Executive Function Measurement in Urban Schools: Exploring Links between Performance-Based Metrics and Teacher Ratings

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This manuscript reflects a sub-set of analyses conducted as part of the first author's doctoral dissertation. Preregistration, data/analyses, and a preprint are openly available for Sample 1 (preregistration: <https://osf.io/4hrvj>; materials and data/analyses: <https://osf.io/whzrg/>) and Sample 2 (preregistration: <https://osf.io/8n2e3>; data/analyses: <https://osf.io/fkw5m/>). The manuscript preprint is available from <https://psyarxiv.com/myr2s/>.

Author Contributions

Sample 1

Ellefson, Serpell and Parr submitted the initial grant application and study concept. Ellefson oversaw the development of the Thinking Games website. Data collection was supervised by Ellefson, Serpell and Parr. Ellefson and Serpell managed and conducted the scoring, data entry, data cleaning and all other general data management for the computerized tasks and teacher surveys.

Sample 2

Zonneveld and Ellefson developed the data collection plan as part of Zonneveld's doctoral research. Zonneveld managed and conducted all data analysis and data entry.

Manuscript

Zonneveld and Ellefson wrote the R scripts for data wrangling and analysis; they interpreted the results here as well as Zonneveld for a thesis submitted as partial fulfillment of a doctoral degree at the University of Cambridge. Zonneveld and Ellefson prepared the open

science data files. Zonneveld and Ellefson drafted the manuscript. All authors approved the final draft.

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Research Highlights

- This study explores whether teacher ratings of children's everyday executive functioning (using standardized behavior rating scales) capture distinctions between performance-based measures.
- Results indicate that BASC2_{EF} teacher rating scale (Karr & Garcia-Barrera, 2017) is not a good representation of everyday executive function behaviors by children from schools in high-poverty communities.
- The findings suggest that restricting BASC2_{EF} analyses to only items included in BASC3_{EF} (Reynolds & Kamphaus, 2015) or using BASC3_{EF} for high-poverty populations.
- BASC3_{EF} seems better able to capture the different components of performance-driven tasks, whereas BASC2_{EF} captures overall executive functioning better than individual tasks.

Abstract

When compared to research centered on the executive function development of white, middle-class children, relatively little is known about their non-white, low socioeconomic status peers. In an effort to harmonize how executive functions are measured within under-represented contexts, the present study addresses gaps in the evaluation of everyday executive functioning to better understand whether behavior rating scales completed by teachers (BASC2_{EF} – Karr & Garcia-Barrera, 2017; BASC3_{EF} – Reynolds & Kamphaus, 2015) capture distinctions between performance-based measures. This study includes two large samples of older, ethnic minority children from high-poverty backgrounds (Sample 1. $N = 243$; $M_{age} = 9.28$ years, $SD_{age} = 0.80$; $n_{female} = 125$; $n_{AfricanAmerican} = 216$, $n_{LatinAmerican} = 15$, $n_{AsianAmerican} = 6$; Sample 2. $N = 229$; $M_{age} = 10.02$ years, $SD_{age} = 1.01$; $n_{female} = 120$ $n_{AfricanAmerican} = 132$, $n_{LatinAmerican} = 92$, $n_{White} = 3$, $n_{PacificIslander} = 1$). Based on structural equation models testing the links between computerized performance-based measures and the teacher rating scales, the results indicate that BASC2_{EF} in its original form might be a good fit for some populations but there is not a strong factor structure for the current high-poverty samples. In addition, post-hoc analyses suggest that only including BASC2_{EF} items also in BASC3_{EF} or using BASC3_{EF} is best practice for high-poverty populations. BASC3_{EF} seems better able to capture different components of performance-driven tasks, whereas BASC2_{EF} captures overall executive functioning better than individual tasks. These findings encourage continued questioning surrounding metrics used to assess everyday executive functions in older children from diverse backgrounds.

