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Validity of the behavior rating inventory of executive function in children with ADHD and/or Tourette syndrome[☆]

E. Mark Mahone^{a,b,*}, Paul T. Cirino^{a,b}, Laurie E. Cutting^{a,b},
Paula M. Cerrone^{a,b}, Kathleen M. Hagelthorn^{a,b}, Jennifer R. Hiemenz^{a,b},
Harvey S. Singer^{a,b}, Martha B. Denckla^{a,b}

^a*Department of Neuropsychology, Kennedy Krieger Institute, 1750 East Fairmount Avenue,
Baltimore, MD 21231, USA*

^b*Johns Hopkins University School of Medicine, Baltimore, MD, USA*

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Abstract

The dynamic, multidimensional nature of executive function (EF), thought to be characteristically impaired in those with attention deficit hyperactivity disorder (ADHD), has been challenging to operationalize and assess in a clinical setting [Barkley, R. A. (1997). *ADHD and the nature of self-control*. New York: Guilford Press.]. Gioia, Isquith, Guy, and Kenworthy [Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000) *Behavior Rating Inventory of Executive Function*. Odessa, FL: Psychological Assessment Resources.] developed the Behavior Rating Inventory of Executive Function (BRIEF) to address these concerns. In order to provide concurrent validity information on the BRIEF, parents of 76 children (ADHD = 18; Tourette syndrome (TS) = 21; TS + ADHD = 17; controls = 20) completed the BRIEF, additional behavior rating scales and interviews, measures of psychoeducational (PE) competence, and performance-based measures of EF. Both ADHD and TS + ADHD groups were rated as more impaired ($P < .0001$) than the other groups on the five primary BRIEF indices. BRIEF index scores showed no significant correlation with performance-based EF or PE measures, with the exception of math achievement; however, the BRIEF showed a strong relationship with interviews and other parent rating measures of behaviors seen in ADHD. Future attempts to validate the BRIEF should

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* Corresponding author. Tel.: +1-410-502-9442; fax: +1-410-502-8196.

E-mail address: mahone@kennedykrieger.org (E.M. Mahone).

focus on differences within subtypes of ADHD (e.g., inattentive, combined subtypes), and separating ADHD from other clinical groups in which EF is reported to be a problem.

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1. Introduction

Executive function (EF) is a term used to refer to self-regulatory behaviors necessary to select and sustain actions and guide behavior within the context of goals or rules. In essence, EF involves developing and implementing an approach to performing a task that is not habitually performed. Initiation, planning, shifting of thought or attention, organization, inhibition of inappropriate thought or behavior, and efficiently sustained and sequenced behavior are crucial elements of the EF construct. Inhibition (Barkley, 1997, 2000) and working memory (Pennington, 1997) appear to be fundamental subsystems involved in the development of EF competence. EF is viewed as being supported by a distributed neural network with cortical and subcortical components (Denckla, 1996a; Denckla & Reiss, 1997). This network supports “how and when” functions that range from the more elementary “boredom tolerance” to higher-order problem solving functions. Integrity of these functions is considered critical for compensation of deficits in other domains such as language or visuospatial skills; as such, the relationship between EF measures and “real life” behavior is critical.

Executive dysfunction (EdF) is a characteristic feature in a variety of clinical disorders in children (e.g., Barkley, 1998; Denckla, 1994, 1996a; Pennington & Ozonoff, 1996). Attention deficit hyperactivity disorder (ADHD) and Tourette syndrome (TS) have been of interest for investigators of EdF (Cirino, Chapieski, & Massman, 2000; Harris et al., 1995; Mahone, Koth, Cutting, Singer, & Denckla, 2001; Pennington & Ozonoff, 1996; Schuerholz, Baumgardner, Singer, Reiss, & Denckla, 1996) because both are presumed to be symptomatic of anomalous basal ganglia–thalamo-cortical loops that involve the prefrontal cortex (Baxter, Schwartz, Guze, Bergman, & Szuba, 1990; Denckla & Reiss, 1997), and poor performance on measures that involve novelty, planning, inhibition, organization, and other EF features is characteristic of individuals with damage to circuits that involve the prefrontal regions (Cummings, 1993; Levin et al., 1991; Lou, Anderson, Steinberg, McLaughlin, & Friberg, 1998; Lou, Henriksen, & Bruhn, 1984).

In studies of children and adults with ADHD, there is consistency in the presence of difficulties in sustained attention (Harris et al., 1995; Levy & Hobbes, 1997), and several investigators have found deficits in one or more areas of EF (Aman, Roberts, & Pennington, 1998; Grodzinsky & Diamond, 1992; Reader, Harris, Schuerholz, & Denckla, 1994). Mahone, Hagelthorn, et al. (1999) found significant differences between ADHD and controls on tests of variables of attention—visual (TOVA-V) commissions and response variability, but only for children with average IQ, contrasted to those with high average and/or superior IQ. Lovejoy et al. (1999) attempted to use measures of EF to predict diagnostic classification in ADHD, and found that, while rates of positive predictive power were high, false negatives were also common. This finding suggests that, although performance-based measures of EF may be

sensitive, there is more question about their specificity (Gordon & Barkley, 1998; Grodzinsky & Barkley, 1999).

Problems with attention may not be the central deficit in ADHD. Barkley (1997, 1998, 2000) has argued that the cardinal feature of ADHD is EdF, especially difficulties with inhibitory control in the combined type. Others note that “intention” systems dependent on the integrity of frontal–striatal brain systems (including response preparation and inhibitory control), rather than “attention” systems (e.g., sustained, selective), represent the salient areas of deficit (Denckla, 1994, 1996a; Heilman, Voeller, & Nadeau, 1991). These theoretical formulations have been well grounded but somewhat difficult to operationalize. Researchers are only now beginning to examine these patterns of deficits according to theoretical frameworks.

