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Executive and nonexecutive demands of constructional measures within a children's psychiatric inpatient setting

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ABSTRACT

This study examined the role of executive functioning in constructional task performance (measured with the Rey Complex Figure Test-Copy Condition [RCFT] and Beery-Buktenica Developmental Test of Visual-Motor Integration [Beery-VMI]) within a children's psychiatric inpatient setting. A chart review was conducted for 88 children (aged 6–12) who received a neuropsychological evaluation during a psychiatric inpatient hospitalization. Multiple regression analyses investigated the role of executive and nonexecutive demands on RCFT and Beery-VMI performance. Forty-three percent of the sample displayed a constructional weakness. Children with a constructional weakness had lower FSIQ scores and a higher rate of executive dysfunction. Performance on the RCFT was independently predicted by perceptual ability (i.e., Matrix Reasoning; $p = .008$; $\beta = .340$) and attention/executive dysfunction ($p = .003$; $\beta = -.342$; 9.4% of variance), while performance on the Beery-VMI was independently predicted by constructional ability (i.e., Block Design; $p = .004$, $\beta = .338$). Results of this study demonstrate that the RCFT has greater executive demand than the VMI and yields a greater rate of impaired performance in an inpatient child sample as compared to the VMI. Clinical and research practices should consider the distinct differences between various constructional measures to ensure their proper use and interpretation with consideration to their varying executive and nonexecutive demands.

KEYWORDS
Executive; neuropsychology; psychiatric; RCFT; VMI

Introduction

The Beery-Buktenica Developmental Test of Visual-Motor Integration (Beery-VMI; Beery & Beery, 2004) and Rey Complex Figure Test, copy condition (RCFT; Strauss, Sherman, & Strauss, 2006) are two highly valued tasks that are commonly used in pediatric practice to measure visual-constructional abilities (Akshoomoff & Stiles, 1995a, 1995b from Senese, Lucia, & Conson, 2015). Both the Beery-VMI and RCFT are complex drawing tasks that involve constructional, perceptual, spatial, and motor components (Baron, 2004; Fischer & Loring, 2004; Sutton et al., 2011). In addition, the Beery-VMI and RCFT are thought to contain demands on executive functions (EFs). Neuropsychologically, executive functions encompass a range of abilities that are required for goal-directed behavior including inhibitory control, working memory, and cognitive flexibility. Such functions are often related to planning, strategizing, organizing, and executing tasks.

A heuristic framework of executive functions argues for the discrimination between hot and cold EFs. Hot EFs are more likely to be elicited by problems that involve the regulation of affect, whereas cold EFs are more likely to be elicited by abstract, decontextualized tasks or problems. Measures of EF generally require a combination of hot and cold EF; however, objective measures of executive functioning that are common in neuropsychological practice typically assess cold EF processes. Alternatively, self-report measures also utilized to assess EF can provide insight into daily tasks and processes that are executively focused and affectively salient (i.e., hot executive functions).

Research on the neurocognitive, including the executive functioning, aspects of the Beery-VMI, is limited. Although some studies have used demographic

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and intellectual measures for predicting visual-motor integration ability (Di Blasi, Elia, Buono, Ramakers, & Di Nuovo, 2007; Memisevic & Sinanovic, 2012; Wuang, Wang, Huang, &, 2008), there is a sparse amount of research that utilizes or suggests the utility of executive measures as predictors of visual-motor integration. One study using the Beery-VMI found that parent-rated executive functions, specifically working memory and monitoring, were associated with Beery-VMI performance in a sample of children with intellectual disability (Memisevic & Sinanovic, 2012). Other studies have demonstrated no association between aspects of executive functions and performance on the Beery-VMI (Schultz et al., 1998). The relationship between executive functions and visual-motor integration is unclear, especially, given the confounding effect of intellectual functioning. As such, the Beery-VMI is more likely associated with broad intellect similar to other tests of visual-motor integration (e.g., clock drawing; Dilworth, Greenberg, & Kusché, 2004), but does not appear to be strongly associated with executive functioning.