Key Words: executive functions, teacher rating scales, behavior rating scales, socioeconomic status, ethnic minority, late childhood

Executive Function Measurement in Urban Schools: Exploring the Links between Performance-Based Metrics and Teacher Ratings

There is a growing body of literature that investigates executive functions of children in ethnic minority families from high-poverty communities (e.g., Choi et al., 2016; Lawson et al., 2018; 2012; Nesbitt et al., 2013). However, this population is often excluded from psychometric and cognitive development research. While some attempts have been made in recent years to norm standardized executive function tasks using nationally representative samples (e.g., Flores et al., 2017; Weintraub et al., 2013; Zelazo et al., 2013), much of the existing psychometric research overrepresents children from white, middle-income, or affluent families. Far less is known about whether these findings can be generalized to children from ethnic minority families in low-income communities. A critical part of understanding current views about the universality of executive function development must involve this important group of children (Miller-Cotto et al., 2021). For example, recent data indicate that approximately 14% of children from the United States live in poverty, nearly 50% are from ethnic minority families, and approximately 71% of children living in poverty are from ethnic minority families (Children's Defense Fund, 2021). However, reaching ethnic minority families from low-income communities for research is challenging. One way to promote their participation in developmental research is to run studies in collaboration with their local schools, providing excellent opportunities to include teacher ratings of executive function related behaviors in the classroom. However, relatively little is known about how well teacher rating scales capture executive functions in low-income, ethnic minority communities compared to those of their White, more affluent peers.

Executive functioning is often thought to involve higher-order mental processes needed to facilitate goal-oriented behavior through conscious control of thoughts and actions (Diamond, 2001; Miyake et al., 2000). However, authors often conceptualize these skills differently based on their own theoretical backgrounds and there is not yet a full consensus on a single definition

(Jacob & Parkinson, 2015; Nilsen et al., 2017). Despite the widespread challenges in defining executive functions, common components include working memory, inhibition, and shifting (Miyake et al., 2000; Riggs et al., 2006). Each component provides an element of purposeful self-directed behavior, making each important for cognitive development.

Performance-Based Tasks

An increasing number of studies are looking at the development of executive functions using performance-based tasks. Generally, these studies find skills increase from early childhood into young adulthood (e.g., Lee et al. 2013). Individuals with better performance-based scores (compared to their age-matched peers) tend to do better on various academic metrics. For example, they have more successful transitions into school (e.g., Müller et al., 2017), better academic achievement in elementary (e.g., Monette et al., 2011) and secondary school (e.g., Samuels et al. 2017), better mental health (e.g., Diamond, 2013) and better long-term employment potential (e.g., Bailey, 2007). Children entering school with better cognitive skills seem to be in a better position to grow academically and progress, while children with poor cognitive skill development seem to fall behind further over time (e.g., Abenavoli et al., 2015). Given the key role of executive functions in child development, it is important to understand the nature and course of its development across a wide range of children.

There are variations across different groups of children that help to better understand the course of executive function development. Children facing great adversity like developmental disabilities (e.g., Hosenbocus & Chahal, 2012), extreme levels of stress (e.g., Blair & Raver, 2016), or high levels of poverty (e.g., Lawson et al., 2013) have lower skills. More recent large-scale longitudinal studies afford a better look at the development of these skills across a wider range of children (e.g., NICHD Study of Early Child Care and Youth Development in the United States and the Millennial Cohort study in the United Kingdom), but performance-based task data collection remains time/staff intensive.

Behavior Rating Scales

Given the importance of better understanding of the development of executive functions and resource-heavy constraints of performance-based tasks, there have been attempts to develop alternatives. Commonly called, “everyday measures,” these ecologically valid metrics have been developed to assess executive function abilities through day-to-day behaviors in real-world contexts (Kouklari et al., 2018). One useful approach involves metrics that can be completed by parents, caregivers, or teachers rather than trained researchers or clinical/educational psychologists. However, developing such metrics made it clear that although performance-based tasks have strong links to everyday outcomes, they are not necessarily sensitive to day-to-day executive functioning, meaning that they tend to have low ecological validity (Burgess et al., 2006). Behavior rating scales became an effective way to gauge everyday executive functioning for younger populations. They can provide a unique perspective on different elements that performance-based tasks may not measure (e.g., Isquith et al., 2004; Soto et al. 2020). In addition, they can be completed by parents or teachers because they have more extensive experience with the child.