Studies involving individuals with TS have only recently begun to examine the role that comorbid ADHD plays in the manifestation of EdF in children with TS (Yeates & Bornstein, 1994). For example, children with ADHD and TS demonstrate slow and variable reaction time on the TOVA-V (Harris et al., 1995; Shucard, Benedict, Tekok-Kilic, & Lichter, 1997). Cirino et al. (2000) found that children with TS only did not differ from children with both TS and ADHD on two card sorting tasks. On one of these tasks [Wisconsin Card Sorting Task (WCST)—perseverative errors], the performances of the TS + ADHD and TS-only groups were within the average range. Mahone, Koth, et al. (1999) found that although their TS-only group outperformed their TS + ADHD group on the Letter Word Fluency (LWF) task, there were few differences between children who had ADHD only and those with both TS and ADHD. Mahone et al. (2001) found significant differences between children with TS only and a control group on CVLT-C intrusions, with the TS-only group having more difficulty. This pattern was also present in other studies on the WCST (e.g., Harris et al., 1995) and letter fluency (Schuerholz et al., 1996; Sutherland, Kolb, Schoel, Whishaw, & Davies, 1982). In their review of EdF among a variety of developmental disabilities including TS, Pennington and Ozonoff (1996) concluded that, while the evidence for EdF in some populations (e.g., autism) was high, there was less conclusive evidence for these deficits in TS, especially when TS was unaccompanied by ADHD.

Despite the hypothesized role of EdF in ADHD and/or TS, laboratory or performance-based measures, when used alone, have been inconsistent and difficult to characterize in their prediction of group differences (Grodzinsky & Barkley, 1999; Pennington & Ozonoff, 1996; Rice & Weyandt, 2000). The inconsistency of findings and frequent failure of performance-based EF measures to discriminate clinical groups from controls may be attributed to a variety of factors, including diverse and imprecise definitions of EF (Barkley, 1997; Denckla, 1996b), variability in criteria used to define experimental populations with ADHD (National Institutes of Health, 1998), dosing and effects of stimulant medicines during testing (Nigg, Hinshaw, & Halperin, 1996; O'Toole, Abramowitz, Morris, & Dulcan, 1997), as well as the developmental relationship between measures of EF and sex (Grodzinsky & Diamond, 1992; Seidman et al., 1997), EF and IQ (Arffa, Lovell, Podell, & Goldberg, 1998; Dodrill, 1997), and EF and age (Welsh & Pennington, 1988; Welsh, Pennington, & Groisser, 1991). In addition, the highly structured clinical testing setting may not place a high-enough demand on EF because of the external constraints and supports necessarily imposed on the child by the examiner (Bernstein & Waber, 1990). Some investigators have argued that valid

performance-based measures of EF may have lower reliability as a result of their format, which necessarily involves novelty. Despite these latter difficulties, there has been some recent support recently for the separation between performance-based measures of EF and IQ measures (Ardila, 1999) and other frequently used measures of psychological functioning (Ardila, 2000).

Given the difficulties in using only performance-based measures of EF, there has been increased interest in methods to improve the ecological validity of comprehensive neuropsychological assessments (Sbordone, 1996, 2000). In clinical practice with children, many providers use both performance-based tests and caregiver rating scales in their diagnostic formulations (e.g., Cripe, 1996). While rating scales that assess a wide range of behavioral problems and adaptive skills in children are common (Achenbach, 1991; Conners, 1997; Reynolds & Kamphaus, 1992; Sparrow, Balla, & Cicchetti, 1984), few specifically address the construct of EF. Gioia, Isquith, Guy, and Kenworthy (2000b) were among the first to develop a rating scale designed specifically to assess the EF construct in children. The Behavior Rating Inventory of Executive Function (BRIEF) is a parent or teacher report measure designed to address the multidimensional nature of the EF construct. The BRIEF assesses eight theoretically and statistically derived subdomains of EF. It was designed to be used for a wide range of childhood disorders in order to augment traditional clinic-based assessments, and to provide an increased level of ecological validity for clinical assessments (Rabbitt, 1997). Given the theoretical importance of EdF to ADHD in particular, the BRIEF also has scales similar in concept to, but different in content from, the DSM-IV (American Psychiatric Association, 1994) diagnostic criteria for ADHD, as well as two scales developed to be useful in differentiating the diagnostic subtypes of ADHD. Specifically, the Working Memory and Inhibit scales are considered by the authors of the BRIEF to have the greatest overlap with diagnostic criteria for inattentive and hyperactive-impulsive types of ADHD, respectively (Gioia et al., 2000b).

We explored the convergent and discriminant validity of the BRIEF in children with TS and/or ADHD by administering the BRIEF Parent Form along with a selected set of both broad-band and ADHD-specific behavior rating scales, as well as performance-based measures of EF and traditional measures of intellectual and educational competence. Four primary hypotheses were explored in the present study. First, review of the ADHD and TS literature suggests that children with ADHD may exhibit deficits in some aspects of EF, regardless of the presence of TS. Children with TS only may in turn exhibit only subtle differences in EF functioning relative to controls. Therefore, we hypothesized that children with ADHD would be rated as more impaired by parents on the BRIEF than children without ADHD, regardless of comorbid TS status. Secondly, we also hypothesized that the TS-only group would be rated by parents as having more EF difficulties on the BRIEF than a control group. Third, given the reported separation of IQ and EF constructs, we hypothesized that parent ratings on the BRIEF would be more strongly correlated with performance-based measures of EF (given the same construct) than with general intellectual and academic measures. Finally, because of the reported overlap in behavioral symptomatology between ADHD and EF, we hypothesized that the BRIEF (in particular, the Working Memory and Inhibit scales) would be significantly correlated with other parent ratings of behavioral disturbance, particularly symptoms of ADHD.

