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Psychometric Analysis of the Repetitive Behavior Scale-Revised using Confirmatory Factor Analysis in Children with Autism

Jessica L. Hooker[1], **Deanna Dow**[2], **Lindee Morgan**[3], **Christopher Schatschneider**[4], **Amy M. Wetherby**[5]

[1]School of Communication Science and Disorders, Florida State University, 201 W. Bloxham Street, Tallahassee, FL, 32306-1200, USA;

[2]Department of Psychology, Florida State University, 1107 W. Call Street, Tallahassee, FL 32306-4301, USA;

[3]Marcus Autism Center, School of Medicine, Emory University, 1920 Briarcliff Road, Atlanta, GA 30329-4010, USA;

[4]Department of Psychology, Florida Center for Reading Research, Florida State University, 2010 Levy Avenue, Suite 100, Tallahassee, FL 32320;

[5]Department of Clinical Sciences, Autism Institute, College of Medicine, Florida State University, 2312 Killearn Center Boulevard, Building A, Tallahassee, FL 32309-3524, USA;

Abstract

Research examining restricted and repetitive patterns of behavior or interests (RRB) in autism spectrum disorder (ASD) has increased our understanding of its contribution to diagnosis and its role in development. Advances in our knowledge of RRB are hindered by the inconsistencies in how RRB is measured. The present study examined the factor structure of the Repetitive Behavior Scale-Revised (RBS-R) in a sample of 350 children with ASD ages two to nine. Confirmatory factor analysis designed for items with categorical response types was implemented to examine six proposed structural models. The five-factor model demonstrated the most parsimonious fit based on common overall fit indices that was further supported by examinations of local model fit indicators, though, the four- and six-factor models evidenced adequate-to-good fit as well. Examinations of RRB factor score approaches indicated only minor differences between summed item subscale scores and extracted factor scores with regard to associations with diagnostic measures. All RRB subtypes demonstrated significant associations with IQ and adaptive behavior. Implications for future research validating the RBS-R as a more extensive clinical measure of RRB in ASD are discussed.

Lay Summary

Repetitive behaviors are one of the two main symptoms of autism spectrum disorder (ASD). To better understand the role of repetitive behaviors, we must establish effective ways of measuring them. This study assessed the measurement qualities of the Repetitive Behavior Scale-Revised

Corresponding Author: Jessica L. Hooker, School of Communication Science and Disorders, Florida State University, 201 W. Bloxham Street, Tallahassee, FL, 32306-1200, USA; jessica.hooker@med.fsu.edu;.

(RBS-R) in a sample of 350 children with ASD ages two to nine. We found that the RBS-R measures multiple types of repetitive behaviors and that these behaviors are related to thinking ability and independence.

Keywords

restricted/repetitive behaviors; children; adaptive behavior; autism; factor analysis

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder comprising two core domains–impairments in social communication and restricted and repetitive patterns of behavior or interests (RRB; American Psychiatric Association, 2013). ASD research has focused primarily on examining social communication impairments; however, further investigation of RRB is needed as these behaviors significantly interfere with active engagement with others (Harrop, McConachie, Emsley, Leadbitter, & Green, 2014; Nadig, Lee, Singh, Bosshart, & Ozonoff, 2010; Stronach & Wetherby, 2014). An increase in research on RRB in ASD has resulted in several key findings contributing to a richer conceptualization of this domain.

A major contribution to the understanding of RRB is the growing consensus on the presence of multiple distinct subtypes of RRB (Bishop et al., 2013; Lam & Aman, 2007; Lam, Bodfish, & Piven, 2008; Leekam, Prior, & Uljarevic, 2011). The distinction between subtypes of RRB has helped to clarify research examining patterns of RRB in relation to multiple factors including age, cognitive ability, social communication, and adaptive behavior (Harrop et al., 2014; Jones et al., 2017; Stronach & Wetherby, 2014; Wolff et al., 2014). Growing research in these areas has, in turn, promoted progress in identifying the underlying etiology of RRB in children with ASD (Brundson & Happé, 2014; Jones et al., 2017; Leekam et al., 2011).

While there has been a significant increase in RRB research, there remains a lack of clarity in our understanding including some variability regarding subtypes of RRB and inconsistent associations with related areas of functioning. Many factors, such as the age, diagnostic characteristics, and sample size, may explain the variability and inconsistent associations observed in previous research. Some of the discrepancies can be attributed to variability in the measurement of RRB. Multiple measures have been used to examine RRB including the Autism Diagnostic Interview-Revised [ADI-R; Rutter, LeCouteur, & Lord, 2003] based on interview, the Autism Diagnostic Observation Schedule based on structured observations with presses [ADOS; Lord, Rutter, DiLavore, & Risi, 1999, 2002], the Repetitive Behavior Scale-Revised [RBS-R; Bodfish, Symons, Parker, & Lewis, 2000] based on parent report, direct observation [Stronach & Wetherby, 2014; Watt, Wetherby, Barber, & Morgan, 2008], and case history reports [Troyb et al., 2016]. As Leekam and colleagues (2011) discuss, the content and scope of a measure delineates the subtypes of behaviors being assessed. For example, measures with a fewer number of items examining RRB are likely to identify fewer numbers of subtypes, potentially leading to a more limited characterization of RRB.

