Predicting GPAs with Executive Functioning Assessed by Teachers and by Adolescents Themselves

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Abstract: Executive functions (EFs) show promise as important mediators of adolescent academic performance. However, the expense of measuring EFs accurately has restricted most field-based research on them to smaller, non-longitudinal studies of homogeneous populations with specific diagnoses. We therefore monitored the development of 259 diverse, at-risk students' EFs as they progressed from 6th through 12th grade. Teachers completed the Behavior Rating Inventory of Executive Function (BRIEF) for a random subset of their students. At that same time, those same students completed the Behavior Rating Inventory of Executive Function-Self Report (BRIEF-SR) about themselves; teachers generally reported stronger EFs in students than students reported in themselves. Results further indicated that both BRIEF and BRIEF-SR Global Executive Composite (GEC) scores—measures of overall executive functioning—significantly predicted overall GPAs more than was already predicted by students' gender, IEP status, and eligibility for free/reduced school lunch. BRIEF (teacher) scores were better predictors and contributed more to predictive accuracy than the BRIEF-SR (student) scores; BRIEF scores even added additional predictiveness to a model already containing BRIEF-SR scores, while the reverse did not hold. This study provides evidence for valid use of BRIEF and BRIEF-SR GEC scores to predict middle and high school GPAs, thereby supporting practitioners use for this purpose within similar, diverse, at-risk populations. The study also illuminates some of the EF development for this population during adolescence.

Keywords: *academic performance, adolescence, Behavior Rating Inventory of Executive Function, executive function, GPA, longitudinal, validity*

Introduction

Executive Functions (EFs) can be generally defined as a set of cognitive and behavioral control processes that individuals use to regulate and direct attention, memory, thoughts, emotional reactions, and behaviors so that they may attain both short- and long-term goals (Best & Miller, 2010; Diamond & Lee, 2011; Blair & Raver, 2012). This ability to direct one's attention and behavior towards meeting a goal is necessary to complete most academic tasks. It is not surprising, then, that EFs are found to be associated with adolescents' academic success (Best, Miller, & Naglieri, 2011; Bierman, Torres, Domitrovich, Welsh,

& Gest, 2009; Kotsopoulos & Lee, 2012; Authors, 2016; Vuontela et al., 2013; Waber, Gerber, Turcios, Wagner, & Forbes, 2006). This is true for mathematics (Andersson, 2008; Bull & Lee, 2014; Lee, Ng, & Ng, 2009; van der Ven, Kroesbergen, Boom, & Leseman, 2012) as well as reading, writing, and science (Monette, Bigras, & Guay, 2011; St Clair-Thompson & Gathercole, 2006).

Most research, however, has focused on children (e.g., Carlson, 2005; Garon, Bryson, & Smith, 2008), perhaps because EF tasks rapidly develop during the preschool and early school years (e.g., Carlson &

Moses, 2001; Zelazo, Muller, Frye, & Marcovitch, 2003). Nonetheless, EFs continue to develop throughout adolescence or even early adulthood (Best, Miller, & Jones, 2009; Best & Miller, 2010; Best et al., 2011), and the etiology of their development during adolescence—and their ability to predict academic outcomes during this period—remain poorly understood (Ahmed, Tang, Waters, & Davis-Kean, 2018; Conklin, Luciana, Hooper, & Yarger, 2007).

Although EFs hold promise for diagnosing adolescents' needs, the current dearth of ways to measure EFs—let alone measure them cost-effectively—hinders school psychologists' practice (Hughes, 2011). The research that does exist largely includes small samples of particular populations, and the few large studies on diverse adolescent populations that exist do not yet present a coherent picture (Ahmed et al., 2018; Best et al., 2011; Authors, 2016). We therefore investigated predictive aspects of the validity of two common measures of EFs in academics, an important form of success during adolescence.

Environmental factors can affect the rates at which EFs develop during adolescence. For example, their development can be impeded among those who have endured impoverished backgrounds (Dunn, 2010; McDermott, Westerlund, Zeanah, Nelson, & Fox, 2012) or traumatic events (DePrince, Weinzierl, & Combs, 2009; Masten et al., 2012; Perkins & Graham-Bermann, 2012). EFs also appear to play an even more important role in the academic success of at-risk students (Buckner, Mezzacappa, & Beardslee, 2003; Buckner, Mezzacappa, & Beardslee, 2009; Hostinar, Stellern, Schaefer, Carlson, & Gunnar, 2012; Lemberger & Clemens, 2012; Masten et al., 2012; McDermott et al., 2012; Waber et al., 2006). Dilworth-

Bart (2012), for example, argues that EFs can mediate the effects of socio-economic status on mathematics performance among young children.