2. Method

2.1. Participants

Seventy-six children were research participants for this study, and were also participants in a larger study of developmental pathways to learning disabilities. Children were included if they were between the ages of 6 and 16, and had no history of seizures, head injury, or other neurologic illness. Clinical participants were recruited for the study via flyers sent to local clinicians, and from clinics at a large university-affiliated medical center outpatient department. Among clinical groups, diagnosis of ADHD was made after participants met the following criteria: (1) identification and referral by professionals (psychologists, psychiatrists, pediatricians, and neurologists) in the local community as having a current diagnosis of ADHD; (2) independent DSM-IV diagnosis of ADHD (any type) based on interview at the time of testing; and (3) parent rating of 2 or higher (on a four-point Likert scale ranging from 0 to 3) for six of nine items assessing inattention and/or six of nine items assessing hyperactivity–impulsivity on the ADHD Rating Scale IV (DuPaul, Power, Anastopoulos, & Reid, 1998). Diagnosis of TS was made by a pediatric neurologist (HSS) on the basis of The Tourette Syndrome Classification Group (1993) criteria. In order to be included in the TS group, children had to manifest all the following symptoms: (1) onset of tic symptoms before age 21, (2) multiple motor tics, (3) one or more vocal tics, (4) tic frequency that changes over time, (5) duration of tic symptoms greater than 1 year, (6) tics not secondary to other medical conditions, and (7) tics are witnessed by a reliable observer. Overall, tic severity was reported to be mild to moderate in the TS group sample, although individual measurement of tic severity was not obtained.

Control participants were recruited through parents of the children in the clinical groups using a “snowball” technique, similar to that described in published studies (e.g., Fischer, Barkley, Edelbrock, & Smallish, 1990). Control group participants ($n = 20$) included nine unaffected siblings from projects involving genetically based disorders (Fragile X, Neurofibromatosis Type 1, and Turner syndrome), and unrelated controls recruited from the larger community.

There were a total of 18 children in the ADHD-only group (age range 7–15), 21 in the TS-only group (age range 7–14), 17 in the TS + ADHD group (age range 6–16), and 20 controls (age range 6–16). None of the children in the two TS groups had previous diagnosis of comorbid obsessive–compulsive disorder (OCD), while only one of the children in the ADHD group had been previously diagnosed with OCD. The ADHD-only group included 7 children with predominantly inattentive and 11 children with either hyperactive–impulsive or combined-type ADHD, as defined by pattern of caregiver responses on the ADHD Rating Scale IV Home Version. Using the same criteria, the TS + ADHD group included 12 children with inattentive-type patterns and 5 with either hyperactive–impulsive or combined-type patterns.

2.2. Procedures

Participants completed the performance-based measures in 1 day as part of a larger battery of neuropsychological tests. Evaluators were blind to subject diagnosis. All participants (control and clinical groups) were administered the same tests and were rated on the same rating scales.

Parents completed rating scales and a structured diagnostic interview at the time of their child's testing. Participants were not on stimulant or tic-suppressing medication at the time of testing. None of the children in the study was noted to have tic behavior or hyperactivity that interfered with test validity.

2.3. Rating scales and structured interview

2.3.1. BRIEF Parent Form (Gioia et al., 2000b)

The BRIEF Parent Form consists of 86 items sampled from practicing neuropsychologists, based on theoretical and empirically based definitions of the EF construct. Parents rate their child's behavior on a three-point Likert scale (never, sometimes, and often). Eight scales are obtained (Initiate, Working Memory, Plan/Organize, Organization of Materials, Monitor, Inhibit, Shift, Emotional Control), along with a Metacognition Index (MCI), Behavior Regulation Index (BRI), and a Global Executive Composite (GEC). Higher ratings are indicative of greater perceived impairment. The BRIEF Parent Form was normed on 1419 control children and 852 children from referred clinical groups. Factor analytic studies of the normative sample support the existence of two underlying factors, which have been used to develop the MCI and BRI (Gioia, Isquith, & Guy, 2000a). Mean internal consistency ratings reported for clinical populations using the BRIEF Parent Form range from .82 to .98. Three-week test–retest correlations for clinical populations on the Parent Form range from .72 to .84. For purposes of this study, the three main index scores (GEC, BRI, and MCI) were chosen for analysis. Two diagnostic scales (Working Memory and Inhibit) were also analyzed because of their presumed overlap with diagnostic criteria for inattentive and hyperactive–impulsive types of ADHD, respectively (Gioia et al., 2000b). Examples of items from the Working Memory scale include: “forgets what he/she was doing,” or “has trouble remembering things, even for a few minutes.” Items from the Inhibit scale include: “talks at the wrong times” and “gets out of control more than friends.”

2.3.2. ADHD Rating Scale IV—Home Version (DuPaul et al., 1998)

This is an 18-item scale (nine inattention items and nine hyperactivity–impulsivity items) linked to DSM-IV diagnostic criteria for ADHD, and completed by parents describing the child's behavior over the past 6 months. Responses are coded on a four-step Likert scale from “not at all” to “very much.” The normative sample consisted of 2000 children selected to approximate the 1990 US census data. Four-week test–retest reliability is reported to be .78 for the inattention score, .86 for the hyperactivity–impulsivity score, and .85 for the total score. The ADHD Rating Scale IV is noted to have strong correlation with the Conners' Parent Rating Scales as well as prediction of teacher observations of hyperactivity and inattention (DuPaul et al., 1998). The dependent measures were the number of items rated “2” or higher on the each of the two subscales.

2.3.3. Child Behavior Checklist—Parent Report Form (CBCL; Achenbach, 1991)

The CBCL is a broad-band child behavior rating scale that can be completed by parents of children aged 4–18 years. The behavioral problem items require the parent to use a three-step response scale (not true, somewhat/sometimes true, and very often true). The CBCL was

normed on 2368 children, and scales were validated with 4455 clinically referred children. One-week test–retest reliability for the CBCL is reported to be .88 for girls and .90 for boys. Validity for the CBCL has been demonstrated by the factor analytic scale construction, which yielded two factors on an externalizing–internalizing dimension (Achenbach, 1991). The dependent measure in this study was the *t*-score for the Attention Problems scale. The Attention Problems scale has been found to correlate with performance on tests that have a strong attentional component, especially for children over age 8 (Massman, Nussbaun, & Bigler, 1988).

