory scale, F (8, 228) = 2.72, $p > .01$.

The 3x3 MANOVA revealed a significant interaction effect for age and IQ, Wilks' $\Lambda = .92$, F (8, 454) = 2.47, $p < .05$, partial $\eta^2 = .04$. Noting that the significant interaction takes precedence over interpreting main effects, the multivariate main effect for age was also significant, Wilks' Λ = .93, F (4, 454) = 4.21, p < .01, partial η^2 = .04. Pillai-Bartlett's trace, Hotelling's T^2, and Roy's Largest root all supported the significant multivariate effects. The multivariate main effect for IQ was not significant. Examining the univariate effects, the interaction effect was significant for the Cognitive-Restrictive subscale only, F (4, 228) = 3.79, p < .01, partial η^2 = .06. The interaction effect was not significant for the Motor-Sensory subscale. The univariate main effect for age was significant for both the Cognitive-Restrictive subscale, F (2, 228) = 6.32, p < .01, partial η^2 = .05 and for the Motor-Sensory subscale, F (2, 228) = 4.13, p < .05, partial η^2 = .04. Because the multivariate effect for IQ was not significant, we did not look at the univariate effects for IQ.

We then examined pairwise differences for the main effects to inform our understanding of the interaction effect. For the Cognitive-Restrictive subscale, Gabriel's post-hoc tests revealed significant differences across all age groups. That is, adolescents had lower rating scores than those in middle childhood (mean difference = 1.35, *SD* = .44, p < .01) and those in middle childhood had lower rating scores than those in early childhood (mean difference = 1.31, *SD* = .42, p < .01). Across the entire age span, adolescents had lower scores than those in early childhood (mean difference = 2.66, *SD* = .47, p < .001). For the Motor-Sensory subscale, the interaction was not significant, so the significant main effect for age was interpretable. Pairwise differences revealed that adolescents had lower ratings than both groups of children (middle childhood: mean difference = .75, *SD* = .24, p < .01; early childhood: mean difference = 1.01, *SD* = .27, p

< .001). There was not a significant difference between early and middle childhood. The results of the univariate analysis and pairwise comparisons are shown in the table below.

Table 11 ADI-r Subscales: Effects of Age and IQ

	Items	*F*	Mean diff. (*SD*)	*p*	Partial η^2
Age*IQ	Cognitive-Restrictive	3.79 (4)	-	.005	0.06
Age	Cognitive-Restrictive	6.32 (2)	-	.002	0.05
	Adolescence vs. Middle Childhood	-	1.35 (0.44)	.006	-
	Adolescence vs. Early Childhood	-	2.66 (0.49)	<.001	-
	Middle Childhood vs. Early Childhood	-	1.31 (0.42)	.006	-
	Motor-Sensory	4.13 (2)	-	.017	0.04
	Adolescence vs. Middle Childhood	-	0.75 (0.24)	.005	-
	Adolescence vs. Early Childhood	-	1.01 (0.27)	.001	-

Illustrated in the figures below, older individuals with average and high IQs had lower mean scores on the Cognitive-Restrictive subscale. However, individuals with low IQs (in the left box) did not show the same pattern of lower scores in the older age groups (the middle and right boxes). It appeared that for individuals with low IQ, ratings on the Cognitive-Restrictive subscale remained constant, or were perhaps higher, for the individuals of the older age cohorts. This was supported by the post-hoc tests for the Cognitive-Restrictive subscale across age groups. The second figure for the Motor-

Sensory subscale shows the age effect of lower scores for the adolescent group but also shows that there were no differences across the IQ groups (compared across the three boxes).