Students with cognitive or emotional disabilities are also often at risk of academic failure, and research has demonstrated deficits in their EFs. Alloway, Gathercole, Adams, and Willis (2005), for example, found lower levels of EFs among older children with disabilities. Similarly, Semrud-Clikeman, Fine, and Bledsoe (2014) found that children with non-verbal learning disorders or Asperger's syndrome demonstrated EF-related cognitive deficits compared to matched controls, although which areas were deficient depended on the diagnosis (not all areas were deficient) and EF deficits covaried with IQ. Further, Jansen, De Lange, and Van der Molen (2013) reported that adolescents with mild to borderline Intellectual Disabilities demonstrated depressed EFs and that lower EFs were related to poorer performances in mathematics; after a five-week intervention, many of the adolescents' mathematics performance improved, but their EFs did not. Controlling for IQ, Diamantopoulu, Rydell, Thorell, and Bohlin (2007) found that EFs and Attention-Deficit / Hyperactivity Disorder (ADHD) independently predicted academic performance about one year later; they also reported that ADHD and EFs were related, and that they interacted with special education status: Children with both high levels of ADHD and low levels of EFs were most likely to receive special educational supports. Finally, Schuchardt, Bockmann, Bornemann, and Maehler (2013) found that lower EFs and working memory were evident among children with Dyslexia and among children with serious deficits in language production and/or reception. Given this evidence, the present study focused on the assessment of the EFs of

adolescent students who are at risk of academic failure.

Gender differences may also be more pronounced in EFs related to processing speed/maintaining attention (Brocki & Bohlin, 2004) and to inhibition (Berlin & Bohlin, 2002) but not, e.g., working memory. Gender differences are not always strong or present (Welsh, Pennington, & Groisser, 1991), however. We therefore also studied gender since its role here is poorly understood.

Assessment of EF through the BRIEF

Many studies have examined EF using a comprehensive multidimensional measure: the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000), an 86-item instrument developed to assess—via parent and/or teacher reports—EF manifestations in the everyday lives of children and adolescents aged 5 – 18 years. The BRIEF has been widely used in clinical applications as well as in a variety of research studies involving children and adolescents who are typically and atypically developing (for review, see Isquith, Roth, & Gioia, 2013; Roth, Isquith, & Gioia, 2014). The BRIEF is one of the EF instruments most sensitive both to ADHD (Reddy, Hale, & Brodzinsky, 2011; Toplak, Bucciarelli, Jain, & Tannock, 2008) and to changes following brain injury (Chevignard, Soo, Galvin, Catroppa, & Eren, 2012). It has been widely used to assess outcomes following a variety of interventions (Isquith, Roth, Kenworthy, & Gioia, 2014) and is associated with academic performance (Roth et al., 2014; Authors, 2016).

The BRIEF has shown good inter-item and test-retest reliability (Gioia et al., 2000). The BRIEF has also

been found to be a practical tool showing valid uses in school and clinical settings as well as in research; there are over 400 peer-reviewed publications supporting the reliability, clinical utility, and valid uses of the BRIEF. Overall, reviews of the BRIEF have been positive (Baron, 2000; Goldstein, 2001; Strauss, Sherman, & Spreen, 2006). To our knowledge, however, no studies have yet investigated its valid use to predict academics in the field and among diverse, community-dwelling adolescents.

The Behavior Rating Inventory of Executive Function—Self-Report Version (BRIEF-SR) offers another method to measure EFs among older children and adolescents. The BRIEF-SR is designed for children and adolescents aged 11 – 18 years to self-report the frequency of various EF-related behaviors through 80 items that measure nearly the same domains as the BRIEF (Guy, Isquith, & Gioia, 2004). The use of the BRIEF-SR may therefore allow for investigations of EFs among adolescents while relying on a different source for information that may reduce the burden on any one participant while also providing a complimentary—or perhaps even an alternate—vehicle for measurement. Guy et al. (2004) provide evidence for the BRIEF-SR's ability to validly measure EFs, including through its relationship with the Behavior Assessment System for Children Parent Rating Scales (BASC-PRS) and for Teacher Rating Scales (BASC-TRS)—but, importantly, not directly against the BRIEF. Indeed, few studies have compared versions of the BRIEF side-by-side with the BRIEF-SR, but the present study undertakes this task. The parental version of the BRIEF and the BRIEF-SR have been compared in studies on adolescents with particular disabilities, viz., specific language impairments (Hughes, Turkstra, & Wulfeck, 2009),

myelomeningocele and congenital hydrocephalus (Mahone et al., 2002), and Traumatic Brain Injuries (TBIs; Wilson, Donders, & Nguyen, 2011).