More research has focused on the broader neurocognitive demands and executive demands of RCFT performance (Kirkwood, Weiler, Bernstein, Forbes, & Waber, 2001; Sami, Carte, Hinshaw, & Zupan, 2003; Schwarz, Penna, & Novack, 2009; Senese et al., 2015; Smith & Zahka, 2006; Watanabe et al., 2005). The RCFT is often used to assess visual-perceptual organization (Lezak, Howieson, & Loring, 1995; Waber & Holmes, 1986), visuospatial perception and orientation (Akshoomoff & Stiles, 1995a; Shorr, Delis, & Massman, 1992), and behavioral planning, organization, and sequencing (Deckersbach et al., 2000; Waber & Holmes, 1986). In one related study, measures of executive functions accounted for 11% of the variance in the copy trial of the RCFT (Schwarz et al., 2009). However, such findings are frequently related to the use of more executively-focused RCFT scoring criteria, such as the Developmental Scoring System (DSS; Bernstein & Waber, 1996) and Boston Qualitative Scoring System (BQSS; Stern et al., 1999). More traditional scoring systems such as the original 36-point scoring system (Osterrieth, 1944) and the revised 18-point Taylor scoring system (Duley et al., 1993) are most commonly used in clinical and research practices because they are well-defined, quantitative scoring approaches that yield greater reliability than more idiographic scoring systems such as the more recently proposed executively-focused qualitative scoring systems.

Although the RCFT and Beery-VMI are widely used, only a few studies to date have investigated the role of executive and nonexecutive skills in the drawing abilities of children, and have focused almost exclusively on the RCFT in normative child samples. Senese et al. (2015) investigated cognitive predictors of RCFT performance in a sample of 277 typically developing children between the ages of 7 to 10 and found that cognitive flexibility, working memory, visual perception, and mental rotation were all predictive of the RCFT copy condition. According to their study of a neurologic adult sample, Westervelt, Somerville, Tremont, and Stern (2000) summarized that higher order executive functions—namely planning and organization—directly impact copy performance and, subsequently, immediate recall performance on the RCFT. Deficits in attention, perception, or executive functioning were related to inadequate copy performance on the RCFT (Budd, Houtz, & Lambert, 2008). Interestingly, subsequent studies including the RCFT and Beery-VMI found that fine motor coordination was not associated with performance on either task (Klein, Guiltner, Sollereder, & Cui, 2011; Schwarz et al., 2009). There is a reciprocal link between environmental experiences and children's development of core neurocognitive capacities (Brocki & Bohlin, 2004). Children's construction skills are known to be impacted by exposure to trauma (e.g., De Bellis, Hooper, Spratt, & Woolley, 2009), while executive functions have been found to be impacted by institutionalization and post-institutionalization (e.g., Merz, Harlé, Noble, & McCall, 2016). Executive functions are impaired in many psychiatric disorders including addictions (Baler & Volkow, 2006; Smith et al., 2014), attention deficit hyperactive disorder (AD/HD; Diamond, 2005; Lui & Tannock, 2007), oppositional-defiant disorder/conduct disorder (Fairchild et al., 2009; Ogilvie et al., 2011), major depressive disorder (Taylor-Tavares et al., 2007), bipolar disorder (Snyder, Miyake, & Hankin, 2015), obsessive-compulsive disorder (Penades et al., 2007), and schizophrenia (Barch, 2005). Executive deficits have been identified in groups of individuals with panic disorder, social anxiety disorder, and generalized anxiety disorder (Airaksinen, Larsson, & Forsell, 2005; Mantella et al., 2007). Although not entirely conclusive, preliminary studies suggest that executive functions are impaired in persons with post-traumatic stress disorder (Polak et al., 2012). A meta-analytic review of childhood disorders by Willcutt et al. (2008) identify and highlight the significance of the executive functioning deficits associated with diagnoses of AD/HD, autism, and childhood onset schizophrenia. Although milder, associations between executive deficits and juvenile bipolar disorder, oppositional-defiant disorder/conduct disorder, and Tourettes syndrome and other tic disorders are also observed in children (Willcutt, Sonuga-Barke, Nigg, & Sergeant, 2008).