As a result, there has been a call for the use of more extensive measures of RRB in this population (Leekam et al., 2011; Papageorgiu, Georgiades, & Mavreas, 2008).

The RBS-R is one of the more-thorough clinical measures of RRB. Initially developed from multiple scales of related behaviors (Bodfish et al., 2000), the RBS-R is an informant-report of the presence and severity of a variety of RRB. Its use in studies of individuals with ASD has resulted in its popularity as one of the most frequently used parent-reports of RRB. There continues to be some inconsistency in its use across studies, despite evidence of relatively consistent and distinct subtypes of RRB (Bishop et al., 2013; Lam & Aman, 2007; Mirenda et al., 2010). The RBS-R is commonly implemented as a unidimensional measure of RRB through the use of a total score. The use of a total score warrants further investigation as there have been explicit recommendations against its use with this measure (Mirenda et al., 2010; Scahill et al., 2015). Even when subscales are examined individually, there are differences in how the subscale scores are derived, with some studies using a sum score (Factor et al., 2016; Ventola et al., 2016) and others using a mean-item score approach (Esbensen et al., 2009; Jones et al., 2017).

The variability in how the RBS-R is implemented has likely influenced the characterization of RRB in relation to other areas of functioning, at least partially. The most commonly examined relationship is between RRB and cognitive ability. For example, Schertz and colleagues (2016) observed a significant negative association between overall cognitive ability and the Stereotypic RRB subtype, but reported nonsignificant relationships with the Self-Injurious, Ritualistic/Sameness, and Restricted Interest RRB subtypes in their sample of toddlers (ages 16 to 31 months) with ASD using a summed item, five-factor model of the RBS-R. Conversely, Wolff and colleagues (2014) observed no relation between overall cognitive functioning nor nonverbal ability specifically and the total number of items endorsed nor the original six subscales of the RBS-R in a sample of toddlers with ASD at ages 12 and 24 months.

There is a continued need for further analysis of the RBS-R in order to more fully characterize its psychometric properties and promote consistency in the use of the measure. The factor analysis framework is an effective approach for examining complex relations among variables and characterizing the underlying dimensions of a measure (Brown, 2015). To date, four studies have implemented a factor analysis framework to examine the RBS-R (Bishop et al., 2013; Georgiades, Papageorgiou, & Anagnostou, 2010; Lam & Aman, 2007; Mirenda et al., 2010). Three of these studies explored the underlying factor structure from an exploratory factor analysis (EFA) approach (Bishop et al., 2013; Georgiades et al., 2010; Lam & Aman, 2007) with the study by Lam and Aman (2007) being the first independent validation of the RBS-R on a sample of 307 individuals between three and 48 years of age. The Bishop et al. (2013), whose sample included 1,825 individuals with ASD aged 4–18 years old, and Lam and Aman (2007) studies both identified a five-factor solution comprising Stereotyped Behaviors, Self-injurious Behavior (SIB), Compulsive Behavior, Ritualistic Sameness Behaviors, and Restricted Behaviors, that provided the best fit; though there were differences regarding which items were retained in the measure and the composition of some of the factors. The Georgiades et al. (2010) study reported a two-factor solution comprising Compulsive-Ritualistic-Sameness-Restricted Behaviors and

Stereotyped-Self-Injurious Behavior on which four items cross-loaded onto both factors in their sample of 205 Greek individuals with ASD aged 2–48 years. While this work is essential in the initial examinations of the dimensionality, this approach is data-driven and does not require a priori hypotheses regarding the specific structure of the factors (Brown, 2015). Further, these studies were conducted with samples comprising large age ranges, potentially masking quantitative and qualitative differences across age groups.

Confirmatory factor analysis (CFA) is a hypothesis-driven approach that can be used to examine the construct validity of a measure (Brown, 2015). Only one study to date has implemented this approach with the RBS-R in a sample of young children with ASD (Mirenda et al., 2010). Results of Mirenda's CFA using data on 287 preschool children (aged 24–64 months) with ASD provided support for a five-factor solution similar to the ones proposed in the EFA studies. The authors also supported a three-factor solution combining Compulsive Behavior with Ritualistic Sameness Behaviors and Stereotyped Behavior with Restricted Interests. Both models demonstrated promising reliability scores with alpha coefficients ranging from 0.72 to 0.91 across factors in both models. The authors also provided support for the convergent validity of these models through associations between factors and scores across multiple subscales of the Child Behavior Checklist (Achenbach & Rescorla, 2000).