The BRIEF and BRIEF-SR were constructed to measure two general areas of EF: metacognition and behavioral regulation (Gioia et al., 2000; Guy et al., 2004), themselves each comprised of further subscales. Exploratory factor analyses of the eight subscale divisions of the parent and teacher forms of BRIEF showed the same two-factor solution in both normal controls and specific clinical subjects (Gioia et al., 2000). The metacognition and behavioral regulation areas can be combined to create an overall Global Executive Composite (GEC) score. As operationalized by the BRIEF and BRIEF-SR, metacognition includes the "ability to initiate, plan, organize, and sustain future-oriented problem solving in working memory" (Gioia et al., 2000, p. 20). Behavioral regulation involves the "ability to shift cognitive set and modulate emotions and behavior via appropriate inhibitory control" while allowing "metacognitive processes to successfully guide active, systematic problem solving (and supports) appropriate self-regulation" (Gioia et al., 2000, p. 20). Clearly the functions subsumed by these general areas inter-relate, justifying the creation of the BRIEF and BRIEF-SR as instruments that subsume both domains of executive functioning.

Some evidence for the valid use of these instruments in academic settings is proffered by Langberg, Dvorsky, and Evans (2013) who investigated academic outcomes among ~100 adolescents diagnosed with ADHD. They used the parent and teacher versions of the BRIEF and found that teacher-rated scores on the Plan/Organize subscale of the

BRIEF significantly contributed to the prediction these students' overall grade point averages (GPAs) beyond that made by the number of parent-reported ADHD symptoms. Although limited to students diagnosed with ADHD, Langberg, Dvorsky, and Evans' study is among the few to use these instruments to study EFs and academics among adolescents—in contrast to the larger amount of research conducted among children (e.g., Clark, Pritchard, & Woodward, 2010; Locascio, Mahone, Eason, & Cutting, 2010; Waber et al., 2006). Best et al. (2011) investigated the relationships between EFs and academic achievement among a sample of over 2,000 children and adolescents using the Planning scale of the Cognitive Assessment System (Naglieri & Das, 1997); they found that EFs were moderately correlated with success in both math and reading achievement. Boschloo, Krabbendam, Aben, de Groot, and Jolles (2014), however, did not find a significant relationship between some subscores on a Dutch version of the BRIEF-SR and grades in Dutch, English, and mathematics; they also did not find that grades were predicted by behavioral measures of EFs from the Delis-Kaplan Executive Functions System.

The BRIEF-SR has been used less frequently than the BRIEF in research. It may be that studies like that reported by Boschloo et al. (2014) represent similar null findings that others find and do not publish, or that adolescents' insights into their own EFs remain an understudied area. Adolescents have been found to be able to rate their own behaviors accurately (Wichstrøm, 1995); nonetheless, individuals of many ages who are still developing an ability are often not so good at rating themselves on that ability (Dunning, Johnson, Ehrlinger, & Kruger, 2003), and the ability to monitor aspects of one's own performance is itself

an EF, so adolescents who are still developing the ability to monitor their own behaviors may not be so able to accurately rate themselves. One of the goals of the present study is to investigate the relationship of BRIEF and BRIEF-SR in predicting academic performance, comparing them against each other and conducting an initial foray initial to the role of self-monitoring on the predictive aspects of the BRIEF-SR's validity here.

Assessment of Academic Success through GPA

In addition to strongly predicting future grades, middle school grades are among the best predictors of high school graduation (Lohmeier & Raad, 2012) and performance on standardized exams such as the Stanford Test of Basic Skills (Wentzel, 1993). High school grades predict college grades better than SAT scores (Geiser & Santelices, 2007).

Second, despite possible concerns with bias and generalizability, GPA remains both a common and well-predictive variable that gives complementary and non-redundant information predicting students' future academic success. Third, we believe that it is indeed under-valued while standardized scores are sometimes over-valued.

Goals and Hypotheses

The primary goals of the current study are to (1) investigate the predictive validity using of the BRIEF for experimental uses in schools by analyzing the contribution of BRIEF GEC scores to predictions of academic performance among at-risk adolescents from 6th to 12th grade, (2) investigate the predictive validity using of the BRIEF-SR for experimental uses in schools by analyzing the contribution of BRIEF-SR GEC scores to the predictions of these same outcomes,

and (3) directly compare the contributions of the BRIEF with those of the BRIEF-SR for their uses as experimental tools. The secondary goal of the study is to investigate changes in EFs over these years.

We hypothesized that BRIEF GEC scores would show valid uses in middle and high school by predicting academic performance well. We also hypothesized that the valid predictive use of BRIEF-SR GEC scores here may not be as well supported (i.e., will not predict academic performance as well as BRIEF GEC scores) given the equivocal findings on the use of the BRIEF-SR in academic settings outlined earlier. We further hypothesized that EFs would improve, although the extent of their improvements may be affected by students' demographics.