There are a few different examples of behavior rating scales that tap directly into everyday executive functioning (e.g., Behavior Rating Inventory of Executive Functions, Gioia et al., 2000; Child Executive Functioning Inventory, Thorell & Nyberg, 2008; Behavior Assessment System for Children, Reynolds & Kamphaus, 1992, 2004, 2015). The present study focuses on the Behavior Assessment System for Children (BASC; Reynolds & Kamphaus, 1992, 2004, 2015). The BASC has been used in a variety of developmental and clinical settings for a few decades, but it is only recently that a subset of items has been used for everyday executive functioning (Garcia-Barrera et al., 2011; Karr & Garcia-Barrera, 2017). It has been validated with clinical samples in the United States (e.g., Soto et al., 2020). There are parent and teacher versions for participants ages 2 to 25 years (teacher version only to 18 years).

Comparing Performance-Based and Rating Scales

There are now a good number of studies comparing performance-based tasks with rating scales, but the results are not consistent. Some studies have small sample sizes ($n < 200$; e.g., Choi et al., 2016; McAuley et al., 2010), often due to clinical samples that could lead to Type II errors. Large, sufficiently powered, nationally representative samples, from a variety of contexts (e.g., Finders et al., 2021; Litkowski et al., 2020) are important for a better understanding of how well these different metrics can be used to measure skill development. Additionally, some studies indicate that behavior rating scales have better reliability and ecological validity than performance-based measures (Barkley & Murphy, 2010). Others suggest that performance-based tasks and rating scales assess different aspects of executive functions and could be complementary (Karr & Garcia-Barrera, 2017). Toplak et al. (2013) ran a meta-analysis on 68 studies and found a median correlation of $r = .18$ between performance-based and rating scales. However, they did not split their sample by type of rating scale or whether the study used parent or teacher versions. Studies that do split these two versions seem to suggest that the teacher version is more reliably correlated to performance-based tasks than the parent version (e.g., Gutierrez et al., 2021). Teachers might be more able to assess a student more objectively and have a better grasp of the student's attitude towards learning and disruptive behavior that may signal executive functioning difficulties (van Tetering & Jolles, 2017).

While there is a body of work that examines the relationships between performance-based tasks and parent/teacher rating scales (e.g., McAuley et al., 2010; McCoy, 2019; Sherman & Brooks, 2010; Sulik et al., 2010), most of these studies of typically developing children include samples that are from predominantly White, affluent backgrounds (e.g., Magimairaj, 2018; Miranda et al., 2015). We could find only one study with a high proportion of children from ethnic minority or low-income backgrounds by Camerota et al. (2018), who found good links between the CHEXI rating scale and a battery of computerized performance-based tasks in a large sample ($N = 844$) of children ages 3-5 years, with 46% from families considered at or below the United States federal government poverty threshold and a good mix of racial and ethnic

backgrounds (60% White, 31% African American, 20% Hispanic, 7% Asian American, 1% Native American, 1% Pacific Islander). However, although statistically significant, the correlations were small effect-sized ($r = .10$). Establishing a universal theory about everyday executive functioning requires samples from a wide range of typically developing backgrounds. Furthermore, it is important that attention is placed on the metrics being used to assess cognitive skills as it may not be appropriate to use the same assessments with individuals of various racial/ethnic minority groups and socio-economic backgrounds.

The Current Study

The current study is designed to address specific gaps in the evaluation of everyday executive functioning in children with the aim of understanding whether behavior rating scales capture distinctions between performance-based measures.

First, we include two large samples of older children largely from ethnic minority families living in high-poverty communities because they are an important part of understanding the development of these essential cognitive skills.

Second, we compare two versions of a behavior rating scale, the BASC-2 and BASC-3, completed by teachers with computerized performance-based tasks. Despite the existence of a newer version of the BASC (BASC-3), the BASC-2 behavior rating scale is included in the present study for two reasons; (1) the BASC-3 was not available when Sample 1 data collection began; and (2) many archived and longitudinal datasets use the BASC-2. The behavior rating scales tap into different behaviors exhibited by students and fall into four sub-scales: *problem solving*, *behavioral control*, *attentional control*, and *emotional control*. We selected computerized tasks because of their relevance to this age group and because they can be administered to larger groups of students, making the large sample size possible.