The Mirenda and colleagues' (2010) study was the first study to examine the factor structure of the RBS-R using CFA. These results are promising and largely consistently with work of Bishop et al. (2013) and Lam and Aman (2007). However, the results of this study would be strengthened by additional replication as several of the model fit indices across both model the three- and five-factor models were well outside of the recommended cutoffs of reasonable fit. Even those falling within range only provided evidence of reasonable, but not good fit. The validity of the three-factor model is questionable, as only a single fit index fell within the acceptable range, and this model evidenced inferior fit to the four-, five-, and six-factor models. Further, it does not appear the categorical nature of the items was accounted for, likely violating the assumption of multivariate normality and biasing the estimation. Continued evaluation of the factor structure in additional samples is necessary to provide clarity on the dimensionality of the RBS-R.

Thus, the primary goal of this study is to build upon and strengthen previous work examining the constellation of RRB subtypes on the RBS-R in a large and well-characterized sample of children with ASD. In approaching this, an estimation approach designed to handle the categorical structure of the items was implemented to compare previously proposed and conceptually-derived models of RRB subtypes. Additionally, this study aims to provide supplementary investigations regarding the performance of the RBS-R in relation to diagnostic domains with the goal of informing researchers about its functioning and promote consistency in its use with similar samples.

Method

Participants

In total, 350 children with ASD, drawn from two larger studies, participated in the present study. A subsample of 154 participants (M_{age} = 6.78, SD = 1.00; range = 4 – 9 years old) were recruited from a larger, cluster randomized trial of the Classroom SCERTS Intervention (CSI; Morgan et al., 2018), a comprehensive intervention promoting the active engagement of elementary students with ASD in the classroom. Measures included in this study were attained at baseline, prior to the start of intervention. The second subsample of 196 participants (M_{age} = 2.82, SD = 0.63; range = 2 – 4 years old) were recruited as part of the ongoing, prospective FIRST WORDS® Project (Delehanty, Stronach, Guthrie, Slate, & Wetherby, 2018; Dow, Guthrie, Stronach, & Wetherby, 2017; Wetherby, Brosnan-Maddox, Peace, & Newton, 2008), which screens for ASD and communication delays in primary care settings. The Florida State University Institutional Review Board approved this study. Research reliable diagnosticians administered the ADOS. A cognitive assessment (Mullen Scales of Early Learning [Mullen, 1995] or Stanford-Binet Intelligence Scale [Roid, 2003]) and an adaptive behavior measure (the Vineland Adaptive Behavior Scales [Sparrow, Cichetti, & Balla, 2005]) were also administered. All participants received a clinical diagnosis of ASD as determined by a clinical team that included both a speech-language pathologist and psychologist. Demographic information is summarized in Table 1.

Measures

Repetitive Behavior Scale-Revised (RBS-R; Bodfish, Symons, & Lewis, 1999; Bodfish et al., 2000).—The RBS-R is an informant-reported scale of RRB. Six conceptually derived subscales (Stereotyped Behavior, Self-Injurious Behavior, Compulsive Behavior, Ritualistic Behavior, Sameness Behavior, and Restricted Behavior) comprise 43 items assessing the reported severity of each behavior. Informants rate each behavior on a zero to three rating scale with “0” indicating the behavior does not occur and “3” indicating the behavior is a severe problem. The RBS-R was completed by the primary caregiver for all participants.

Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999, 2002).—The ADOS is the gold standard tool for assessing ASD symptomology. The semi-structured assessment examines social communication and RRB through a series of standardized activities and presses to derive two domain scores (RRB and Social Affect) and a total score. Because children in the current sample demonstrated variability with respect to age and communication ability at the time of evaluation, participants received different modules of the ADOS (Modules 1 – 3). To account for differences between modules, scores for the RRB and Social Affect domains as well as the Total score were converted into calibrated severity scores (CSS) based on previous validation studies (Gotham, Pickles, & Lord 2009; Hus, Gotham, & Lord 2014). CSS allow for comparisons with regard to severity of ASD symptomology across modules. A score of ten indicates greater severity of symptoms. Diagnostic characteristics of participants are summarized in Table 1.

Stanford-Binet Intelligence Scale-Fifth Edition (SB-5; Roid, 2003).—The SB-5 is a norm-referenced assessment of cognitive functioning designed for individuals ages 2 through 85. This measure was administered to children from the CSI group only (n = 154). An abbreviated IQ standard score was derived from the verbal and nonverbal routing tests of the SB-5. The SB-5 has been previously utilized in samples of children with ASD (e.g., Locke, Williams, Shih, & Kasari, 2017; MacDonald, Lord, & Ulrich, 2013; Samson, Hardan, Podell, Phillips & Gross, 2015).

Mullen Scales of Early Learning (MSEL; Mullen 1995).—The MSEL is a norm-referenced assessment of cognitive functioning in children from birth to age five. Participants from the FW group (n = 196) were administered the subscales assessing motor ability, visual reception, and language abilities to derive, the Early Learning Composite, an overall estimate of cognitive ability. The MSEL is a commonly used assessment in studies of young children with ASD (e.g., Morgan, Wetherby, & Barber, 2008; Wolff et al., 2014).