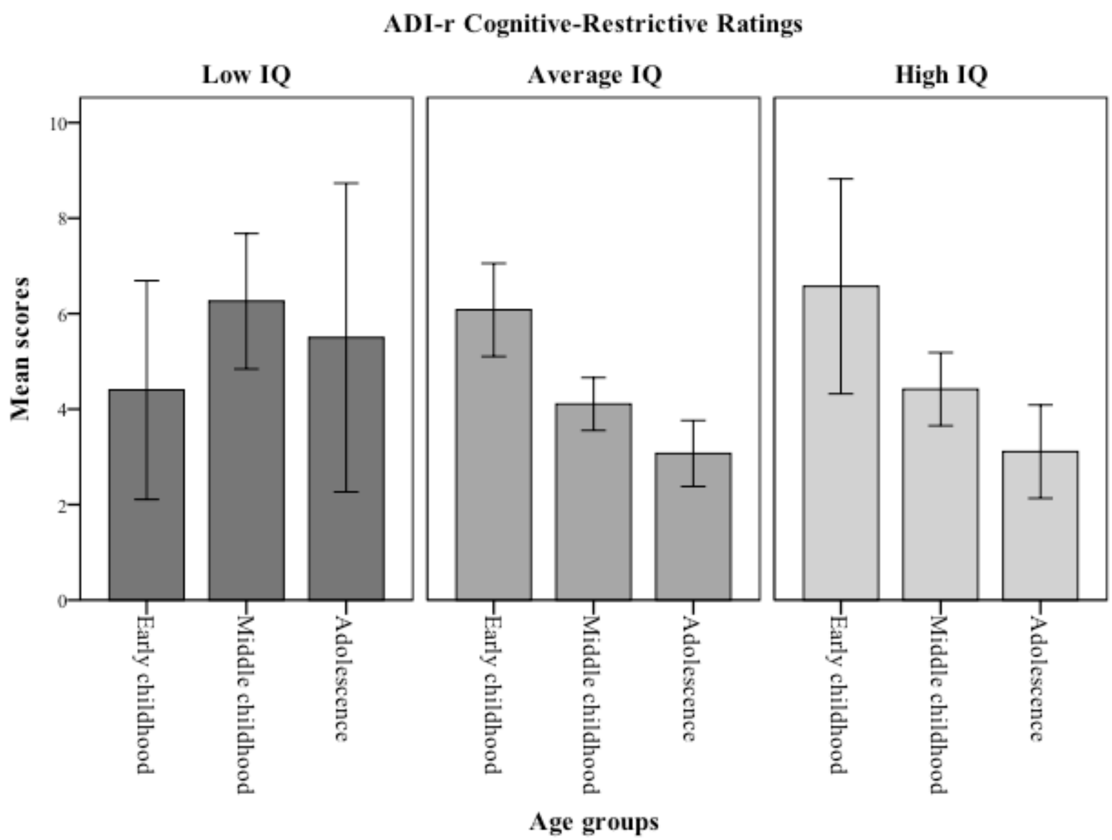

Figure 7 ADI-r Cognitive-Restrictive Ratings by Age and IQ

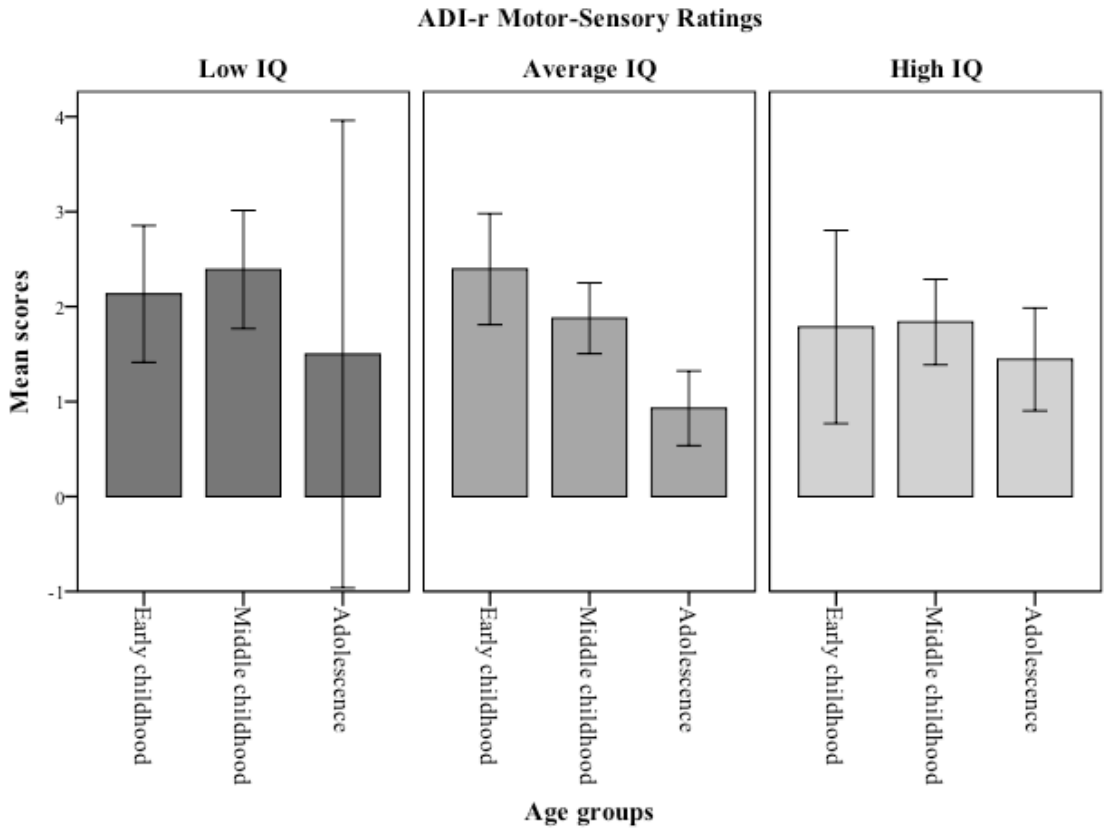

Figure 8 ADI-r Motor-Sensory Ratings by Age and IQ

Research Question 3

How similarly do the ADOS and ADI-r measure the impairment severity of RRBIs?

For our third research question, we matched items across the instruments that measured the same behaviors and ran correlation analyses using Kendall's τ. We then converted the τ statistics into the more frequently-used and commonly-understood Spearman's ρ and Pearson's r, to allow for comparisons with other study findings. The conversion to Pearson's *r* also allowed us to calculate the coefficient of determination (r^2) in order to examine the percentage of overlapping variance between items.

The correlations for the matched items can be seen in the table below. Only the unusual sensory interests items ($r = .31$) had a moderate correlation. 10% ($r^2 = .10$) of the variance for this item was shared across instruments, representing a somewhat moderate amount. The three item pairs of restricted interests had weak-to-moderate correlations, from $r = .22$ to $r = .25$. About 5% ($r^2 = .05$) of the variance for these items was shared across instruments, representing a small amount. Three of the items had weak correlations, with *r* values below .20. For these items, only 1% - 3% of the variance was shared across instruments, representing a trivial amount (Cohen, 1992).

Table 12 Correlations for ADOS and ADI-r Corresponding Items

ADOS Item	ADI-r Item	τ	ρ	r	r^2
Stereotyped speech	Verbal rituals	.07	.11	.11	.01
Highly specific/ repetitive interests & behaviors	Unusual preoccupations	.16	.24	.25	.06
	Circumscribed interests	.14	.21	.22	.05
	Repetitive interest in/use of objects	.15	.22	.23	.05
Compulsions/rituals	Compulsions/rituals	.07	.11	.11	.01
Unusual sensory interests	Unusual sensory interests	.20	.30	.31	.10
Hand & finger mannerisms	Hand, finger, & body mannerisms	.11	.16	.17	.03
	Other body mannerisms/ stereotyped body movements	.13	.19	.20	.04