Method

Participants

All of the 259 participating students attended the same charter school located in New York City. The school is designed to serve mainly at-risk students by providing them with an enriched environment that prepares them for future academic success, including preparation for college. The ages of the participating students ranged from 9 to 18 years (mean = 13.45, *SD* = 2.65). About 85% of the school's students are eligible for either free (68%) or reduced-priced (17%) school lunches. Many of the students come from minority ethnicities: 32% self-identify as Hispanic; among the non-Hispanic students, 42% identify as African-American, 8% identify as Asian-American, and 17% identify as European-American. Finally, 40% of the students have diagnosed disabilities.

Students who participated in the study were enrolled in grades 6 through 12. Students contributed data for

each year they were enrolled at this school; students who left the school or graduated ceased being measured; 38 (14.7%) of the students left the school before the end of the study. Those who left early did not significantly differ from those who stayed in terms of overall mean GPA ($t_{36.0}$ = 1.42, p = .16), BRIEF GEC scores ($t_{37.6}$ = -1.07, p = .29), or BRIEF-SR GEC scores ($t_{50.31}$ = 0.40, p = .69).

The data analyzed included EF scores and GPAs from the current academic year as well as available EF scores and GPAs from all previous years. School lunch status, Individualized Education Program (IEP) status, and gender were all considered to be fixed terms here. Forty-six teachers participated in this study by completing the BRIEF for students in their classes. The students whose teachers were asked to rate were selected at random within constraints to balance the effect of teachers' course content expertise. The constraints were to ensure that the contents areas of teachers were equally sampled (thus reducing and equating any effect of a given teacher's effect on both GPA and BRIEF scores) and that each teacher reported on an equal number of students (thus equating any effect of within-rater variance). In addition, none of the teachers rated the students more than once: Each year, a different set of teachers rated the students, further limiting the effect of any one teacher on both BRIEF scores and GPA.

The identities of the students or the rating teachers were not disclosed to the researchers. Students' ages, gender, whether they were eligible to receive free/reduced school lunches, and whether they had an IEP were provided by the school.

Materials

Executive functioning

BRIEF

The Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000) includes a Teacher Form that is an 86-item paper-and-pencil instrument used by teachers (employed in this study) or parents to rate the several aspects of EFs demonstrated through the behaviors of a target child or adolescent. Individual items on the BRIEF are summed to compute two indices, the Metacognitive Index and the Behavioral Regulation Index, which are added together to create a Global Executive Composite (GEC) score, which offers an overall measure of EFs. We will focus on the GEC since individual executive functions may develop at different rates during adolescence (Best & Miller, 2010), to facilitate comparisons with the BRIEF-SR, and to create a manageable set of analyses.

BRIEF-SR

The Behavior Rating Inventory of Executive Function-Self-Report (BRIEF-SR) was created to compliment the information obtained through the BRIEF with the insights that older children and adolescents can provide about themselves (Guy et al., 2004). Items on the BRIEF-SR are also grouped into a Metacognitive Index and the Behavioral Regulation Index, and those two indices are summed to create a GEC score. Although fewer studies have employed the BRIEF-SR than the BRIEF, Guy et al. (2004) found that the BRIEF-SR possesses good inter-item and test-retest reliabilities and moderate correlations (rs ≈ .3) with the BRIEF Teacher Form used here.

Academic Performance

Academic performance is operationalized here as annual cumulative GPA in core courses, viz.,

English/language arts (ELA), mathematics, science, social studies, and Spanish. GPAs were computed for grades 6 – 12, the grade levels investigated in this study. Note that the teacher who rated each student through the BRIEF also teaches one of that student's courses and therefore contributes one of the five grades that comprise that student's GPA for that year (but for no other year). The teachers all taught various subjects, and the subjects taught were balanced across teachers, so this potential bias was distributed across all of the five courses.

Procedure

The BRIEF was distributed to the participating teachers by the school administration within two weeks of the end of every academic year for five consecutive years. The teachers used the BRIEF to rate a predetermined, randomly-selected subset of their students within one week of distribution of the instrument to them, as described in the Participants section, above.

The students were all administered the BRIEF-SR on the same day that the teachers were initially given the BRIEF. Students completed the BRIEF-SR on that same day; absent students completed it on the same day that they returned to school. With institutional and school IRB permission, all of these data were linked, anonymized, and given to the authors for analysis.

Analyses

Hypotheses were primarily tested through the series of nested and partially nested multilevel models of change reported here. We assessed whether BRIEF and/or BRIEF-SR GEC scores made significant contributions to predictions of total GPA by comparing differences in how well the models fit the

data with and without BRIEF/BRIEF-SR scores added to them. We also added EF-Score x Time interaction terms to the models; these interaction terms test whether the influence of EF on GPAs changes over time.