Third, we compare models where the performance-based tasks make individual predictions with those where they are mapped onto one latent construct to gain a sense of how well behavior rating scales capture the distinctions between performance-based tasks. Studies

using pairwise correlations between each rating scale and performance-based task tend to show nonsignificant correlations (e.g., Davidson et al., 2016; Gross et al., 2015), whereas those using composite scores for performance-based tasks sometimes show stronger correlations (e.g., $r = .30$ in Soto et al., 2020). In line with existing research, we hypothesize that behavior rating scales are reliant upon behaviors that use multiple executive function skills and might not fully capture the distinctions between performance-based tasks (Isquith et al., 2013; Soto et al., 2020; Toplak et al., 2013).

Method

Participants

Sample 1

Sample 1 included 243 older children ($N = 243$; $M_{age} = 9.28$ years, $SD_{age} = 0.80$; $n_{female} = 125$), who are predominantly African American ($n = 216$), with students from Latin American ($n = 14$), Asian American ($n = 6$), Pacific Islander ($n = 5$) and White ($n = 3$) backgrounds. Most qualified for free and reduced lunch ($n = 241$). Data were collected during after-school hours from elementary schools in high-poverty urban areas in the eastern United States. Participants were recruited from 12 public schools where administrators agreed to participate and host the program. The data reported here are from the baseline testing of a larger sample of third to fifth-grade students participating in an after-school program to learn how to play chess (see <https://osf.io/yac8e/> for a summary of the funded project). The overall project received ethical review from multiple institutions: University of Cambridge's Psychology Research Ethics Committee (IRB 2011.39), Virginia State University (IRB 1011-37), and Virginia Commonwealth University (IRB HM20000017).

Sample 2

The second sample included 229 older children ($N = 229$; $M_{age} = 10.02$ years, $SD_{age} = 1.01$; $n_{female} = 120$), who are predominantly African American ($n = 132$), with students from Latin

American ($n = 92$), White ($n = 3$), and Pacific Islander ($n = 1$) backgrounds. All students qualified for free and reduced lunch ($n = 229$). Data were collected during school hours from elementary schools in a high-poverty urban area in the midwestern United States. Participants were recruited from three public schools where administrators and teachers agreed to participate during school hours. Data collection for Sample 2 received ethical review from the University of Cambridge's Faculty of Education Ethics Committee.

Sample Recruitment

Recruitment procedures were similar for both samples; study invitations included flyers sent home, teacher announcements, and advertising during after-school professional development sessions. Parental consent and child assent were collected from each participant. In Sample 1, children received a \$10 gift card and a small prize for completing the computerized tasks. In Sample 2, children received two small prizes for completing the computerized tasks. BASC rating forms were presented to teachers in a secure envelope; teachers completed one rating scale for each student and returned them to the researcher to maintain confidentiality. Teachers were asked to complete ratings based on how students behaved in school over the previous several months. As an incentive, teachers in Sample 1 were compensated \$10 for each completed student rating form. For Sample 1, BASC2_{EF} and performance-based data were collected within four weeks, and within one week for Sample 2.

Materials and Procedures

Teacher Behavior Rating Scales

Sample 1. BASC2_{EF} (Karr & Garcia-Barrera, 2017) is part of an ecologically valid (BASC2; Reynolds & Kamphaus, 2004), psychometrically sound teacher rating scale that includes 33 items about executive functioning in a classroom setting verified in cross-cultural and clinical samples (Garcia-Barrera et al., 2011; 2013; 2015). Classroom teachers completed a full BASC2 for each child, but only BASC2_{EF} items are used here. Karr & Garcia-Barrera (2017) evaluated the psychometric properties of the BASC2_{EF} teacher version and found strong internal

consistency (*Cronbach's α* range .81 to .89) for four subscales: (1) *behavioral control* includes items on distractibility and disruptive/harmful behavior towards peers; (2) *attentional control* includes items on following directions and keeping focused; (3) *problem solving* includes items on a child's ability to practice good study routines, cooperate with classmates, stay organized, make decisions, solve problems, and work in stressful settings; and (4) *emotional control* includes items on the propensity for anger or getting upset as well as adjustment to changing/stressful circumstances. The subscales contained 12, 7, 9, and 5 items, respectively. Responses to each item are given using a four-point Likert scale: *never*, *sometimes*, *often*, and *always*.