Note. τ = Kendall's τ; ρ = Spearman's ρ; r = Pearson's r

We were also interested in how well the subscales would correlate across the instruments. That is, would total RRBI scale scores, Cognitive-Restrictive subscale scores, and Motor-Sensory subscale scores from the ADOS correlate to their respective scores on the ADI-r? The correlations for the scales can be seen in the table below. The ADOS and ADI-r Motor-Sensory subscales had a moderate correlation, $r = .37$, with 14% ($r^2 = .14$) of the variance for the scales shared across instruments. The ADOS and ADI-r Total RRBI scales had a weak-to-moderate correlation, $r = .25$, for which 6% ($r^2 = .06$) of the variance was shared across the instruments. The ADOS and ADI-r Cognitive-

Restrictive subscales had a relatively weak correlation (r = .20), for which only 4% (r^2 = .04) of the variance in the scales was shared across the instruments (Cohen, 1992).

Table 13 Correlations for ADOS and ADI-r Scales

Scale	τ	ρ	r	r^2
Total RRBI scales	.16	.24	.25	.06
Cognitive-Restrictive subscales	.13	.19	.20	.04
Motor-Sensory scales	.24	.35	.37	.14

Note. τ = Kendall's τ; ρ = Spearman's ρ; r = Pearson's r

DISCUSSION

Repetitive and restricted behaviors and interests can create significant constraints on an individual's quality of life, interfering with daily living, social interactions, and learning (Gabriels et al., 2005; Lee et al., 2007; South et al., 2005). Previous research has found that overall RRBIs may lessen in impairment severity with age (McGovern & Sigman, 2005; Seltzer et al., 2004), but that may not be true for all behaviors within the domain (i.e. Richler et al., 2007; Militerni et al., 2002). Additionally, researchers have found that the intensity of RRBIs is negatively correlated with intellectual functioning levels (Seltzer et al., 2003; Turner, 1999), although, again, this may not be the case for all behaviors (i.e. Bishop et al., 2006; Szatmari et al., 2006). Thus, the question has arisen as to whether there may be distinguishable subtypes of RRBIs uniquely associated with age and IQ.

This study was designed to contribute to the research literature by examining these questions in a relatively high-functioning sample of children and adolescents with ASD. The three research questions will be addressed separately. Each question was examined using information from both the ADOS and ADI-r to evaluate findings across multiple sources.

Research Question 1

Are ratings of the impairment severity of RRBIs different across early childhood, middle childhood, and adolescence and across individuals with low, average, and high IQs?

For the first question, our results generally corroborated earlier research findings that RRBIs diminished in impairment severity with age. Specifically, adolescents showed lower severity ratings for total RRBIs than the two younger children's groups. Our findings were also consistent with previous researchers that suggested that individuals with lower IQs have higher RRBIs severity ratings than those with higher IQs. However, it is important to note that the findings from the ADOS and the ADI-r differed slightly. Specifically, with the ADOS data, we found no interaction for age and IQ. However, with the ADI-r data, we did find an interaction for age and IQ. For the ADOS data, we found lower RRBI severity ratings for adolescents than for younger children. This would mean that improvements in RRBI ratings may not occur until the teen years. We also found lower RRBI severity ratings for individuals with average IQ scores than individuals with low IQ scores, The individuals with the highest IQ scores fell in between, but were not different from, the other two groups on severity ratings. On the other hand, we found that with the ADI-r data, there was an interaction between the factors age and IQ. ADI-r RRBI severity ratings were higher for individuals with average and high IQ scores in the older age groups. But individuals with low IQ scores showed no differences in RRBI severity ratings. On the ADI0r, when individuals of all functioning abilities were examined together, it appeared that they all had lower ratings of RRBI impairment severity. The interaction shows that this was not so for individuals with below-average IQs. Thus, for parents reports of developmental history, both age and IQ are related to RRBI impairment severity.