2.3.4. *Diagnostic Interview for Children and Adolescents, Fourth Edition (DICA-IV; Reich, Welner, & Herjanic, 1997)*

This is a semistructured interview that is designed for determining selected current and retrospective psychiatric diagnoses; the parent version was administered. The ADHD Scale total score (present) was analyzed for the current study. The OCD and Tic scales were not administered.

2.3.5. *Four-factor Index of Social Status (Hollingshead, 1975)*

This commonly employed measure of socioeconomic status (SES) incorporates both parents' highest level of education and current occupation. Weighted scores are assigned such that greater weights represent higher levels of education and (usually) jobs of higher prestige/income. Information was obtained for both parents if available and the higher rating was used in all analyses.

2.4. *Psychoeducational (PE) measures*

2.4.1. *Wechsler Intelligence Scale for Children, Third Edition (WISC-III; Wechsler, 1991)*

This is a commonly used, well-normed version of the popular intelligence test. The dependent measure used was the Full Scale IQ (FSIQ) score, which is a standard score.

2.4.2. *Wechsler Individual Achievement Test (WIAT; Wechsler, 1992)*

The Reading Composite Score was comprised of the Basic Reading (i.e., single-word reading) and Reading Comprehension (i.e., passage comprehension) subtests. The Math Composite is comprised of the Mathematics Reasoning and Numerical Operations subtests. These derived Reading and Math composite scores are standard scores and were used as dependent measures in this study.

2.5. *Performance-based EF measures*

2.5.1. *Controlled Oral Word Association Test (Benton, Hamsher, Varney, & Spreen, 1998)*

The Controlled Oral Word Association Test, which we label LWF, was used to measure initiation, fluency, and rapid lexical retrieval. The child is asked to produce as many words as possible beginning with the letter 'F,' then 'A,' and then 'S,' within 1 min (for each letter). The number of correct items, repetitions, and rule breaks provide information not only about speed and efficiency of lexical retrieval, but also about executive functioning, since the task requires inhibition of rule breaks as well as initiation and organization of a systematic search

of the internal lexicon. [Levin et al. \(1991\)](#) have shown significant increases in performance on this task with age, which they attributed to frontal lobe maturation. [Elfren and Risberg \(1998\)](#) found increased left frontal activation (regional cerebral blood flow) during a letter fluency task. Reduced letter fluency has been found in individuals with TS ([Schuerholz et al., 1996](#); [Sutherland et al., 1982](#)).

2.5.2. Tower of London (TOL; [Shallice, 1982](#))

This task taps the ability to plan complex spatial strategies and then execute the appropriate sequence of movement to implement them. It places significant demands on spatial working memory, as well as planning, sequencing, and the ability to maintain rule-governed behavior. Three beads of different colors (red, green, and blue) are stacked on posts that can hold either one, two, or three beads. The beads are arranged in a particular starting order and the subject must rearrange them to conform to a visually presented model. Only one bead can be moved at a time. Dependent measures are the number of trials required to solve each of the 12 problems. [Shallice \(1982\)](#) found that individuals with frontal lobe damage were deficient on this task. Cortical activation studies using SPECT showed increased left prefrontal activation during performance of this test ([Morris, Ahmed, Syed, & Toone, 1993](#)). Normative data have been obtained on 205 children in Grades 1–8, as well as 74 undergraduate college students with average receptive vocabulary scores ([Krikorian, Bartok, & Gay, 1994](#)), and on 376 children ages 7–14 ([Anderson, Anderson, & Lajoie, 1996](#)). Validity studies show very low correlation with receptive vocabulary and moderate correlation with the Porteus Maze Test, another EF (planning and motor execution) task ([Krikorian et al., 1994](#)), and moderate correlation with other measures of EF ([Anderson et al., 1996](#)). The computerized version of this test published by [Davis and Keller \(1998\)](#) was used in the present experiment to minimize errors of administration and scoring.

2.5.3. TOVA-V ([Greenberg, 1996](#))

The TOVA-V is a go/no-go continuous performance task that uses two geometric designs, a target and a nontarget, displayed on a computer monitor and requires a manual response in a go/no-go format. It is designed as a measure of sustained readiness to respond, inhibition, persistence, and consistency of response time. The test has been normed on 775 children (377 boys and 398 girls) between ages 6 and 16 ([Greenberg & Waldman, 1993](#)), as well as 168 adults between the ages of 20 and 69. Children with ADHD and TS demonstrate slow and variable reaction time on the TOVA-V ([Harris et al., 1995](#); [Shucard et al., 1997](#)). The dependent variables were, consistent with prior studies using this measure [Mahone, Hagelthorn, et al., 1999](#), total scores for omission (inattention) and commission (impulsivity) errors, reaction time to correct responses (processing time and motor speed), and variability of reaction time (variability of attention).

2.6. Sample characteristics

Demographic (age, percentage of males, and SES) and ancillary rating scale information are provided in [Table 1](#). All participants had FSIQ (WISC-III) of 80 or above (range 82–146). The sample was predominantly Caucasian (93%) as well as right-handed (93%), based on

Table 1
Demographics and ancillary rating scales

Demographic	ADHD (<i>n</i> = 18)		TS (<i>n</i> = 21)		TS + ADHD (<i>n</i> = 17)		Controls (<i>n</i> = 20)	
	<i>M</i>	S.D.	<i>M</i>	S.D.	<i>M</i>	S.D.	<i>M</i>	S.D.
Age	11.20	2.50	10.00	1.80	10.80	2.70	10.60	3.60
Percentage of males ^{a,b,c}	66.70	–	71.40	–	82.30	–	30.00	–
Mother Hollingshead Index	36.60	17.20	42.30	20.10	48.50	19.00	38.30	19.20
Father Hollingshead Index	32.70	14.90	37.50	14.80	38.50	13.40	35.10	20.60
CBCL attention problem ^{d,e}	68.40	7.32	56.30	6.16	71.30	8.80	50.50	1.60
DICA-IV ADHD present	8.79	2.55	2.89	2.54	7.50	2.82	2.00	1.58
ARS-A ^d	7.24	1.95	1.65	1.63	7.00	2.58	0.47	0.92
ARS-H ^d	4.82	2.88	0.95	1.32	3.44	3.22	0.27	0.80