Vineland Adaptive Behavior Scales, 2nd Edition (VABS-II; Sparrow, Cichetti, & Balla, 2005).—The VABS-II is a structured interview with caregivers to examine adaptive behaviors associated with independence. Standard scores summarize adaptive functioning across four dimensions: Communication, Socialization, Daily Living Skills, and Motor Skills. Performance in the former three dimensions was of interest in the present study. Additionally, an Adaptive Behavior Composite is derived from the Communication, Socialization, and Daily Living Skills subscales to provide an estimate of an individual's overall adaptive functioning. The original validation of the VABS-II indicated good internal consistency, with reliability coefficients ranging from .87 – .93 for the age ranges similar to the current sample.

Analysis

Analyses were run using SPSS (IBM SPSS Statistics, IBM Corporation, Version 23) and Mplus 8 Software (Muthen & Muthen, 1998–2017). Descriptive information including analysis for missing data, frequency across responses categories and examination of distribution graphs were conducted for each item prior to employing CFA. Polychoric correlations were examined to assess if the pattern and strength of relation between items were in agreement with the currently specified model.

Confirmatory factor analysis.—Robust weighted least squares estimation (WLSMV) was implemented for the CFA. WLSMV is robust to violations of multivariate normality and is recommended for structural equation modeling with ordinal variables (Finney & DiStefano, 2013; Lei, 2009; Muthén, du Toit, & Spisic, 1997). This estimation method also performs well with smaller sample sizes (Flora & Curran, 2004). When covariates are present in the model using WLSMV estimation, missing data is a function of the covariates; however, pairwise deletion is the default when no covariates are in the model (Muthen & Muthen, 1998–2017). Pairwise deletion with WLSMV has been shown to compute parameters consistently with single level models (Asparouhaov & Muthén, 2010) Therefore, participants with missing data were retained in the data set.

Overall model fit was examined using commonly reported indices: the root mean square error of approximation (RMSEA), the comparative fit index (CFI), the Tucker-Lewis index (TLI), and the weighted root-mean-square residual (WRMR). Model fit indices under WLSMV perform similarly to maximum likelihood (ML) estimated indices when the number of item categories is four (Beauducel & Herzberg, 2006); therefore, the ML-based cutoffs described by Hu and Bentler (1999) were used for determining reasonable fit. RMSEA values less than 0.06 and CFI and TLI values greater than 0.95 indicate good fit. The WRMR index is specific to weighted least square estimation. A value of 1.0 is indicative of good model fit with dichotomous variables and sample sizes greater than 250 (Yu, 2002). Because the data were not normally-distributed, and models contained a large number of items, the estimated χ^2 goodness of fit statistic for each model was biased (see Finney & DiStefano, 2013); however, this was reported for all models in line with common practice. The DIFFTEST function in Mplus, which rescales the χ^2 values from each model prior (Brown, 2015), was implemented to compare differences between nested models.

Localized areas of strain in the final model were assessed through examinations of item factor loadings, factor correlations, and the residual correlation matrix. The residual correlation matrix represents the difference between the observed polychoric correlation matrix and the expected polychoric correlation matrix estimated by the model. Large residual correlations indicated poor item fit within the model; however, recommendations for cut-offs have not been established with WLSMV. To further assess model fit, models evidencing reasonable fit under WLSMV estimation were examined with full-information maximum likelihood (FIML) estimation using the ‘mirt’ package (Chalmers, 2012) in R version 3.5.1 ((http://cran.r-project.org/). The Metropolis-Hastings Robbins-Monro algorithm was implemented in model estimation given the high-dimensionality of the models in the present study (Cai, 2010). Two indices of fit were extracted: the Akaike information criterion (AIC) and the sample-size adjusted-Bayesian information criterion (BIC). Smaller values for each index are indicative of better fit.

Factor score estimation, convergent validity, and reliability.—Factor scores based on the results of the CFA were extracted using the FSCORES function in Mplus and correlated with related diagnostic measures. Sum scores aligning with the structure of the final model were computed and correlated with measures of cognitive functioning, RRB, and adaptive behavior. Differences in correlation coefficients with diagnostic measures were examined using the ‘cocor’ (Diedenhofen & Musch, 2015) package in R. Results were based on the approach recommended by Steiger (1980) for correlations from dependent samples. Scale reliability for each factor was estimated with the lower bound estimate approach recommended by Raykov (2001, 2004).

Models

Model composition in the present study were based on previous conceptualizations of RRB subtypes (see Leekam et al., 2011), previous validation studies (Bishop et al, 2013; Lam & Aman, 2007; Mirenda et al., 2010), the structure of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) criteria under the RRB domain of ASD (APA, 2013), and the original composition of the RBS-R.

Model I.—All items were loaded onto a single RRB factor, representing a unidimensional model of RRB.

Model II.—Factors for this model were based on previous conceptualizations of RRB subtypes as “lower level” and “higher level” behaviors (Leekam et al., 2011). Model II comprised a Lower Level factor (items 1 – 14) and a Higher Level RRB factor (items 15 – 43). This model is similar to the two-factor model tested by Mirenda et al. (2010); however, items from the original Restricted Interests subscale were loaded onto Higher Level RRB for this study as items were perceived as “higher level” repetitive behaviors.