It is worth noting at this point that we use the term "prediction" in the statistical sense of using known information (viz., EF scores and demographic information) to infer unknown information (viz., overall GPA). Nonetheless, the EF-score term establishes the y-intercept, thus using initial EF scores to infer information about future GPAs, therefore also addressing in part the more traditional use of the term "prediction" in that we are using prior scores to test for later scores. Nonetheless, we did not manipulate either EFs or GPAs: Although we can test predictive relationships, we cannot test for causal relationships between EFs and GPAs.

We compared the fits of models to the data using deviance statistics: –2 log-likelihoods (–2*LL*s) for comparisons between models using the same data and Bayesian Information Criteria (BICs) for comparisons of models that did not use the exact same data (i.e., the fit of the model containing BRIEF scores vs. the model containing BRIEF-SR score).

The multilevel models of change used here can easily accommodate instances where some time-varying data are missing for some participants, e.g., if a student does not have an EF score for a given year (Singer & Willet, 2003). However, differences in deviance statistics can only be validly analyzed when those statistics are computed from the exact same data set. For completeness, then, we also assessed whether using the subset of the whole data set that contained

only complete data for each participant appreciably affected the results. It did not: The term values of the models were not meaningfully different between analyses conducted with the entire set of data and analyses conducted with only data with no missing values. We therefore proceeded with the comparisons reported herein.

BRIEF and BRIEF-SR scores and GPAs were standardized. Time was measured as the number of days since that student's tenth birthday that the BRIEF was completed; these ages were then also standardized. Data were analyzed using R, version 3.0.2 (R Core Team, 2012). R packages used included nlme (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2015) and psych (Gelman, Hill, & Yajima, 2012; Revelle, 2014).

Results

Descriptive Statistics

The teachers reported knowing the student they were rating an average of 12.47 ($SD = 6.74$) months. In addition, only 5.52% of the teachers indicated that they knew the given student they were rating "not well" while 49.11% indicated they knew that student "moderately well" and 45.37% indicated they knew that student "very well".

Table 1 presents the number (and percent) of female and male students with and without IEPs. The mean GPAs, BRIEF GEC scores, and BRIEF-SR GEC scores for females and males are presented in Table 2. In general, teachers tended to rate a students' EFs as stronger (via lower BRIEF scores) than students rated their own EFs (via less low BRIEF-SR scores).

Table 3 presents the means for GPAs, BRIEF scores, and BRIEF-SR scores for students with and without IEPs. Students with IEPs tended to have lower GPAs and higher BRIEF and BRIEF-SR scores than students without IEPs.

Table 1

Number (and percent) of Male and Female Students with and without IEPs

	Male	Female	Total
Does Not Have an IEP	93 (35.9)	93 (35.9)	186 (71.8)
Has an IEP	47 (18.2)	26 (10.0)	73 (28.2)
Total	140 (54.1)	119 (45.9)	259 (100)

Table 2

Mean (and standard deviation) of total GPA and EF scores for students with and without IEPs

	Male	Female	All Students
Total GPA	80.72 (9.07)	84.35 (8.10)	82.44 (8.83)
BRIEF	132.87 (42.83)	115.60 (43.35)	124.86 (43.95)
BRIEF-SR	149.71 (36.17)	153.94 (35.87)	151.71 (36.03)

Table 3

Mean (and standard deviation) of total GPA and EF scores for students with and without IEPs

	Does Not Have an IEP	Has an IEP
Total GPA	83.19 (7.79)	77.39 (8.39)
BRIEF	115.43 (40.08)	140.29 (40.97)
BRIEF-SR	140.16 (34.87)	152.77 (35.26)

Main Findings: Predicting GPA with BRIEF and BRIEF-SR scores

Analyses of model-level fits indicated that both BRIEF and BRIEF-SR GEC scores made significant contributions to predictions of GPAs when either term and its interaction with time were added to models containing gender, IEP status, and lunch status. Adding BRIEF GEC main effect and interaction terms to a model that already contained BRIEF-SR GEC terms (and terms for lunch status, etc.) significantly improved the fit of that model. However, adding BRIEF-SR terms to a model that already contained BRIEF terms (and lunch status, etc.) did not significantly improve the fit of the model.

Table 4 presents the taxonomy of the models predicting GPA. Model 1 in Table 4 predicts total GPA from only non-EF-related terms: gender, lunch status, whether a student does or does not have an IEP, and the student's age. Model 2 presents the change in model fit when standardized teacher BRIEF scores are added to Model 1. Model 3 presents the changes when standardized student BRIEF-SR scores were instead added to Model 1. Model 4 presents the changes when both teacher BRIEF and student BRIEF-SR scores are added.