ADHD: attention deficit hyperactivity disorder; TS: Tourette syndrome; DICA-IV: Diagnostic Interview for Children, Fourth Edition, raw score for present ADHD symptoms; CBCL: Child Behavior Checklist; ARS-A: ADHD Rating Scale IV, number of inattention symptoms endorsed at a level of 2 or higher; ARS-H: ADHD Rating Scale IV, number of hyperactivity symptoms endorsed at a level of 2 or higher. In the ADHD group, there were 17 ARS scores; in the TS group, there were 20 ARS and 20 CBCL scores; in the TS + ADHD group, there were 16 ARS scores; in the control group, there were 19 CBCL and 15 ARS-IV scores.

^a Controls > ADHD, *P* < .05.
^b Controls > TS + ADHD, *P* < .05.
^c Controls > TS, *P* < .05.
^d ADHD, TS + ADHD > controls, TS, *P* < .01.
^e TS > controls, *P* < .05.

responses to the Edinburgh Handedness Inventory (Oldfield, 1971). All participants were assessed for presence of learning disabilities in reading and mathematics. For the present study, a learning disability was defined as a 1.5 S.D. discrepancy between WISC-III FSIQ and achievement on the Reading or Math composite from the WIAT (Wechsler, 1992). Only two participants in the sample had this discrepancy, and in each case, their academic performance was solidly in the average range.

2.6.1. Control participants

There were no significant differences between subjects recruited as controls and control subjects who were unaffected siblings of other research participants on FSIQ or CBCL Attention Problems scores.

2.6.2. ADHD groups

Among the 35 participants with ADHD in both comparison groups (ADHD and TS + ADHD), there were no significant differences between those children with inattentive patterns of ADHD symptoms and those with hyperactive–impulsive or combined patterns of ADHD on age or FSIQ. When comparing the four study groups (TS only, ADHD only, TS + ADHD, and control), there was an expected between-group difference on the DICA-IV ADHD scale ratings for present symptoms score [*F*(3, 47) = 19.8; *P* < .001]. Post hoc tests (Tukey HSD) revealed that the group difference was accounted for by both ADHD groups being rated significantly higher than the two non-ADHD groups (*P* < .05). Similarly, there was a significant

group difference for parent ratings on the CBCL Attention Problems scale [$F(3, 69) = 42.5$; $P < .001$]. Again, both ADHD groups were rated more impaired than both the TS-only group ($P < .00001$) and the control group ($P < .00001$). The TS-only group had significantly higher CBCL ratings than the control group ($P < .005$), although their mean t -score on this scale (56.3) was well within the average range. It is possible that these minor elevations were accounted for by the item “nervous movements or twitching” on that scale.

2.6.3. Sex effects

The three clinical groups were predominantly male, while the control group was predominantly female; however, there were no significant differences in the overall sample between boys and girls in either age or parent DICA-IV rating of present ADHD symptoms. Because of the potential interaction between sex and diagnostic group, we also examined group differences between the control group (which was mostly female) and the TS-only group, which was predominantly male. There were no significant differences between the controls and TS-only group on age, FSIQ, DICA-IV ratings of present ADHD symptoms, and parent ratings (ADHD Rating Scale IV) of inattentive and hyperactive-impulsive symptoms.

2.6.4. Age effects

Among the four diagnostic groups, there were no significant between-group difference in either age or parental SES. In the total sample, age was not significantly correlated with FSIQ, WIAT Reading and Math composites, and LWF z -score, as expected given the standard score nature of those variables. Age was also not significantly correlated with any of the five BRIEF indices studied. In contrast, among other raw score variables, there was a significant ($P < .01$) correlation with age for TOL ($r = -.43$), and for TOVA omissions ($r = -.46$), commissions ($r = -.37$), response latency ($r = -.53$), and variability ($r = -.32$). In subsequent analyses with these measures that used raw score responses (TOL and TOVA-V), age was used as a covariate.

2.7. Group comparisons on performance-based measures

Performance on PE and EF measures is presented in Table 2. There was a significant between-group difference in FSIQ [$F(3, 72) = 3.1$; $P < .05$], with post hoc tests (Tukey HSD) revealing the control group to have significantly higher FSIQ than the TS + ADHD group ($P < .05$), with all other between-group comparisons nonsignificant. There were also significant differences in WIAT Reading [$F(3, 68) = 3.9$] and Math Composite [$F(3, 67) = 6.0$] scores. On both measures, post hoc tests (Tukey HSD) revealed that the control group had higher scores than the TS + ADHD group ($P < .01$); additionally, the control group had higher scores on the Math Composite than the ADHD-only group ($P < .05$). A multivariate analysis of covariance (controlling for age) was used to examine group differences on the six performance-based EF measures using raw scores. Raw scores were used for the LWF task in this analysis. After covarying for age, the analysis revealed no significant multivariate between-group differences [$F(18, 60) = 0.76$; $P = .74$], for these performance-based measures.

Table 2
Performance on psychoeducational and neuropsychological measures

Test/scale	ADHD (<i>n</i> = 18)		TS (<i>n</i> = 21)		TS + ADHD (<i>n</i> = 17)		Controls (<i>n</i> = 20)	
	<i>M</i>	S.D.	<i>M</i>	S.D.	<i>M</i>	S.D.	<i>M</i>	S.D.
FISQ ^a	108.20	14.2	108.30	13.6	100.10	12.4	113.20	10.9
WIAT Reading composite ^a	107.40	12.0	105.20	12.4	100.30	16.8	115.90	14.4
WIAT Math composite ^{a,b}	102.20	12.8	106.30	14.5	95.10	13.9	115.60	15.3
LWF <i>z</i> -score	−0.55	1.0	−0.25	1.6	−0.18	1.2	0.17	1.0
TOL percentage over optimal	66.50	25.7	49.60	24.8	57.20	25.6	43.00	18.0
TOVA-V omissions	30.50	30.2	21.40	31.5	13.30	14.0	28.40	40.4
TOVA-V commissions	48.40	55.3	25.70	13.9	26.40	25.4	35.90	28.8
TOVA-V response time	560.70	121.9	530.00	118.7	544.56	109.4	570.00	171.6
TOVA-V variability	251.90	114.8	187.40	122.4	176.10	63.1	223.30	118.0

ADHD: attention deficit hyperactivity disorder; TS: Tourette syndrome; FISQ: WISC-III Full Scale IQ; TOL: Tower of London; TOVA-V: Tests of Variables of Attention, Visual. All TOVA-V scores are total raw scores.