Model III.—Model III comprised the same Higher Level RRB factor (items 15 – 43), a Stereotypic Behavior factor (items 1 – 6), and a SIB factor (items 7 – 14). The items regarding SIB were moved from the Lower Level factor into a SIB factor, as these behaviors were hypothesized to be conceptually distinct from the Stereotypic RRB.

Model IV.—Model IV comprised the same Stereotypic Behavior factor (items 1 – 6) and SIB factor (items 7 – 14) as well as a Compulsive/Ritualistic/Sameness factor (items 15 – 39) and a Restricted Interests subscale were loaded onto a Restricted Interests factor (items 40 – 43). The items from the original Restricted Interests subscale were separated from the Higher Level RRB factor in Model III because they are distinguished according to the DSM-5 criteria under the RRB domain of ASD (APA, 2013).

Model V.—This model replicates the five-factor solution examined by Mirenda and colleagues (2010) and is similar to the five-factor results reported by Lam and Aman (2007) and Bishop et al. (2013) studies. Model V comprised the same Stereotypic Behavior factor (items 1 – 6), SIB factor (items 7 – 14), Restricted Interests factor (items 40 – 43), as well as a Compulsive Behavior factor (items 15 – 22) and a Ritualistic/Sameness Behavior factor (items 23 – 39). Because of possible functional differences between compulsive behaviors and ritualistic and sameness behaviors, the Compulsive/Ritualistic/Sameness factor from Model IV was separated into two factors for this model.

Model VI.—The final model comprised six factors, one for each of the original six subscales on the RBS-R (Bodfish et al., 2000): Stereotypic Behavior factor (items 1 – 6), SIB (items 7 – 14), Compulsive Behavior (items 15 – 22), Ritualistic Behavior (items 23 – 29), Sameness Behavior (items 30 – 39), and Restricted Interests (items 40 – 43).

Results

Descriptive Data Results

A total of 11 (3.14%) participants were missing responses for one item, and a single participant (0.29%) was missing responses for two items. All items demonstrated responses across each of the four rating categories. Examination of item distributions revealed 11 of 43 items showed positively skewed distributions with estimates of skewness above 2.00. Kurtosis values above 2.00 were observed for 18 of the 43 items.

Confirmatory Factor Analysis—Results of overall fit across models are presented in Table 2. Model I, the general one-factor RRB model, provided the poorest fit to the data. All fit indices showed improvement with each successive model. Models II through VI demonstrated reasonable RMSEA values, though Models V and VI demonstrated the lowest values, indicating excellent fit. All models exhibited WRMR values above the 1.0. CFI and TLI values demonstrated acceptable fit for Models IV, V and VI. Across all pairs of nested models, the χ^2 difference test indicated significantly superior fit of the more complex model compared to the simpler, more restrictive model. Overall, WLSMV fit indices indicated Model VI was the statistically best fitting model. Models IV, V, VI were further examined with FIML estimation. AIC and adjusted-BIC values were lowest for Model V. Analysis of variance of FIML results indicated Model V fit indices were significantly lower compared to Model IV ($\chi^2 = 89.29$, $p < .001$), but not significantly different from indices for Model VI ($\chi^2 = -199.76$, p >.05).

While Models IV, V, and VI all demonstrated adequate-to-good fit, Model V was selected as the most parsimonious model for several reasons. First, Model V evidenced good fit for all model indices. The AIC and sample-size adjusted BIC values were lowest for Model V, and Model VI resulted in a factor correlation of 0.88 between the Sameness factor and Ritualistic Behavior Factor, indicating significant overlap between the two factors.

Item endorsements, standardized factor loadings, and item R^2 for Model V are summarized in Table 3. Item endorsement, defined as any non-zero rating, demonstrated wide variability, with the lowest endorsement for item 10 (Bites self) and highest for item 31 (Upset if interrupted). Overall, standardized factor loadings were large across each factor. The lowest factor loadings were observed for items 19 (.53) and 20 (.53). This pattern was also present in the item R^2 values with only 29% of the variance in both items being explained by the model. Correlations among factors are presented in Table 4. Large correlations between all factors in the model were observed. Examinations of the residual model correlation matrix indicated minimal differences between the observed and expected matrices for a majority of the items.

Reliability.: Reliability estimates and 95% confidence intervals are reported in Table 4. All factors demonstrated strong scale reliability, with highest estimate for Ritualistic/Sameness Behavior at .95 and the lowest for Stereotypic Behavior at .83.

Factor Score Estimation and Convergent Validity—Factor and summed scale score correlations with cognitive ability, ADOS RRB, and the VABS-II composite are presented in Table 5. Differences in correlation coefficients were significant with regard to the VABS-II composite across all factors. The extracted scores evidenced a slightly larger association relative to the summed scores. Regarding IQ and ADOS RRB, correlation coefficients for the extracted factor scores were observed to be significantly greater for the SIB, Compulsive Behavior, and Ritualistic/Sameness Behavior factors compared to the summed scores. Differences between score type for Stereotypic Behavior and Restricted Interests with regard to cognitive functioning and ADOS RRB were non-significant.