Sample 2. Like BASC2_{EF}, BASC3_{EF} is a psychometrically sound (Garcia-Barrera et al. 2011; 2013; 2015; Goldstein & Naglieri, 2014) teacher rating scale that includes 31 items about executive functioning in a classroom setting and includes the same subscales as BASC2_{EF} (Reynolds & Kamphaus, 2015). The items in each subscale changed slightly from the BASC2_{EF} to the BASC3_{EF}, with several items updated or removed. There is strong internal consistency (*Cronbach's α* range .90 to .94) for the four subscales: (1) *behavioral control* did not include new items, but continued to include items on self-control and distractibility, and had fewer items about harmful and disruptive behavior; (2) *attentional control* added more items about following directions and keeping focused; (3) *problem solving* removed items on good study routines, cooperating with classmates, staying organized, making decisions, and working in stressful settings, and instead targeted planning and analyzing problems; and (4) *emotional control* removed items about adapting to changing circumstances while centering on adjustment to stressful situations and propensity for anger. The subscales contained 7, 8, 9, and 7 items, respectively.

Computerized Performance-Based Tasks

Children from both samples completed the same six performance-based tasks using the secured Thinking Games website (<http://instructlab.educ.cam.ac.uk/TGsummary/>) to allow for

in-school administration of tasks to large groups and streamlined data management (materials openly available from <https://osf.io/whzrg/>). Each task took about 5-7 minutes to complete, with task order determined by the logistics for the wider projects. Sample 1 participants completed tasks in varied orders over multiple days as part of a large battery of tasks administered during the after-school club, Sample 2 completed tasks in the same order and in one session during the regular school day.

Participants were encouraged to respond as quickly as possible while still being accurate. Accuracy and response time were collected for each trial on every task. Overall accuracy and response times to correct items were used to compute an efficiency score for each task (Ellefson et al., 2017; see Equation 1).

$$\frac{\text{Accuracy (number correct responses)}}{\text{Time (in seconds, to make correct response)}} \quad \text{Eq. 1}$$

Efficiency is a way to incorporate both accuracy and speed while avoiding extensively non-normal distributions usually seen in these tasks for accuracy (ceiling effects) and response time (long tails). The expected response times and number of trials make the efficacy scores vary substantially across tasks, as such z scores are computed for each task and used in the analyses.

These computerized tasks have been used extensively in cognitive psychology, cognitive development, and cognitive neuroscience. They have not been standardized in the same way that clinical neuropsychology tasks might be, as they have been developed for slightly different purposes. There is a large literature base that supports the use of performance-based tasks derived from a cognitive psychology perspective for measuring executive function skills (Bignardi et al. 2021, Diamond et al., 2007; Espy et al., 2001; Zelazo, 2006). The tasks described below are commonly used tasks to measure the specific executive function skills linked to them (Luciana & Nelson, 2002; Parsey & Schmitter-Edgecombe, 2013; Patel et al., 2021).

Inhibition – Stop Signal Task. This child-friendly version of the original stop signal task (Logan, 1994) presents an image of a soccer field with a ball centrally positioned either on the left- or right-hand side of the computer screen. The task includes 108 trials (presented in three blocks). Participants are instructed to use their keyboards to click the left arrow key when the ball is on the left-hand side of the screen and the right arrow key when the soccer ball is on the right-hand side of the screen. Left-hand and right-hand trials are divided equally (54 trials each). Participants are instructed to refrain from clicking either arrow when they hear a referee's whistle. The referee's whistle is played randomly on 20% of the total trials. In line with standard stop signal procedures, the time gap between the presentation of the image and the presentation of the whistle sound is either increased or decreased depending on participant accuracy.

Sustained Attention –Continuous Performance Task. This child-friendly version of the children sustained attention task (Servera & Cardo, 2006) is a computerized task based on the continuous performance tests paradigm (Rosvold et al., 1956). The current version included 300 trials. During each trial, a random numeral between one and nine was presented in the middle of the screen. Participants pressed the spacebar for each numeral, except when they see the number four. Each numeral appeared with equal probability.