^a Controls > TS + ADHD, *P* < .05.

^b Controls > ADHD, *P* < .05.

3. Results

3.1. Group comparisons on brief scales and index scores

Group means for the five BRIEF scales are presented in Table 3. There was a significant multivariate group effect (Pillai’s) for the five scales (*P* < .00001). Univariate tests for the two scales considered to be useful for differentiating the subtypes of ADHD (Working Memory and Inhibit) and three primary index scores (MCI, BRI, and GEC) revealed significant group differences (*P* < .0001). Post hoc tests (Tukey HSD) showed that the ADHD and TS + ADHD groups were rated higher than the TS-only and control groups (*P* < .01) on all scales and indices. There were no significant differences on any of the BRIEF scales or indices between the ADHD and TS + ADHD groups. It was hypothesized that the TS-only group would show

Table 3
Group differences on the BRIEF Parent Form

BRIEF index	ADHD (<i>n</i> = 18)		TS (<i>n</i> = 21)		TS + ADHD (<i>n</i> = 17)		Controls (<i>n</i> = 20)	
	<i>M</i>	S.D.	<i>M</i>	S.D.	<i>M</i>	S.D.	<i>M</i>	S.D.
Working Memory scale ^{a,b}	2.39	0.34	1.57	0.44	2.46	0.40	1.23	0.29
Inhibit scale ^a	2.23	0.48	1.41	0.42	2.05	0.64	1.22	0.26
Metacognition Index ^a	2.37	0.28	1.59	0.32	2.36	0.29	1.38	0.25
Behavioral Regulation Index ^a	2.06	0.46	1.44	0.36	1.94	0.54	1.30	0.29
Global Executive Composite ^a	2.25	0.29	1.53	0.30	2.19	0.33	1.35	0.25

BRIEF: Behavior Rating Inventory of Executive Function; ADHD: attention deficit hyperactivity disorder; TS: Tourette syndrome. All BRIEF scores are raw score means.

^a ADHD, TS + ADHD > controls, TS, *P* < .01.

^b TS > controls, *P* < .05.

subtle impairments, relative to controls, on the BRIEF. However, in the analyses reported above, there was no difference between the individuals with TS and controls on four of the five BRIEF indices; however, individuals with TS did have higher ratings ($P < .05$) than control participants on the Working Memory scale.

3.2. Correlations between the BRIEF and performance measures

Correlations among BRIEF index scores and performance-based measures are listed in Table 4. Overall correlations between the BRIEF and performance-based EF measures were low to moderate. For the performance-based EF measures, partial correlations (controlling for age) were used on rawscore variables. After using Bonferroni correction for multiple ($n = 30$) comparisons, none of the correlations was significant. Zero-order correlations were obtained between the BRIEF and standard scores from PE measures. Again, after correcting for multiple correlations ($n = 15$), all five BRIEF scales and index scores were significantly correlated with the WIAT Math Composite. The BRIEF scales and indices were not, however, significantly correlated with FSIQ or the WIAT Reading Composite.

To determine whether the BRIEF was correlated more strongly with EF measures or PE measures, mean correlations of the five BRIEF scales/indices with each of the three PE and six EF measures were calculated. Utilizing Fisher’s r -to- z transformation (Hays, 1988), these mean correlations were assigned z -scores, and t -tests were performed on the resultant z -scores for the BRIEF with each combination of PE and EF measures (18 comparisons in all). There were no significant differences for any comparison at the .05 level (in fact, most t -scores were below 1.0). Thus, none of the mean correlations between the BRIEF and the six EF

Table 4
Correlation among BRIEF index scores and performance measures

	FSIQ	Read	Math	LWF	TOL	Omi	Com	RT	Var
WM	−.26	−.23	−.37***	.26	.35	.19	.17	.30	.21
MCI	−.28	−.29	−.41***	.28	.43	.24	.21	.31	.30
Inh	−.19	−.19	−.37***	.20	.22	.36*	.22	.24	.36**
BRI	−.21	−.28	−.34***	.19	.17	.31	.24	.14	.29
GEC	−.27	−.31	−.41***	.26	.35	.29	.24	.26	.32
<i>n</i>	73	72	71	73	31	60	59	62	62

BRIEF: Behavior Rating Inventory of Executive Function, Parent Form; FSIQ: WISC-III Full Scale IQ; Read: Wechsler Individual Achievement Test (WIAT) Reading Composite; Math: WIAT Math Composite; LWF: Letter Word Fluency total correct $x (-1)$; TOL: Tower of London percentage over optimal; Omi: Tests of Variables of Attention (TOVA) total omissions; Com: TOVA total commission errors; RT: TOVA total mean response time; Var: TOVA total variability score; WM: BRIEF Working Memory scale; MCI: BRIEF Metacognition Index; Inh: BRIEF Inhibit scale; BRI: BRIEF Behavior Regulation Index; GEC: BRIEF Global Executive Composite. Partial correlations (correcting for age) were used for LWF, TOL, and all TOVA scores. Bonferroni correction used for significance ($\alpha = .05/30 = .0017$) for comparisons between BRIEF scales and LWF, TOL, and TOVA scores. Bonferroni correction used for significance for psychoeducational measures ($\alpha = .05/15 = .0033$).