The largest correlations across both factor score types were observed for the VABS-II composite. All factors scores were also significantly associated with cognitive functioning, though these associations were small (ranging from r = −0.15 to −0.32). Ritualistic/ Sameness Behavior across both score types was not associated with ADOS RRB severity. For Compulsive Behavior and SIB, only the extracted factor scores were observed to be significantly associated with the ADOS RRB severity; however, these associations were also small in size (r = 0.13 and 0.14, respectively). Small, significant correlations with RRB severity on the ADOS were observed across both factor score types for both Stereotypic Behavior and Restricted Interests.

Discussion

This study sought to further validate the factor structure of the RBS-R in a community sample of children with ASD using a CFA approach designed for categorical items. To date, a single study has implemented CFA in a sample of preschool children with ASD (Mirenda et al., 2010). The present study utilized an alternate CFA approach (WLSMV) in a larger sample of young children with a broader age range. Consistent with previous work, results provided evidence for multiple constellations of RRB subtypes on the RBS-R, with a five-factor model being the most parsimonious solution. Results of the five-factor model evidenced high reliability across factors, negligible differences between extracted scores and summed scores, and small, but significant associations with diagnostic measures.

In agreement with the results reported by Mirenda et al. (2010), the present study provided strong evidence that the four-, five-, and six-factor models provided excellent fit across multiple indices. A promising result of the present study is the relatively superior fit of the models compared the fit of similar models examined in the Mirenda et al. (2010) study. This difference is likely due, at least partially, to the implementation of an alternate estimation method, but could also reflect differences in sample characteristics. The use of WLSMV was chosen as the more appropriate approach because it was expected to provide the least-biased measure of model fit given the categorical nature of the items on the RBS-R. Considering the categorical structure of the items is especially important considering a majority of the items evidenced a slight positive skew in the distribution of item responses, which could potentially lead to model misspecification with other approaches.

This study is also the first to report on indices of localized strain in the CFA, including factor loadings, item-level R^2, and residuals. The examination of these indicators is necessary to provide evidence for the absolute-fit of a model as complex models may produce acceptable overall fit indices when they are misspecified (Brown, 2015). The large factor loadings across factors, considerable R^2 values across items, and small residual correlations provide strong evidence that the five-factor model in this study is robust against this issue. The high scale reliability estimates provided additional support for this model structure.

Examining the influence of factor score approaches indicated that, statistically, the relationships with related measures may be slightly underestimated when using a summed score approach. However, as can be observed from this study, the differences between the two scoring approaches with regard to tertiary variables of interest were small and not practically significant. The differences between the scoring approaches are likely explained by the fact that summing item scores weights each item equally within the factor and does not account for measurement error in its computation. Conversely, more ‘refined’ methods (Distefano, Zhu, & Mîndrilă, 2009), such as the extracted factor scores estimated by Mplus, can account for these elements.

Every factor was significantly associated with cognitive functioning, with the strongest associations for Stereotyped Behavior and Restricted Interests. These results differ somewhat from the results of the Mirenda et al. (2010) which reported no relationship between this factor structure and their measure of cognitive functioning. Associations with the ADOS RRB domain score revealed significant correlations between three of the five factors (summed factor scores) and ADOS RRB CSS. This is similar to the results of Mirenda’s (2010) study, which reported a significant association between the ADOS RRB total score and RRB subtypes, though this was true for only two of the five factors (stereotyped behaviors and restricted behaviors). Across both studies, the largest association, albeit small to moderate, was observed for the stereotyped behavior subtypes, which likely reflects the composition and limited number of the ADOS RRB items. Largely consistent with previous research on these subtypes, the significant associations observed in this study were small in size across both cognitive ability and ADOS RRB, which may be an indication of the limitations of these measures.

Both studies observed correlations between all five RRB subtypes and the adaptive behavior composite of the VABS-II. While this may be due, in part, to the fact that the RBS-R and the VABS-II are both parent report measures, an etiological link between impaired adaptive behavior and the presence of RRB in ASD has been previously theorized (see Leekam, Prior, & Uljarevic, 2011). The associations between adaptive behavior and RRB in the present study reported larger associations compared to those in the Mirenda study, which may reflect differences in the estimation approach as well as the sample as a whole.

The validity of the RBS-R as a clinical diagnostic assessment for the RRB domain of ASD is unclear at this point. Others have recognized the potential of the RBS-R as a more ecological diagnostic measure of RRB in individuals with ASD and a tool for distinguishing RRB phenotypes in genetic research compared to the demands of the ADOS and ADI-R (Bishop et al., 2013). The convergent validity of the RBS-R with the ADI-R (Bishop et al. 2013) and research demonstrating significant differences between individuals with ASD and typically developing peers (e.g., Shephard et al., 2017; Van Eylen , Boets, Steyaert, Wagemans, & Noens, 2015; Wolff et al., 2014) and individuals with intellectual disability (e.g., Bodfish et al., 2000; Joseph, Thurm, Farmer, & Shumway, 2013) provides evidence of its potential diagnostic utility in conjunction with other gold standard measures. However, research on this topic is limited. Additional research examining the association of the RBS-R with diagnostic status that includes related disorders (e.g., obsessive-compulsive disorder) and younger individuals would further establish the diagnostic validity of this measure.