Research Question 2

Can RRBIs be identified as distinct factors and do these factors demonstrate unique associations to age and IQ?

For the second question, our findings also corroborated the research that suggests there are distinguishable factors of RRBIs. For both the ADOS and the ADI-r, we found two distinct factors of behaviors that we labeled *Cognitive-Restrictive* and *Motor-Sensory*. The Cognitive-Restrictive factor included behaviors that represented a narrowness in thinking, including limited habits, interests, and speech. The Motor-Sensory factor included behaviors that represented physical and sensory stimulation. These factors were similar to the previous factor analyses conducted by Cuccaro et al. (2003), Szatmari et al. (2006), Richler et al. (2007), and Lam et al. (2008). Specifically, our study also found the distinction between a Cognitive-Restrictive (Insistence-on-Sameness/Resistance-to-Change) factor and a Motor-Sensory factor. The variance accounted for by the factors (around 50%) was comparable to that of the previous studies. Importantly, we found these factors on both the ADOS *and* the ADI-r; previous studies had only examined the ADI-r.

Yet there were some key differences with our model, specifically for the ADI-r items. Our study found that the item for *repetitive interest in or use of objects or parts of* *objects* belonged to the Cognitive-Restrictive factor. We believe this may have reflected the characteristics of our high-functioning, wider age-range sample. Specifically, this behavior may have manifested itself as more cognitively sophisticated activities for high-functioning individuals than for lower-functioning individuals. For a lower-functioning child, this action may have involved repetitive rolling of a toy car or spinning of its wheels. For a higher-functioning child, this behavior may have included building complex structural models or being intensely interested in complicated parts of engineering and technology systems. As such, this item might have been rated more similarly to the impairment severity of other cognitive behaviors rather than the impairment severity of motor behaviors.

Additionally, our Cognitive-Restrictive factor included the items for *circumscribed interests* and *unusual preoccupations*, which did not load onto either factor in previous studies. These behaviors might not have been as frequently or highly rated for the younger, lower-functioning participants of previous studies. This finding was unique to our study but seemed fitting for the behaviors engaged in by older, higher-functioning participants. Finally, our study was the first to include verbal rituals, following the new structure of the DSM-5. Importantly, we found that verbal rituals on both the ADOS and the ADI-r represented the same cognitive-restrictive quality of other complex ritualized interests and habits.

While previous studies employed the term “Insistence-on-Sameness”, we chose the term “Cognitive-Restricted”. We feel this term was more inclusive of the behaviors we found for the factor and a more appropriate description of their association. In our opinion, these behaviors represented a narrowness in thinking and engagement with the world, as manifested through interests, habits, and even communication. We saw these behaviors as cognitively driven and surmised that they may serve an inherently different function than motor-sensory behaviors. Specifically, motor-sensory behaviors may provide physical stimulation and sensation. Cognitive-restrictive behaviors may serve as adaptive means for engaging in the world. Empirical and theoretical research should continue to tease out the specific functions these behaviors serve for individuals with ASD.

We then created and examined subscales based on our factors to evaluate the unique associations of age and IQ to the two types of RRBIs. Both of the RRBI subscales showed the same association to age, with older individuals showing lower ratings. This was consistent with the findings for the total RRBI scale. Further, like the total scale, lower scores on both subscales were not evident until adolescence. But for IQ, the subscales did show unique associations. Importantly, only the Cognitive-Restrictive subscale showed different ratings based on IQ. For the ADOS Cognitive-Restrictive subscale, individuals with lower IQs had significantly higher ratings of impairment severity. For the ADI-r Cognitive-Restrictive subscale, there was an interaction effect, where individuals with higher IQs had lower ratings in older groups; individuals with lower IQs did not show lower ratings in the older groups. On both the ADOS and ADI-r, there was no association to IQ for the Motor-Sensory subscale.

Thus, we concluded that there was something unique about the Cognitive-Restrictive behaviors that resulted an negative association of IQ to impairment severity.