* $P = .0058$.
** $P = .0045$.
*** $P < .0033$.

Table 5
Correlation among BRIEF scales and parent rating scales

	CBCL	DICA	ARS-A	ARS-H
WM	.82	.75	.87	.57
Inh	.69	.77	.55	.76
MCI	.81	.74	.85	.59
BRI	.70	.70	.57	.70
GEC	.82	.78	.79	.69
<i>n</i>	73	51	68	68

BRIEF: Behavior Rating Inventory of Executive Function, Parent Form; WM: BRIEF Working Memory scale; Inh: BRIEF Inhibit scale; MCI: BRIEF Metacognition Index; BRI: BRIEF Behavior Regulation Index; GEC: BRIEF Global Executive Composite; CBCL: Child Behavior Checklist Attention Problems scale *t*-score; DICA: DICA-IV Present score for Hyperactivity scale; ARS-A: ADHD Rating Scale IV, number of inattention items rated 2 or above; ARS-H: ADHD Rating Scale IV, number of hyperactivity items rated 2 or above. Bonferroni correction used for significance ($\alpha = .05/20 = .0025$). All correlations listed are significant at $P < .0001$.

measures was significantly higher than the mean correlations between the BRIEF and the three PE measures. However, it was also the case that none of the mean correlations between the BRIEF and the three PE measures was significantly higher than the mean correlations between the BRIEF and the six EF measures.

3.3. Correlations between the BRIEF and other rating scales

Correlations among BRIEF index scores and other behavior rating scales are listed in Table 5. All correlations among rating scales were highly significant ($P < .0001$). Parent ratings on the BRIEF GEC were highly and significantly correlated with ratings on the CBCL Attention Problems scale ($r = .82$), DICA-IV ADHD Scale ($r = .78$) and the ADHD Rating Scale IV (inattention symptoms $r = .79$; hyperactivity–impulsivity symptoms $r = .69$). Although all correlations were significant, a pattern emerged suggestive of discriminant validity between ADHD subtypes. The BRIEF MCI was more strongly correlated with ADHD Rating Scale IV inattention symptoms ($r = .85$) than with hyperactivity symptoms ($r = .59$). Conversely, the BRIEF BRI was more strongly correlated with the ADHD Rating Scale IV hyperactivity symptoms ($r = .70$) than with inattention symptoms ($r = .57$). A similar pattern emerged for the two BRIEF scales believed to be associated with ADHD symptoms. The Working Memory scale was more strongly correlated with ADHD Rating Scale IV inattention symptoms ($r = .87$) than with hyperactivity symptoms ($r = .57$), while the Inhibit scale was more strongly correlated with ADHD Rating Scale IV hyperactivity symptoms ($r = .76$) than with inattention symptoms ($r = .55$).

4. Discussion

Our findings strongly suggest that observed EdF is characteristic of children who have ADHD, consistent with the general assertions of Barkley (2000). As in many rating scales (Abikoff, Gittleman-Klein, & Klein, 1977; Schachar, Sandberg, & Rutter, 1986), the presence

of ADHD strongly influenced reports on the BRIEF, and a majority of variance in the BRIEF ratings were accounted for by presence of ADHD. In general, the presence of TS added little to the BRIEF ratings over and above what would be expected due to the IQ differences in the groups. This finding is inconsistent with previous studies from our center that reveal subtle EF problems in this group (Mahone, Hagelthorn, et al., 1999; Mahone et al., 2001; Schuerholz et al., 1996). This finding could be due to small sample size or because the BRIEF scales have limited sensitivity to detect more subtle variations which may exist in this diagnostic subgroups.

The pattern of correlations between BRIEF ratings and PE measures (BRIEF-IQ and BRIEF-Reading) was comparable (mild-to-moderate range) to the pattern of correlations between BRIEF ratings and performance-based EF measures. Given the generally low correlations, it is likely that the BRIEF is related to different aspects of performance on the EF measures than PE measures. Given that the BRIEF and WIAT are well standardized, and many of the performance-based EF measures are not as well normed and have much lower reliability, it is not surprising to find a pattern in which rating scale measures are similarly correlated with other well-standardized measures (e.g., IQ and academic achievement), suggesting that these correlations are not an artifact of merely having a clinical disorder. To clarify the relationships, we also examined the pattern of correlations between the BRIEF and PE measures, and between the BRIEF and EF measures within two of the groups (TS + ADHD and controls), as it was between these groups wherein most consistent differences in IQ were found. Although the analysis was weakened by low power, a similar overall pattern of correlations was observed.

Parent BRIEF ratings were significantly and strongly correlated with other parent ratings of behavioral dysfunction, particularly those behaviors seen in children with ADHD. The present study supports others (Bussing, Schuhmann, Belin, Widawski, & Perwein, 1998; Schachar et al., 1986), who found that ratings of behavioral dysfunction were similar across different measures. The pattern of correlations among BRIEF scales and index scores with associated rating scales provides some support for the discriminant validity of the BRIEF ratings among children with different types of ADHD profiles, and supports the factor structure and discriminant and convergent validity of the BRIEF ADHD indices. The BRIEF MCI, while not developed as a measure of inattention, has a high degree of overlap with the Working Memory scale. In turn, both scales show a high degree of correlation with other ratings of inattention (e.g., ADHD Rating Scale IV Inattention scale and DICA-IV), compared with more moderate correlations with hyperactivity ratings (i.e., ADHD Rating Scale IV scales and BRIEF Inhibit scale). Conversely, the Behavioral Regulation Index, while not developed as a measure of hyperactivity, was strongly associated with the BRIEF Inhibit scale, and both appeared to have higher relationships with other more direct ratings of hyperactivity (e.g., ADHD Rating Scale IV Hyperactivity scale), compared with ratings of inattention (ADHD Rating Scale IV Inattention scale and BRIEF Working Memory scale).