Working Memory – Spatial Span Task. This child-friendly adaptation of the Corsi blocks tasks (Corsi, 1972) is split into two parts: forwards patterns (presented first) and backwards patterns. The computer screen displays an array of 9 boxes for each trial. Boxes briefly light up in a pre-selected order. Participants are asked to click on the boxes either in the same order (forwards) or the reverse order (backwards) that they appeared. Only the backwards version is included here. After two practice items (each with 2 boxes lighting up), participants receive trials of increasing length, completing two trials each with lengths of 3- to 7-box sequences. The task stops automatically after five consecutively incorrect trials.

Shifting – Figure Matching Task. This task is a slightly modified presentation of Ellefson et al. (2006) and is suitable for children. The task includes 128 trials, each with four simultaneous events. A target figure is presented in the center of the screen and varies by shape (triangle or circle) and/or color (blue or red). In each lower corner of the screen, there is a small figure; one matched the shape of the target and the other matched the color of the target. Participants follow the cue to sort by shape or color by pressing one of two keys on the computer keyboard. The 128 trials are presented randomly within four 32-trial sets, counter-balanced between participants. There are two pure sets (either all color trials or all shape trials) and two mixed sets with color and shape trials presented using an alternating-runs sequencing (Rogers & Monsell, 1995) that changes tasks every two trials (e.g., color-color-shape-shape-color-color-shape-shape).

Planning – Tower of Hanoi Task. This is a computerized version of the task used by Welsh (1991). The Tower of Hanoi task is often referred to as a “disk transfer” task, as participants are asked to transform a start state of disks into a goal configuration in as few moves as possible with a set of rules imposed that restrain the way disks may be moved (i.e., larger disks cannot be placed on smaller disks). The minimum number of moves needed to transform the bottom set to match the top set increases with each successful trial. The increased number of minimum moves increases the overall task difficulty. Participants are given a practice problem and offered feedback for illegal moves. Once the practice trial has been completed, participants are given six 3-disk problems, including 2- to 7-move problems. This is followed by three 4-disk items, including 7-, 11-, and 15-move problems. To progress onto the more difficult problems, participants must make two consecutive minimum-move solutions. Participants have a maximum of 20 moves to match the goal arrangement before being offered a new problem (with a maximum of six attempts to achieve two consecutive minimum-move solutions). The task ends when participants have either successfully solved all problems or when they reached a problem that they could not solve twice in a row within six attempts.

Executive Decision Making – Hungry Donkey Task. This child-friendly version of the Iowa Gambling task measures participants' ability to make decisions under uncertain circumstances, using logic-based, cost-benefit analyses (Crone & van der Molen, 2004). Participants help a hungry donkey collect as many apples as possible by choosing one of the four doors on the screen for each trial. Doors open by pressing the 'a', 's', 'd,' or 'f' keys. Participants win or lose apples when they open a door. Two doors are advantageous (win more apples than lose) and two are disadvantageous (lose more apples than win). For each set of advantageous/disadvantageous doors, one door produces small gains and small losses, while the other large rewards and large losses. The assignment of the doors was counterbalanced across participants. Accuracy is measured here as the total number of advantageous doors selected.

Data Analysis

We used structural equation modeling (SEM) to test links between BASC2_{EF} and computerized performance-based tasks (Figure 2). We ran analyses using *psych* (Revelle, 2021), *lavaan* (Rosseel, 2021) and *SEMtools* (Jorgensen et al., 2021) packages for *R* (R core team, 2019). The analyses were pre-registered; the raw data and R scripts are openly available (<https://osf.io/whzrg/>). To identify the factor structure for the computerized performance-based tasks and BASC2_{EF} rating subscales, we ran reliability tests using Cronbach's alpha and measurement models using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). We ran additional models that had poor fits (including ones preregistered for Sample 1); they are not reported here. Due to space limitations, descriptive statistics, correlations amongst individual items on the BASC2_{EF} and BASC3_{EF}, measurement models for the performance-based tasks and teacher ratings (Samples 1 and 2), goodness-of-fit statistics for the measurement models, and the results of any other models tested that had poor fits are not reported here but are openly available (<https://osf.io/whzrg/>).