Table 4

Predicting GPAs with Executive Functioning Assessed by Teachers and by Adolescents Themselves. N = 259 for all four models. Female = 1, male = 0; free school lunch = 1, reduced = 0, ineligible = -1; has IEP = 1, doesn't have IEP = 0. Higher BRIEF and BRIEF-SR scores denote lower EFs.

		Models			
		Model 1:	Model 2:	Model 3:	Model 4:
Goodness of Model Fit	$-2LL$	1002.0	912.2	989.6	908.4
	BIC	1045.0	967.5	1044.9	976.0
Model Terms					
Gender	b	.498	.403	.521	.418
	t	5.25	4.85	5.60	5.02
	p	< .001	< .001	< .001	< .001
Free / Reduced School Lunch Status	b	−.063	−.053	−.065	−.053
	t	−0.95	−0.93	−1.00	−0.94
	p	.172	.176	.158	.175
Special Education Status (Has /	b	−.551	−.318	−.482	−.297
	t	−4.98	−3.27	−4.40	−3.04
	p	< .001	< .001	< .001	.001
Time	β	.271	.339	.337	.358
	t	4.99	6.59	5.62	6.31
	p	< .001	< .001	< .001	< .001
BRIEF	β		−.349		−.320
	t		−5.52		−4.90
	p		< .001		< .001
BRIEF x Time	β		.036		.051
	t		0.66		0.93
	p		.256		.177
BRIEF-SR	β			−.166	−.104
	t			−2.92	−1.90
	p			.002	.029

Table 4 Continued				
BRIEF-SR x Time	β		−.055	−.061
	t		−1.03	−1.21
	p		.151	.113

Looking at Model 1, we see that boys tended to have lower GPAs than girls and students with IEPs tended to have lower GPAs than students without IEPs. These results reflect those in Tables 2 and 3 where the GPAs, BRIEF GEC scores, and BRIEF-SR GEC scores are broken down by gender and IEP status, respectively. Table 2 also shows that the difference between males and females was greater for BRIEF GEC scores (~17 points different) than the difference between them for BRIEF-SR GEC scores (~4 points). Similarly, the difference between students with and without IEPs (Table 3) was greater on the BRIEF (~25 points) than on the BRIEF-SR (~13 points).

The time main effect in Model 1 also displayed a small but statistically significant, positive effect on GPAs. This indicates that students' GPAs tended to increase across the years. Gender and IEP status both remained significant in all four models. Whether or not students were eligible for free or reduced school lunches remained non-significant in all four models.

Adding teacher BRIEF GEC scores to the model (Model 2) made for a significantly better-fitting model than Model 1: The difference in the –2*LL*s between Model 1 (–2*LL* = 1002.0) and Model 2 (–2*LL* = 912.2) is 89.8 (χ^2 < 8.76, *df* = 2, critical α = .05/4 = .0125). The main effect term for teacher BRIEF GEC scores was significant in Model 2, but the interaction-with-time term was not. The significant BRIEF main effect term indicates that when teacher-measured EF-related behaviors became more frequent (i.e., as BRIEF GEC

scores got smaller), then students tended to have higher GPAs. The non-significant BRIEF x Time interaction indicates the effect of BRIEF-measured EFs on grades did not significantly change over time. Adding instead student BRIEF-SR GEC main and time-interaction terms to the model (Model 3) also significantly improved the model fit (–2*LL* = 12.4). The main BRIEF-SR term was significant; the BRIEF-SR x Time interaction term was not.

The model containing teacher BRIEF GEC scores (Model 2) and the model containing student BRIEF-SR GEC scores (Model 3) are not nested, so we cannot use –2LLs to compare the relative fits of these models to the data against each other. Instead, we can compare these two models' BICs to give an indication of their relative fits (Singer & Willet, 2003). The difference between the BIC of Model 3 (1044.9) and the BIC of Model 2 (967.5) is 77.4, a difference that Raftery (1995) suggests is "very strong."

Summary of Main Findings

Both boys and students with an IEP tended to have lower GPAs; being eligible for free/reduced-price school lunches was not a strong predictor among this nearly uniformly poor sample. When we then considered the role of EF-related behaviors, we found that they made a very strong contribution to our predictions of GPAs beyond that made by both gender and IEP status—regardless of whether the frequency of EF-related behaviors were reported by a student's

teacher or by the student her/himself. Nonetheless, gender and IEP status remained significant predictors of GPAs even when the strongly-predictive terms for EF-related behaviors were added.

Although EF-related behaviors strongly added to our predictions of GPAs, the information we gained from asking teachers about these behaviors was not entirely redundant with the information gained when we asked the students themselves: teacher-generated information was a stronger predictor than student-generated information, but non-EF-related terms remained stronger when we considered only student-generated information. When we considered both teacher- and student-generated information about EF-related behaviors, that generated by teachers tended to overshadow that generated by students. The relationship between teacher- and student-generated scores is next considered further.