This supported earlier suggestions that some RRBIs may be “higher-order” cognitive behaviors that are related to intellectual functioning (Cuccaro et al., 2003; Turner, 1999). But our findings were somewhat inconsistent with other studies in which cognitive behaviors were more problematic for higher functioning individuals (i.e. Bishop et al., 2006; Richler et al., 2007). We found, instead, that cognitive behaviors became less impairing for higher-functioning older individuals, while they did not become less impairing for lower-functioning individuals.

We also concluded from our data that motor-sensory behaviors were just as problematic for individuals with high IQs as those with low IQs. This, however, conflicted with previous findings that physical behaviors were not significantly problematic for higher-functioning individuals (Szatmari et al., 2006; South et al., 2005). Ultimately, the unique association to IQ (and on the ADI-r, to the interaction across age groups) for the Cognitive-Restrictive but not Motor-Sensory subscales bolsters the idea that there are two distinct types of RRBIs, one that may be related to an individual’s functioning abilities and one that is not. Further, we might suggest from our findings that increased intervention for Motor-Sensory RRBIs should be targeted to individuals of all functioning levels, while intervention for Cognitive-Restrictive RRBIs may need to be more individually tailored and more heavily targeted to low-functioning individuals.

Research Question 3

As RRBIs are most commonly rated by the gold-standard ADOS and ADI-r, do these tests correlate in their measurement of RRBIs?

To our surprise, we found rather weak correlations between corresponding items from the two instruments that were intended to measure the same construct. Only the item for unusual sensory interests had a moderate correlation. These findings indicated that the instruments may have been measuring these behaviors differently. The implications for this are interesting to consider. This finding could be seen as a weakness of the assessment instruments. That is, an individual assessed on two similar measures should have scored consistently across them. However, the discrepancy could also be seen as a strength of using the two instruments together as the developers now emphasize. It may be that parents and clinicians had a different point of reference; parents saw behavior in natural settings over extended time periods while clinicians had more expertise in identifying the behaviors of concern. A parent might have missed behaviors that a clinician might have seen and vice versa. Thus, it may be that the instruments each captured something unique about RRBIs and should continue to be used together for assessment.

We also estimated the correlations between the total score and subscale scores of the two instruments. The scales had somewhat stronger, small to moderate correlations across instruments. This, along with the alpha coefficients, provided evidence for the distinct RRBI subtypes. Future research should continue to examine how closely the ADOS and the ADI-r measure RRBIs and how diagnostic accuracy and stability may be improved when the two tests are used in collaboration. Future research should also continue to explore potential RRBI subtypes to better inform our understanding of this heterogeneous group of behaviors.

Overall, the findings from our study related to prior research in the following ways:

1) We found support for prior research that there are distinct factors of RRBIs and that these behaviors may be characterized by a cognitive/physical distinction.
2) We found support for prior research that RRBIs improve (become less problematic) with age, even in a high-functioning population. Our study contributed the unique finding that this was true when RRBIs were examined as a whole (total RRBIs) and when examined as separate subtypes (Cognitive-Restrictive and Motor-Sensory). This trend may not be true, however, for low-functioning individuals, as they did not show changes in Cognitive-Restrictive behaviors across age groups.
3) We can contribute the unique finding that when RRBIs were examined as separate subscales, only the Cognitive-Restrictive subscale had lower impairment severity ratings for higher-functioning individuals. The Motor-Sensory subscale had the same ratings for individuals in all IQ groups. The IQ association may be unique to the Cognitive-Restrictive behaviors only.
4) We found that the age when RRBIs are rated lower in severity differed based on the evaluation measure. On the ADOS, individuals were not rated as having less problematic RRBIs until adolescence. On the ADI-r, individuals were rated as having less problematic RRBIs both in childhood and adolescence. From the different findings across measures, we speculated that parents saw changes in

RRBIs earlier than clinicians <u>or</u> that parents perceived earlier changes while experts did not identify true improvement until later.