A strength of the RBS-R is its significant overlap with the four domains of RRB identified in the diagnostic criteria of ASD. Namely, the inclusion of ritualistic and sameness behavior, stereotypy, and restricted interests align with three of the four diagnostic RRB defined in the

DSM-5 (APA, 2013). Additionally, the RBS-R includes items relating to the fourth domain regarding unusual sensory interests, though these items are few in number and do not comprise their own subscale. The inclusion of SIB and compulsive behaviors on the RBS-R is an important consideration in this context as well. Although individuals with ASD demonstrate these behaviors, the presence of these behaviors is not specific to individuals with ASD and should be considered supplementary information, not clinically defining according to the DSM-5. Consideration of these factors is important when utilizing the RBS-R to characterize the RRB of autism populations within research studies.

Limitations

Limitations of this study must be considered. Despite the considerable sample size, the model may have been underpowered due to the large number of items and factors examined in the current study. Though a sample as low as 100 has been recognized as sufficient for WLSMV estimation (Flora & Curran, 2004), a ratio of 10 cases for each estimated parameter have been recommended as a minimally sufficient sample size in CFA (see Kline, 2011). Differences in the cognitive assessment instruments utilized for each subsample prevented the examination of differences in RRB between verbal and nonverbal cognitive ability. The underrepresentation of females in the present study also prevented investigation of differences in RRB by sex.

Implications for Future Research

The RBS-R continues to be one of few extensive measures of RRB that provides clinically relevant information regarding the topography and severity of this behavior in ASD. The results of this study are consistent with previous research supporting the presence of distinct subtypes of RRB on the RBS-R. Where appropriate, implementation of the five-factor subscale structure of the RBS-R in future research would allow for greater comparisons of results across studies. There are several directions of future research on the RBS-R worth pursuing. Additional examinations of the measure from an item response theory perspective may provide more insight into the functioning the RBS-R. Further investigation of various RRB structures across research contexts may provide additional insight identifying optimal frameworks. Continued exploration of the potential diagnostic validity of the RBS-R may lead to future contributions in the characterization of RRB in clinical research.

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Table 1

Sample Descriptive Statistics (*N* = 350)

Characteristic	Percent	Mean	SD
Age		4.56	2.13
Gender (male)	82.9		
Race			
White	70.6		
Black	16.0		
Asian	4.6		
Multiracial	8.6		
Not Reported	0.3		
Ethnicity			
Hispanic	16.6		
ADOS			
RRB CSS		7.53	1.87
Social Affect CSS		6.60	1.96
Total CSS		6.91	1.92
Cognitive Functioning			
Early Learning Composite† (*n* = 196)		74.62	22.64
Abbreviated IQ‡ (*n* = 154)		72.98	19.43
VABS-II			
Communication		80.38	13.86
Socialization		75.59	10.05
Daily Living Skills		79.73	11.88
ABC		76.60	10.55

Note. ADOS = Autism Diagnostic Observation Schedule; CSS = calibrated severity score; RRB = restricted and repetitive behaviors; VABS-II = Vineland Adaptive Behavior Scales; ABC = Adaptive Behavior Composite

†Mullen Scales of Early Learning.

‡Stanford-Binet Intelligence Scale.

Table 2

Indices of overall model fit

	χ^2	df	DIFFTEST	RMSEA	WRMR	CFI	TLI	AIC	aBIC	LL
Model I	1950.19	860	-	0.060	1.559	0.894	0.888	-	-	-
Model II	1538.78	859	81.88*	0.048	1.305	0.934	0.930	-	-	-
Model III	1477.28	857	29.26*	0.045	1.259	0.939	0.936	-	-	-
Model IV	1366.76	854	73.45*	0.041	1.176	0.950	0.947	23929.99	24052.33	−11787.00
Model V	1253.41	850	73.45*	0.037	1.087	0.961	0.958	23848.70	23958.18	−11742.35
Model VI	1224.88	845	29.02***	0.036	1.061	0.963	0.960	24056.46	24183.98	−11842.23

Note. RMSEA = root mean square error of approximation; WRMR = weighted root mean square residual; CFI = comparative fit index; TLI = Tucker-Lewis index; AIC = Akaike information criterion; aBIC = sample size adjusted Bayesian information criterion; LL = log likelihood value