BRIEF and BRIEF-SR
GEC Correlations

Supporting the analyses comparing model fits, the correlation between the mean BRIEF and BRIEF-SR GEC score for each student across all waves was .38 ($p < .001$). This is somewhat higher than the correlation between these two scores found by Guy et al. (2004), who found the correlation in a stratified sample of 148 adolescents to be .25. In their meta-analysis of a wide range of psychological studies, Achenbach, McConaughy, and Howell (1987) found that the average correlation between a teacher's ratings of students on a given scale and a student's self-ratings on a similar scale was .20.

Although we therefore found a relatively good correlation between students' and teachers' ratings, there is certainly room for BRIEF and BRIEF-SR GEC scores to make unique contributions. The extent to which BRIEF and BRIEF-SR GEC scores can both add to predictions of GPAs is tested in Model 4. Adding both BRIEF- and BRIEF-SR-related terms (Model 4) indeed makes for a significantly better-fitting model than when using only BRIEF-SR-related GEC terms ($-2LL = 81.2$). However, using both BRIEF and BRIEF-SR GEC scores does not make for a significantly better-fitting model than using only BRIEF-related GEC terms ($-2LL = 3.8$).

BRIEF and BRIEF-SR Subscore Correlations

Tables 5 and 6 present the correlations between the BRIEF and BRIEF-SR subscores, respectively. These tables show that the correlations between the subscores within an instrument are all rather high for field-based, social-science research (lowest $r = .37$). Nonetheless, the correlations between the subscores on the BRIEF are all higher than the correlations between the subscores on the BRIEF-SR: The lowest correlation between BRIEF subscores is .84 whereas the highest correlation between BRIEF-SR subscores is .78. The predictiveness of a score is limited by the correlations between its components (Nunnally & Bernstein, 1994), so the relatively lower correlations between the BRIEF-SR subscores likely contributes to the lower predictiveness of BRIEF-SR GEC scores.

Table 5

Correlations between BRIEF subscores.

BRIEF-SR Subscore	Em. Control	Inhibit	Initiate	Monitor	Org. of Materials	Plan/ Organize	Shift	Working Memory
Emotional Control	1	.88	.90	.88	.89	.89	.88	.91
Inhibit	.88	1	.89	.89	.85	.90	.84	.89
Initiate	.90	.89	1	.87	.88	.89	.86	.89
Monitor	.88	.89	.87	1	.86	.90	.89	.91
Organization of Materials	.89	.85	.88	.86	1	.85	.84	.88
Plan/Organize	.89	.90	.89	.90	.85	1	.88	.92
Shift	.88	.84	.86	.89	.84	.88	1	.90
Working Memory	.91	.89	.89	.91	.88	.92	.90	1

Discussion

The present study examined the EF scores obtained by teachers, through the BRIEF, and by their students, through the BRIEF-SR; overall (GEC) scores predicted cumulative GPAs among at-risk students across grades 6 – 12, extending the existing literature to include students through both middle and high school and self-ratings of EFs. This result suggests that either of these two scores could be used alone to make significant predictions about how students perform in middle and high school courses. To the best of our knowledge, this is the first time BRIEF and BRIEF-SR scores have been compared with each other directly to predict academic performance.

This study therefore provides evidence for the valid use of these instruments to predict overall GPA, supporting their use within similar at-risk populations. However, although we found that knowing the BRIEF or BRIEF-SR assigned to a given student can reliably predict that student's current current or future GPA, we cannot infer from our findings whether EFs indeed cause students to have a given GPA. The study design does not allow us to rule out whether GPA causes EFs to attain a given level or whether both are in fact determined by one or more unmeasured moderating variables.

Table 6

Correlations between BRIEF-SR subscores.

BRIEF-SR Subscore	Em. Control	Inhibit	Monitor	Org. of Materials	Plan/ Organize	Shift	Task Comp.	Working Memory
Emotional Control	1	.65	.47	.40	.55	.61	.48	.59
Inhibit	.65	1	.57	.50	.64	.60	.55	.64
Monitor	.47	.57	1	.37	.54	.52	.51	.51
Organization of Materials	.40	.50	.37	1	.64	.52	.58	.60
Plan/Organize	.55	.64	.54	.64	1	.75	.77	.78
Shift	.61	.60	.52	.52	.75	1	.68	.73
Task Completion	.48	.55	.51	.58	.77	.68	1	.68
Working Memory	.59	.64	.51	.60	.78	.73	.71	1

In tracking both BRIEF and BRIEF-SR scores over time, the study helps illuminate some aspects of the development of EFs in this population throughout adolescence. We found that students' EFs tended to increase over the seven years of the study. Students with IEPs and boys tended to show less pronounced improvements. These findings replicate those found by others (e.g., Best et al., 2011; Conklin et al., 2007), but expand upon them in important ways. First, these changes were found when reported either by the student or by a different teacher every year. Second, these effects were found across a range of students all monitored at the same time. Third, these students were largely at-risk of academic failure—a population dissimilar from those in which the BRIEF (Gioia et al., 2000) and BRIEF-SR (Guy et al., 2004) were normed.