This study examined the neurocognitive correlates and psychiatric variables that may be implicated in construction abilities as determined by RCFT and Beery-VMI performance in preadolescent children (6–12) with severe childhood psychiatric disorders. Given the acuity of psychiatric illness, it was hypothesized that a large portion of the sample would display poor constructional abilities (indicated by a high degree of impaired scores). It was also hypothesized that constructional performance would be predicted by a combination of attention/executive and nonexecutive (e.g., visuo-spatial) domains, with RCFT performance better predicted by executive ability than VMI performance. Moreover, it was hypothesized that performance on the RCFT as compared to the Beery-VMI would be more strongly associated with psychiatric conditions that impact executive functioning including attention deficit hyperactive disorder (Diamond, 2005; Lui & Tannock, 2007), conduct disorder (Fairchild et al., 2009), depression (Taylor-Tavares et al., 2007), obsessive-compulsive disorder (Penades et al., 2007), and schizophrenia (Barch, 2005). The overall aim of this study is to strengthen our understanding of how visual-construction and drawing abilities in children may be implicated by neurocognitive and psychiatric variables.

Methods

Participants

IRB approval was obtained to conduct this medical chart review study. Two-hundred and thirty-eight children consecutively referred for a neuropsychological evaluation at a children's inpatient psychiatric program within a medical school-affiliated children's psychiatric hospital were considered for inclusion in the present study. Participants were generally referred for neuropsychological evaluation to characterize neurocognitive function and guide treatment planning.

The program admits children ages 3–12, although the majority of children referred for neuropsychological evaluation are 6–12 years of age. The inclusion criteria for the present study were 6–12 years of age at the time of the neuropsychological evaluation, sufficient information available in hospital medical records to extract key variables, a diagnosis of at least one psychiatric disorder by a hospital psychiatrist according to DSM-IV-TR or later DSM-5 criteria following psychiatric evaluation as part of the hospitalization (American Psychiatric Association, 2000, 2013), and completion of construction, motor/perceptual, and attention/executive measures utilized in the present study. Eighty-eight children met inclusion criteria (out of total 238, primarily due to low sample size of the CPT-II and WCST) and were included in this neuropsychology-referred group. All 88 children completed all tasks.

Neuropsychological evaluation within the inpatient program is typically initiated following the initial psychiatric evaluation and conducted over several sessions and/or days depending on the functioning of the child. A standard neuropsychological battery is administered by the clinical neuropsychologist, psychometrician, and/or graduate-level neuropsychology trainee. Age, sex, race, history of DCYF involvement, use of public insurance, and childhood maltreatment history were used to provide demographic information on the sample. Psychiatric variables included hospitalization length of stay (LOS; in days), status as new admission or re-admission to the hospital, the mean number of diagnoses, rate of diagnostic comorbidity, self-reported anxiety (Multidimensional Anxiety Scale for Children [MASC/MASC-2])/depression (Children's Depression Inventory [CDI/CDI-2]) symptoms and presence of specific psychiatric and neurodevelopmental disorders diagnosed during hospitalization. Mood disorders were categorized into Depressive Disorders (Major Depressive Disorder, Dysthymic Disorder, and Depressive Disorder Not Otherwise Specified), Bipolar Disorder, and (other) Mood Disorders (Mood Disorder Not Otherwise Specified and Disruptive Mood Dysregulation Disorder).

Information on medication status at the time of the neuropsychological evaluation was not available; however, medication status at the time of admission was utilized in the present study. The standard practice is for the children to take their medication as usual during their neuropsychological evaluation. Medications at intake were classified into mood stabilizers, anxiolytics, antipsychotics/atypical antipsychotics, antidepressants (SSRIs and others [e.g., bupropion]), and stimulants/nonstimulants (stimulants [e.g., methylphenidate] and nonstimulants [e.g., guanfacine]). Descriptive data on discharge diagnoses for the sample was also provided.

Neuropsychological measures

Wide range assessment of memory and learning-second edition

The Wide Range Assessment of Memory and Learning-Second Edition (WRAML-2; Sheslow & Adams, 2003) is a standardized test of memory functioning. Verbal attention span was assessed with Sentence Memory.

Wechsler scales

Intelligence was assessed with the Wechsler Abbreviated Scale of Intelligence (WASI-I/II; Wechsler, 1999;

Wechsler, 2011) or Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003). Block Design and Matrix Reasoning subtests from WASI/WASI-II/WISC-IV were used in the present study to assess perceptual reasoning abilities.

Cowat-fas

The Controlled Oral Word Association Test (COWAT) is a task of verbal fluency (Baron, 2004; Strauss et al., 2006). The phonemic condition, FAS, asks the participant to produce words starting with letters F, A, and S for 1 minute per letter. The current study utilized COWAT-FAS to assess verbal fluency.

Trail making test – b

The Trail Making Test-B is a task of attention, speed, and cognitive flexibility (TMT-B; Baron, 2004; Strauss et al., 2006). TMT-B was used in the present study to assess cognitive flexibility.