Our findings highlight the fact that, despite the difficulties involved in measuring the domain of EF as a variable in group data analysis, and despite such results as those cited from Grodzinsky and Barkley (1999), there is a growing literature that raises intriguing points about the complex nature of EdF in ADHD. Barkley's (1997) most recent formulation of EF attempts a linear model explanation whereby inhibition is the fundamental and driving impairment behind all subsequent difficulties with EF in its multiple manifestations. Even motor control enters into Barkley's thinking, as he takes note of the disinhibition on motor

examination present in the form of overflow movements. However, this well-reasoned linear model does not conform to our own clinical experiences and has met with some modification as data have accumulated. For example, Oosterlaan and Sergeant (1998) report results which suggest that a more pervasive cognitive dysfunction also involving response preparation and behavioral intention, rather than a deficit restricted to response inhibition, is characteristic of children with ADHD. These examples examining the Barkley model provide evidence that, while inhibition is important, it is still but one aspect among several within the EF model. One interesting finding is the significant correlation between the BRIEF and the WIAT Math Composite. Compared to the tests that comprise the WIAT Reading Composite, the WIAT Math Composite, which is comprised of the Numerical Operations (e.g., calculation) subtest and the Mathematics Reasoning (concepts) subtests, may place a higher demand on the child's executive skills. Badian (1983) pointed out that many children who are described as inattentive make math calculation errors due to problems with retrieval and use of procedures associated with attentional deficits. As such, children who present with EdF, especially those with ADHD, are likely to be inconsistent in fact retrieval and more likely to evidence procedural errors, leading to lower calculation scores. Similarly, performance on the Mathematics Reasoning subtest of the WIAT is conceptualized as placing demands on both language and executive skills, above and beyond what is required for basic calculation procedures. In addition to calculation, factors underlying the EF construct, particularly planning and mental flexibility, can potentially contribute unique variance to the prediction of the Mathematics Reasoning score.

Several issues require special attention. First, although attempts were made to include equal numbers of females in all groups, this was not the case. However, most developmental disabilities have a male bias, and we found no sex differences in performance-based measures. Second, although evidence suggests that IQ and EF are different constructs (e.g., Ardila, 2000), they are likely not independent of one another. Given these factors and the fact that our control group had higher IQ scores than the TS + ADHD subgroup, it may be argued that differences on the BRIEF between the TS + ADHD individuals, and the control group, were due to the latter group's elevated IQ. However, we were able to obtain a subset of 56 parent BRIEF ratings from the original normative sample (Gioia et al., 2000b), matched for IQ and gender with the 56 children in our three clinical groups. There were no significant differences between the IQ-matched controls and our controls on any of the BRIEF scales or index scores, suggesting that there is a real difference in EF between controls and the TS + ADHD and ADHD-only groups, which is not only due to IQ.

Strengths of this study include the low prevalence of OCD and learning disabilities in our sample, although these may be important determinants in the neuropsychological pattern for individuals with both ADHD and TS. In addition, we attempted to explore the construct of EF in a comprehensive, ecologically valid manner with the use of a rating scale format that circumvented some of the measurement difficulties that manifest frequently in performance-based measures of EF. The population sampled was a group of children for whom the construct of EF is both practically and theoretically relevant.

This study supports the use of the BRIEF in the identification, description, and measurement of EdF. While the Parent Form of the BRIEF may show strong correlations with other rating scales or interviews used to characterize behaviors seen in ADHD (e.g., CBCL, DICA, and ADHD Rating Scale IV), it remains a particularly useful tool for clinicians precisely because it

is *not* designed to be an ADHD diagnostic measure. The BRIEF is particularly useful because it is theory-driven and developed to describe patterns of behavior associated with the various aspects of the EF construct. In clinical settings, the BRIEF may have overlapped with the ADHD rating scales in diagnostic groups with significant EF dysfunction; however, it can potentially delineate those aspects of behavior that are specifically part of the diagnostic criteria of a learning disability or ADHD. Such areas include those involved with basic regulation of behavior (sustained performance, inhibition of inappropriate or competing responses, establishment and maintenance of cognitive set, and concentration and transition to new material). Clinically, it is these types of behavior that are difficult to quantify, and about which parents may have limited understanding. Since such difficulties can cause social and educational problems across academic skill areas and across time, the BRIEF remains potentially useful for a wide range of diagnostic groups, even those with known ADHD.

There were several limitations with the current study. One was the difficulty in fully exploring the impact of ADHD subtypes on BRIEF scores due to sample size constraints. This is particularly salient in our sample because the TS + ADHD group had a higher percentage of inattentive-type ADHD, while the ADHD-only group included mostly combined type. Despite the different ADHD patterns of subtypes in our two ADHD groups, they did not differ on parent BRIEF ratings or any of the performance-based measures. Nevertheless, future studies with larger samples should continue to address ADHD subtype as a predictor of EdF, taking into account the comorbidity of different ADHD subtypes with related conditions, for example, learning disabilities (Willcutt, Chhabildas, & Pennington, 2001).

Future research should also continue to explore the construct validity of the BRIEF among clinical groups with known EF concerns, using parent and teacher ratings, associated measures of adaptive skill development, and, in older children, self-report ratings. Specifically, future studies should address EdF found in children with OCD, and coexisting TS and/or ADHD, given the presumed frontal–striatal system dysfunction these three groups have in common. Also, use of the BRIEF in children with OCD (especially those without comorbid ADHD) may be especially useful given the number of items on the MCI which have to do with shifting set and establishing novel approaches to tasks, which are the reported deficits among children with OCD (Cox, 1997; Goldberg & Podell, 1999). In addition, research that addresses the developmental course of EdF during the school years will also be important, especially considering the possibility that rating scales and performance-based measures of EF may produce different growth curves. Finally, research that incorporates additional neuropsychological measures and that correlates behavioral measures with structural or functional imaging will contribute substantially to our understanding and treatment of the brain systems involved in TS and ADHD. In particular, research aimed at validating the constructs that comprise the “intention” aspects of the EF construct, namely inhibition (behavioral regulation), working memory, organization and planning (response preparation), through functional imaging are indicated.

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