5) We found questionable correlations of assessment of RRBI impairment severity across the two measures. This indicated that the two instruments may measure RRBIs differently, which we suggest has strong implications for their use.

The findings in this study are important for informing our understanding of RRBIs. We know more about the expected presentation of impairment severity of RRBIs at different developmental ages and for different levels of intellectual functioning. This can help us better target and tailor interventions to those individuals showing the greatest risk for these maladaptive behaviors. The findings may also help elucidate the construct of the RRBIs by classifying these heterogeneous behaviors into more specific and homogenous subtypes. This may advance our research as to why individuals with ASD engage in RRBIs. Future studies should aim to identify what distinct functions the RRBI subtypes serve for individuals with ASD.

Limitations

One limitation to this study was the effect of age cohort differences. As this was a cross-sectional study, the variables of interest may have been influenced by population characteristics of the groups. Greater general awareness, more inclusive diagnostic criteria, and more effective interventions over the past two decades have changed the ASD population (Lord & McGee, 2001; Magnusson & Saemundsen, 2001). Thus, the individuals in the older groups did not necessarily have the same behavioral presentation as the individuals in the youngest groups will have in adolescence. Differences across age groups may have been confounded by these population characteristics and not specifically related to changes in behavior. While this study told us about differences at age points, we must be careful in our conclusions about changes over time. Future research should investigate the questions of this study in a longitudinal sample in order to eliminate the influence of the effects of age cohorts.

Another limitation to the study was the lack of variance due to a variety of factors including the population of interest, the instrument rating scales, and the nature of rating aberrant behavior. A narrower sample (in this case, based on functioning level) will show less behavioral variance. Thus, while we were interested particularly in higher-functioning individuals, the limited variance may have made it difficult to see statistically significant differences. Further, the limited range of the ratings scales may also have made it difficult to observe differences. Finally, as the scales measure atypical behaviors, variables will be naturally biased to zero. Future research should continue this investigation using more descriptive measures of RRBIs, such as the Repetitive Behaviors Scales (Bodfish et al., 2000).

Finally, as with all factors analyses, the relationships among the variables were correlations and causal inferences cannot be made. Further, factor analyses produce models that are data specific and the characteristic of our data, including its size and non-parametric nature, may have limited the generalizability of our model to other samples. However, we believe this research is worth pursuing as it informs our understanding of ASD and may further the development of diagnostic practices and behavioral interventions. Future research should evaluate the reliability of our model through replication on other samples and populations.

Conclusions

In this study, we contributed to research of RRBIs in ASD. We examined the domain for potential subtypes and investigated their association with age and intellectual functioning. We found two distinct types of RRBIs based on Cognitive-Restrictive and Motor-Sensory characteristics. Further, we found only the Cognitive-Restrictive subtype was associated with IQ. While these findings can inform intervention, they also hint at different underlying functions for the two types of behavior. For instance, if a child's need for routine is based on narrowness of thinking while finger-flicking is based on a need for motor-sensory stimulation, we will be able to teach the child more effectively to engage in more functional replacement behaviors. More studies are needed to continue investigating the existence of these factors in other samples, their association with other characteristic variables, and ultimately, their function as behaviors. A greater understanding of RRBIs will ultimately inform more targeted interventions and promote optimal developmental outcomes for individuals with ASD.

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BIOGRAPHY

Beth D. Warsof's interest in autism began with her students at the Ivymount School Autism Program in Rockville, MD. Beth began teaching at Ivymount after graduating with a B.A. in Education from American University. There, a true passion was born. Beth went on to earn her M.Ed. in Educational Psychology from the University of Virginia in 2009 and subsequently, her Ph.D. in Applied Developmental Psychology from George Mason University in 2013. Beth is certified in ADOS administration and plans to continue her career in educational and developmental diagnostics and consultation. Beth can be reached at beth.warsof@gmail.com.