Stroop color and word test- children's version

The Stroop Color and Word Test-Children's Version (Golden, Freshwater, & Golden, 2003) is a commonly used measure to assess inhibitory control in children (Baron, 2004; Strauss et al., 2006). The Color-Word condition (Stroop C-W) assessed response inhibition in the current study.

Wisconsin card sorting test

The Wisconsin Card-Sorting Test (WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) is a test of executive function that assesses skills in abstraction, shifting and maintaining focus, goal orientation, and interference control (Baron, 2004; Strauss et al., 2006). The WCST-64 and WCST-128 are included in the current study. The standard neuropsychological battery included WCST-64 (manual administration) until early 2014, at which time the WCST-128 (computerized administration) became part of the standard battery. Therefore, a small subsample of the current study were administered the WCST-128 ($n = 24$). Analysis of variance between WCST-64 and WCST-128 on perseverative errors showed no significant group differences ($F(1,86) = 1.431$, $p = .235$). Perseverative Errors (WCST PE) standardized score (T-score) for WCST-64 or WCST-128 was utilized in the present study to assess cognitive flexibility.

Conners' continuous performance test

The Conners' Continuous Performance Test (CPT-II; Conners, 2000) is a measure of vigilance, attentional control and inhibition (Baron, 2004; Strauss et al., 2006). The Variability score was used in the present study as a gross estimate of overall sustained attention (Baron, 2004).

Rey complex figure test-copy condition

The Rey Complex Figure Test-Copy Condition is a drawing task with constructional, perceptual, spatial and executive components (RCFT; Baron, 2004; Strauss et al., 2006). As part of the clinical neuropsychological battery, the RCFT-Copy condition is scored using the standard Taylor Scoring Criteria (Kolb & Whishaw, 1990). The RCFT is a constructional task (Baron, 2004), yet it contains inherent perceptual/constructional and executive demands (Baron, 2004; Kavanaugh & Holler, 2015). As the purpose of this study is to examine its executive demands, it is utilized as a constructional measure.

Beery-buktenica developmental test of visual-motor integration

The Beery-Buktenica Developmental Test of Visual-Motor Integration- Fifth Edition is a task of visual-motor integration (VMI; Beery & Beery, 2004). The VMI was used in the present study as a measure of constructional ability.

Grooved pegboard

Grooved Pegboard assesses bilateral fine motor speed and dexterity (Strauss et al., 2006). The dominant hand performance was used in the present study to assess dominant hand fine motor skills.

Statistical methodology

Descriptive data (mean and standard deviation [*SD*]) were obtained for each neuropsychological measure. Presence of impairment was calculated for each score, defined as 1.5 *SD*s below the normative mean. Constructional impairment was defined as 2 + impaired construction scores (Beauchamp et al., 2015), while a less stringent constructional weakness was defined as 1 + impaired construction scores. Differences between constructional scores were assessed with paired *t*-tests. Executive dysfunction was defined as 2 + impaired range attention/EF scores (Beauchamp et al., 2015). An attention/executive dysfunction severity score (0–6) was calculated by summing each child's total number of impaired range scores (1.5 SD below mean) derived from attention (CPT-II Variability, Sentence Memory) and executive (WCST, COWAT-FAS, TMT, Stroop) measures. Point-biserial and Pearson analyses assessed associations between demographic/psychiatric variables and constructional performance.

In order to explore differences between children with constructional weaknesses and those without constructional weaknesses, the sample was dichotomized into those children with 1 + impairment range score on either RCFT or VMI ($n = 38$; 'Constructional Weakness Group') and those without any impaired constructional scores ($n = 50$; 'No Constructional Weakness Group'). ANOVAs and chi-squared analyses compared the two groups on relevant variables.

A series of multiple regression analyses examined the predictors of constructional performance. First, the constructional composite score served as the dependent variable, with demographic (age, sex, and number of diagnoses), motor/perceptual, and the attention/executive dysfunction severity score entered as independent variables. Next, individual tests of construction were examined. Myers (1990) suggests that Variance Inflation Factor values greater than 10 would indicate collinearity. Unless otherwise noted, multicollinearity (as assessed with VIF) was not detected in regression analyses.