*** $p < .001$.

Table 3

Item Endorsement, Standardized Item Factor Loadings, Item R^2

Item	Endorsement (%)	Stereotypic Behavior (Factor I)	SIB (Factor II)	Compulsive Behavior (Factor III)	R/S Behavior (Factor IV)	Restrictive Interests (Factor V)	R^2
1. Whole body stereotypy	30.0	0.75					0.56
2. Head stereotypy (n = 349)	30.9	0.70					0.49
3. Hand/finger stereotypy	54.9	0.69					0.47
4. Locomotive stereotypy	60.6	0.67					0.46
5. Object stereotypy	54.0	0.73					0.54
6. Sensory stereotypy	65.4	0.84					0.70
7. Hits self with body part	28.0		0.76				0.59
8. Hits self against surface	27.7		0.67				0.45
9. Hits self with object (n = 349)	16.0		0.90				0.81
10. Bites self (n = 349)	12.6		0.70				0.49
11. Pulls skin or hair	15.7		0.77				0.59
12. Rubs/scratches self	16.3		0.75				0.56
13. Inserts finger/object (n = 349)	13.5		0.71				0.51
14. Skin picking (n = 348)	17.5		0.60				0.36
15. Arranges/orders objects (n = 349)	47.6			0.68			0.47
16. Desires completeness	54.6			0.76			0.58
17. Excessive washing/cleaning	16.3			0.72			0.52
18. Repeated checking	14.9			0.57			0.33
19. Repeated counting	27.4			0.53			0.29
20. Hoarding/saving (n = 349)	19.5			0.53			0.29
21. Repetitious events	29.7			0.80			0.64
22. Touching/tapping (n = 349)	32.7			0.72			0.51
23. Ritualistic Eating	56.3				0.64		0.41
24. Ritualistic bedtime routines	55.4				0.68		0.47
25. Ritualistic self-care routines	27.1				0.73		0.53
26. Ritualistic travel routines	30.3				0.75		0.57
27. Ritualistic play/leisure	40.0				0.70		0.48
28. Ritualistic Communication	41.1				0.61		0.38

Item	Endorsement (%)	Stereotypic Behavior (Factor I)	SIB (Factor II)	Compulsive Behavior (Factor III)	R/S Behavior (Factor IV)	Restrictive Interests (Factor V)	R^2
29. Insists things remain same place	33.7				0.79		0.62
30. Objects to visiting to new places	30.0				0.71		0.51
31. Becomes upset if interrupted (n = 349)	70.2				0.78		0.60
32. Insists on walking in a pattern	15.4				0.67		0.45
33. Insists on sitting at same place	27.4				0.72		0.52
34. Dislikes appearance/behavior changes	27.1				0.75		0.57
35. Insists on particular door (n = 349)	27.2				0.77		0.60
36. Likes same music/videos (n = 349	61.0				0.73		0.53
37. Difficulties with transitions	62.6				0.80		0.64
38. Insists on same schedule (n = 349)	39.5				0.89		0.77
39. Insists specific times/places	25.7				0.84		0.70
40. Preoccupation with one subject	67.7					0.79	0.63
42. Preoccupation with parts of objects	44.6					0.79	0.62
41. Strongly attached to one object	52.9					0.79	0.62
43. Preoccupation with movement (n = 349)	44.7					0.84	0.71

Note. Endorsement represents any non-zero rating; SIB = Self-Injurious behavior; R/S = Ritualistic/Sameness

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Table 4

Model V factor correlations and reliability

	Stereotypic Behavior (Factor I)	**SIB (Factor II)**	**Compulsive Behavior (Factor III)**	**R/S Behavior (Factor IV)**	**Reliability ρ [95% CI]**
Factor I	-				.83 [0.78, 0.86]
Factor II	.77	-			.90 [0.87, 0.93]
Factor III	.79	.62	-		.87 [0.84, 0.90]
Factor IV	.62	.53	.84	-	.95 [0.94, 0.96]
Factor V†	.76	.65	.78	.79	.88 [0.85, 0.90]

Note. SIB = Self-Injurious Behavior; R/S = Ritualistic/Sameness

†Restricted Interests

Table 5

Summed and Extracted Factor Score Correlation Coefficient Comparisons

	IQ†	z	ADOS RRB	z	VABS-II ABC	z
Stereotypic Behavior						
Summed Score	−.32	−0.06	.20	0.18	−.48	2.60**
Factor Score	−.32		.20		−.52	
SIB						
Summed Score	−.15	3.46***	.08	−2.17*	−.39	5.58***
Factor Score	−.24		.14		−.48	
Compulsive Behavior						
Summed Score	−.18	2.75**	.08	−2.17*	−.36	4.13***
Factor Score	−.25		.13		−.46	
R/S Behavior						
Summed Score	−.14	2.63*	.03	−1.98*	−.36	2.46*
Factor Score	−.18		.06		−.40	
Restricted Interests						
Summed Score	−.24	1.39	.14	−0.49	−.36	4.89***
Factor Score	−.26		.14		−.44	

Note. ADOS = Autism Diagnostic Observation Schedule; RRB = restricted and repetitive behaviors; VABS-II = Vineland Adaptive Behavior Scales; ABC = Adaptive Behavior Composite; SIB = Self-Injurious Behavior; R/S = Ritualistic/Sameness

† Includes the Abbreviated IQ score and the Early Learning Composite

*** p <.001

** p < .01.

* p < .05.