Fourth, the diversity of the sample allowed us to test for the effects of IEPs and gender in the field.

As expected, using both BRIEF and BRIEF-SR GEC scores produced a model that fit the data better than a model using only BRIEF-SR GEC scores. This suggests that the BRIEF and BRIEF-SR are not redundant; it also implies that using only BRIEF-SR GEC scores to predict GPAs neglects a significant amount of reliable information about the data that are contained in BRIEF GEC scores.

The BRIEF and BRIEF-SR were not designed to duplicate each other, and differences between their results can be seen itself as potentially complimentary perspectives on the conceptualization of EFs operationalized by the instruments (Guy et al., 2004).

At the very least, including BREIF-SR into models with BRIEF scors may help attenuate resonse bias by the teacher that is common to both their BRIEF responses and the grades they gave that contributed to the overall GPA. Indeed, the relationship between EFs and academic performance is not simple, and investigations into this area will benefit from the more expansive view that including both instruments can lend.

However, adding BRIEF-SR GEC scores to a model that already contained BRIEF GEC scores did not create a significantly better-fitting model. Although the BRIEF and BRIEF-SR may provide somewhat unique perspectives, we found that the one offered by teachers' ratings through the BRIEF was richer and perhaps, in many applications, sufficient. Perhaps relatedly, the BRIEF/BRIEF-SR difference was less pronounced between those students with and without IEPs. Students with IEPs did tend to rate their EF-related behaviors differently than students without IEPs, but the difference between their ratings of themselves (via the BRIEF-SR) was less marked than the ratings of teachers (via the BRIEF).

In any case, both gender and special education status mattered, remaining significant predictors in every model. Jacob and Parkinson (2015) cogently argue that investigations of EFs in academics are greatly hampered by the exclusion of such demographic and individual factors. Indeed, Boschloo et al. (2014) found that including gender and level of parental education reduced the effects of BRIEF-SR scores to non-significance in their study. Relatedly, Authors (2016) found that adding BRIEF-related terms to models predicting overall GPAs could render nonsignificant the previously-significant effects of

gender and IEP status. In the current study, gender and IEP status remained significant even after BRIEF- and BRIEF-SR-related terms were added to the models. Authors included a smaller sample size than we used here, so this difference in results is likely due to the fewer degrees of freedom they had for these other, demographic terms. Given the inter-relatedness of these EF scores with demographic factors, we also strongly advocate including demographic factors—both for the analytic clarity and for the theoretical importance of this inter-relatedness. Although we are not currently able to measure additional factors such as IQ and parental education, we echo Jacob and Parkinson's (2015) recommendation that they be included whenever possible as well.

It is worth noting that since the teachers both rated a subset of the students once (over the seven years of this study) on BRIEF and contributed to a portion of that student's GPA, there is likely a small but non-neglible relationship between teacher-generated BRIEF scors and student GPA. This, of course, is much less likely to affect the relationship between student-generated BRIEF-SR scores and GPA. These results then also provide insights into the relationship between executive functions and GPAs with possible controls on any bias borne from the respondent: The BRIE-SR–GPA provides controls on any covariance from the teacher while the BRIEF–GPA relationship provides controls for a student's still-developing self-awareness. Together, then, they help provide the beginning of a more rounded and nuanced perspective that supports the relationship between executive functions and academic performance as measured through overall GPA.

Limitations

As discussed by Jacob and Parkinson (2015), IQ and EF are known to be highly correlated, although not synonymous. However, we were not able to measure IQ. The measure of academic success employed here is GPA, which is assigned by the students' teachers. Although GPA strongly predicts future grades (Lohmeier & Raad, 2012) and performance on standardized exams (Wentzel, 1993), we should bear in mind that such a measure generally assesses both academic achievement and behavior, and the two cannot be disentangled (Jacob & Parkinson, 2015). Nonetheless, we chose to use them to test the validity of the instruments since GPAs are ubiquitously and heavily relied upon to monitoring students' academic development.

In addition, the teachers who rated the students' EFs also taught one of the five courses which comprised the GPA. Therefore, 20% of a student's GPA was computed from a class that was taught by the same teacher who rated that student, although which course that was balanced across all of the students. Practitioners who do not wish to tolerate any bias in EF ratings introduced by teachers but who nonetheless wish to benefit from the efficiency of this way of measuring EFs could rely instead on students' self-ratings.

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