Results

Group differences and descriptive statistics

Mean (*SD*) values and rates of impairment (1.5 *SD* below normative mean) are provided for each neuropsychological measure in Table 1. FSIQ is reported as a standard score, CPT-II, Stroop C-W, and WCST Perseverative Errors are reported as *t*-scores, COWAT-FAS, TMT-B, Grooved Pegboard, Beery VMI and RCFT scores are reported as z-scores, and remaining scores are reported as scaled scores. No significant skew or kurtosis was observed on any neurocognitive measures. Of the sample, 43.2% displayed 1 + impaired construction scores; 36.4% displayed impaired RCFT-Copy and 15.9% displayed impaired Beery-VMI.

Table 1. Mean, standard deviation (*SD*), and rates of impaired scores (<1.5 *SD* below normative mean) for neuropsychological measures.

	n	Mean (*SD*)	Impaired (%)
Overall Intelligence			
FSIQ	88	94.51 (12.86)	8.0
Constructional			
RCFT	88	−.99 (1.39)	36.4
Beery VMI	88	−.46 (1.07)	15.9
1 + Impairment Score	88	–	43.2
2 + Impairment Scores	88	–	9.1
Motor/Perceptual			
Block Design	88	8.90 (2.74)	6.8
Matrix Reasoning	88	9.59 (2.87)	12.5
Grooved Pegboard	88	−.68 (1.85)	19.3
Attention Span/Sustained Attention			
Sentence Memory	88	9.34 (2.55)	4.5
CPT-II Variability	88	58.34 (9.19)	26.1
Executive Functioning (EF)			
COWAT-FAS	88	−.47 (1.03)	15.9
TMT-B	88	−.46 (1.25)	18.2
Stroop C-W	88	37.85 (10.80)	37.5
WCST Perseverative Errors	88	51.11 (16.19)	15.9
1 + Impaired Attention/EF Score	88	–	63.6
2 + Impaired Attention/EF Scores	88	–	31.8

The majority of psychiatric/demographic variables were not associated with constructional performance. Only ADHD, public insurance, and Department of Children, Youth and Families (DCYF) involvement were correlated, and these variables were subsequently loaded into the regression models. Results are provided in Table 2. Paired *t*-tests indicated that Beery VMI was significantly higher than RCFT performance ($t = 3.424$; $p = .001$).

Constructional weakness group differences

The Constructional Weakness and No Constructional Weakness Groups did not differ significantly on the majority of variables. However, the Constructional Weakness Group displayed lowered FSIQ and a higher rate of executive dysfunction. Results are provided in Table 3.

Primary regression analyses

A multiple regression was run to predict RCFT performance from the attention/executive dysfunction

Table 2. Bivariate correlations between medications, demographic/psychiatric variables, diagnoses, and constructional performance (*r* values).

	RCFT	Beery VMI
Medications		
Stimulant/Nonstimulant	−.20	−.16
Antidepressant	.17	−.01
Mood Stabilizer	−.13	−.06
Antipsychotic	−.18	−.06
Demographic/Psychiatric		
Age	−.02	−.16
% Male	−.02	.06
% Public Insurance	−.22*	−.15
% White	−.03	−.07
% DCYF	−.11	−.24*
Length of Stay	−.20	−.13
MASC/MASC-2	.09	.04
CDI/CDI-2	.07	−.05
Discharge Diagnoses		
# of Diagnoses	.02	−.18
Depression	.10	−.03
Anxiety	.18	.06
Other Mood	−.11	−.10
Behavioral	.07	.01
Adjustment	.07	.04
Bipolar	−.07	.03
Psychosis	−.21	−.13
Language	.04	.08
Tic	−.03	−.15
Learning	−.12	−.03
ADHD	−.16	−.23*

Note. *$p < .05$.

Table 3. Demographic and psychiatric information for constructional weaknesses and no constructional weaknesses groups.

	n	Weakness Group (*n* = 38)	No Weakness Group (*n* = 50)	F/X²
Demographic				
Age				
% Male	88	9/38	17/50	1.104
% DYCF	88	20/36	20/47	1.380
Maltreatment Hx	86	21/36	28/50	.046
% Caucasian	70	20/29	20/41	2.826
% Public Insurance	84	26/38	27/46	.845
Psychiatric/Cognitive				
Readmission	86	12/36	17/50	.004
CDI/CDI-2	77	61.18 (12.30)	64.75 (14.48)	1.299
MASC/MASC-2	81	52.94 (11.84)	55.87 (10.77)	1.348
Length of Stay	86	23.50 (14.35)	20.42 (17.83)	.732
FSIQ	88	91.11 (13.30)	97.10 (12.00)	4.900*
% EF Dysfx	88	19/38	9/50	10.191**
Discharge Diagnoses				
# of Dx				
ADHD	88	30/38	35/50	.895
Depression	88	5/38	11/50	1.135
Bipolar	88	2/38	1/50	.698
Other Mood	88	21/38	22/50	1.096
Anxiety	88	17/38	31/50	2.595
Behavioral	88	6/38	8/50	.001
Adjustment	88	4/38	7/50	.238
Psychotic	88	1/38	0/50	1.331
PDD/ASD	88	1/38	1/50	.039
Learning Disorder	88	2/38	2/50	.079
Language Disorder	88	3/38	4/50	.000
Tic Disorder	88	2/38	2/50	.079
Intake Medications				
Stim/Nonstim	86	18/36	22/50	.303
Antidepressant	86	5/36	16/50	3.720
Antipsychotic	86	10/36	13/50	.034
Mood Stabilizer	86	4/36	5/50	.028

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

severity score after controlling for age, sex, ADHD, public insurance, and DCYF involvement, as well as perceptual/motor performance. The overall model was statistically significant, $F(9,69) = 3.588$, $p = .001$, $R^2 = .319$. Matrix Reasoning ($p = .008$; $\beta = .340$) and the attention/executive dysfunction severity score ($p = .003$; $\beta = -.342$; 9.4% of variance) independently predicted

Table 4. Multiple regression analysis of the predictors of construction composite score.

	RCFT			Beery VMI		
	R^2 Change	β	*p*	R^2 Change	β	*p*
Step 1	.090		.217	.182		.011
Age		−.039	.736		−.268	.016
Sex		−.003	.981		.060	.590
ADHD		−.231	.063		**−.284**	.016
Public Insurance		−.148	.230		−.027	.820
DCYF		−.002	.987		−.161	.155
Step 2	.134		.010	.198		<.001
Block Design		.099	.443		**.338**	.004
Matrix Reasoning		**.340**	.008		.218	.054
Grooved Pegboard		−.008	.953		−.007	.947
Step 3	.094		.003	.004		.496
Atten/Executive Dysfx Severity		**−.342**	.003		−.072	.496

Note. $n = 79$. *p* reflects the *F* Change *p* value.

RCFT performance. A multiple regression was run to predict Beery-VMI performance from the attention/executive dysfunction severity score after controlling for age, sex, ADHD, public insurance, and DCYF involvement, as well as perceptual/motor performance. The overall model was statistically significant, $F(9,69) = 4.779$, $p < .001$, $R^2 = .384$. ADHD ($p = .016$; $\beta = -.284$) and Block Design ($p = .004$; $\beta = .338$) independently predicted Beery VMI performance. Results are provided in Table 4. All analyses had VIF scores 2.

Discussion

In the present study attention/executive (attention span, sustained attention, inhibitory control, cognitive flexibility, and problem solving) and nonexecutive (perception, fine-motor dexterity, and block construction) abilities were systematically evaluated to better understand the neurocognitive predictors of constructional impairment as defined by the RCFT and the Beery-VMI. A sample of 88 children referred for neuropsychological evaluation during an inpatient psychiatric hospitalization was utilized to determine the psychiatric and cognitive variables associated with visual-construction ability. Prior research suggests that the RCFT contains distinct executive demands (e.g., Schwarz et al., 2009), while similar studies on the Beery-VMI remain inconsistent (Memisevic & Sinanovic, 2013; Schultz et al., 1998). As such, it was hypothesized that executive dysfunction would be more strongly related to RCFT impairment than to Beery-VMI impairment.

As expected, RCFT impairments were more pronounced; 36.4% of the sample displayed RCFT impairment (>1.5 *SD* below mean), while 15.9% displayed VMI impairment (>1.5 *SD* below mean). Forty-three percent of the total sample of children displayed constructional weaknesses, consistent with prior research on constructional impairments in childhood psychiatric and neurodevelopmental disorders (Daniels & Ryley, 1991; Kaslow, Tanenbaum, Abramson, Peterson, & Seligman, 1983; Schultz et al., 1998; Sutton et al., 2011; Waber & Bernstein, 1995). Children who demonstrated a constructional weakness had higher rates of executive dysfunction and lower overall FSIQ composite scores as compared to the children who did not demonstrate constructional weaknesses. These results provide support for an association between constructional abilities and executive and intellectual functioning (Memisevic & Sinanovic, 2013).

To further explore this association between executive functioning and construction, we examined the predictive utility of executive and nonexecutive variables in constructional performance. In the present study there was notable variability in the association of executive and nonexecutive variables to constructional performance. Only block construction significantly predicted constructional performance as measured by the Beery-VMI. Alternatively, perceptual reasoning and attention/executive dysfunction significantly predicted constructional performance as measured by the RCFT, with attention/executive dysfunction accounting for 9.4% of RCFT performance variance. Results provide consistent evidence that the Beery-VMI is strongly associated with another measure of construction (i.e., block construction), whereas RCFT is more closely linked with perceptual and attention/executive domains. These results highlight critical distinctions between the Beery-VMI and the RCFT in that the RCFT has greater executive demand than the Beery-VMI, as is consistent with past studies (Schwarz et al., 2009; Senese et al., 2015).

Overall results of this study support findings from previous research, which argue that the RCFT has greater executive demand than the Beery-VMI (Schwarz et al., 2009; Senese et al., 2015). Although previous studies have demonstrated an association between Block design, visual-motor integration tasks, and the RCFT-copy trial (Senese et al., 2015; Weber, Riccio, & Cohen, 2013), the present study did not find a strong association between block construction and RCFT performance. Poor performance on the Beery-VMI was associated with ADHD diagnoses. Several studies on children with attention-deficit hyperactivity disorder (ADHD) as a single diagnosis (Kaiser, Schoemaker, Albaret & Geuze, 2015; Tseng, Henderson, Chow, & Yao, 2004) suggest an association between ADHD diagnosis and poor fine motor and graphomotor skills, that are improved with appropriate stimulant medication treatments (e.g., methylphenidate; Tucha & Lange, 2001).

The current study had several limitations. The sample size was relatively small, with uneven distribution among core demographic variables such as sex (where 70% of the entire neuropsychology-referred sample was male). Given the retrospective nature of this study, data extraction was limited to available variables, and some children were excluded due to incomplete data. Participants in the current study were those clinically referred for neuropsychological evaluation during their psychiatric hospitalization and may not reflect the entire inpatient population. Only 37% of the children referred for a neuropsychological evaluation in this setting were able to complete all portions of the neuropsychological battery required for this study. Given the high rate of noncompletion for children in an inpatient psychiatric hospital, it is important to consider the possibility that impaired performance on any one of a variety of measures could be due to undefined psychiatric causes (e.g., malingering, variable effort, frustration, or other behavioral responses). The degree to which executive functioning can account for the variability in RCFT performance is variable between different populations (Schwarz et al., 2009), and may be impacted by minor distinctions between various clinical and nonclinical groups. Prior literature on the RCFT suggests that executive functioning impacts performance in an additive way, such that deficits in multiple executive domains (e.g., planning, organization, sequencing, flexibility) impact performance more greatly than a stronger deficit in just one executive domain. As such, future studies should consider the effects of distinct executive domains on various graphomotor tasks. Future studies may also wish to compare clinical versus nonclinical populations to determine the generalizability of our findings in children with less severe psychopathology. Additionally, given the developmental trends of executive functioning that persist well beyond adolescence and into adulthood, future studies may wish to look at different age cohorts to determine whether the executive demands of the RCFT are upheld throughout the lifespan, as well as what possible age effects may exist for other graphomotor construction measures including the Beery-VMI.

Overall, the results of this study argue that the RCFT and Beery-VMI are distinct graphomotor tasks that should not be substituted in clinical practice and their distinct differences should not be overlooked. Failure to acknowledge the executive aspects of the RCFT that are not consistent across all constructional tasks including the Beery-VMI may yield interpretive errors in neuropsychological evaluations. Moreover, simply choosing to use one constructional measure—as is often the case in neuropsychological practices given the pressures of time—requires that practitioners evaluate the underlying neurocognitive correlates of that measure to accurately define the measure and its interpretive standards. As such, the RCFT may be a more effective measure when assessing executive aspects of construction such as perception, planning and organization, and spatial awareness, while the Beery-VMI may be a more effective measure when assessing pure graphomotor ability.

Disclosure of interest

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