Initial models run with all BASC2_{EF} items were poor fits. We decided to look at the specific items in BASC3_{EF} and noticed that many of the problematic items from BASC2_{EF} were not in BASC3_{EF}. BASC2_{EF} model fits improved after removing the items not in BASC3_{EF}. BASC2_{EF} models for which items not appearing in the BASC3_{EF} have been removed are labeled ‘adapted’ models. These models are reported here. BASC3_{EF} was not available when we started the Sample 1 study. Based on the post-hoc, BASC2_{EF} results, we collected Sample 2 data using BASC3_{EF} so that we could test how well BASC2_{EF} models applied to BASC3_{EF}. We report BASC3_{EF} models with all items (note – BASC3_{EF} models with only items in both versions had similar fits).

Before running the analyses, we took a few preliminary steps. We converted Likert scale responses from the rating scales to numerical values, with 1 for *never*, 2 for *sometimes*, 3 for *often*, and 4 for *always*. Reverse coding was used so that all items used positive valent scales so that higher scores represented frequent positive behaviors. Efficiency scores were computed for each of the computerized performance-based tasks. We converted efficiency scores for each performance-based task to standardized z-scores because the variability in scores due to the number of trials and time needed to complete the items across tasks created is problematic for SEM. Following procedures adopted by Lawson and Farrah (2017), we created age-adjusted data by taking residuals from a linear regression with age as the predictor and each individual performance-based efficiency score and BASC item as an outcome. Missing data were classified as missing at random and were replaced using full information maximum likelihood estimation (FIML; Allison, 2012; Enders, 2013). We adjusted for non-normal distribution in some of the measured variables using the Yuan-Bentler MLR estimation and reported only the scaled values for the fit indices (Bentler & Yuan, 1999; Brown, 2015; Tong et al., 2014; Yuan & Bentler, 1998). The goodness-of-fit of each models was assessed using well-accepted criteria for SEM: a non-significant chi-square value ($CFI > .90$, $TLI > .90$, $RMSEA \leq .07$, and $SRMR < .08$; e.g.,

Cheung & Rensvold, 2002; Hooper et al., 2008; Schumacker & Lomax, 2016). The Akaike Information Criterion (*AIC*) and the Bayesian Information Criterion (*BIC*) were used to compare model fit for models with different structures (lower values = better fit).

Results

Pairwise Pearson correlations on the age-adjusted data for each performance-based task and mean response scores for each item of the BASC2_{EF}/BASC3_{EF} subscales show many statistically significant correlations, although most are small effect sizes (Table 1; $r < .30$).

Cronbach's alpha tests indicated high reliability between the age-adjusted items for the BASC2_{EF} (behavior control = .90, attentional control = .93, problem solving = .81, emotional control = .83) and BASC3_{EF} factors (behavior control = .96, attentional control = .96, problem solving = .96, emotional control = .95).

The age-adjusted models with the full set of BASC2_{EF} items (see Table 2) are a poor fit compared to the adapted BASC2_{EF} models (Models 1a and 1b, Table 2 and Figure 2).

BASC2_{EF} and BASC3_{EF} Capture Different Components of Performance-Based Tasks

Sample 1

Model 1a (Figure 2) indicates that many of the links between individual computerized performance-based tasks and BASC2_{EF} factors were not significant. Span task (working memory) efficiency scores were significantly linked with behavioral control ($\beta = .26, p < .001$), attentional control ($\beta = .35, p < .001$), problem solving ($\beta = .33, p < .001$), and emotional control ($\beta = .25, p < .001$). Figure matching (shifting) scores were significantly linked with behavioral control ($\beta = .14, p = .01$), attentional control ($\beta = .19, p = .003$), problem solving ($\beta = .20, p = .001$), but not emotional control ($\beta = .12, p = .07$). Hungry donkey (executive decision making) efficiency scores had significant inverse links with problem solving ($\beta = -.14, p = .03$), and emotional control ($\beta = -.17, p = .02$), but not attentional control ($\beta = -.12, p = .06$) or behavioral control ($\beta = -.08, p = .19$). Stop signal (inhibition) efficiency scores were significantly linked with

emotional control ($\beta = .16, p = .04$), but not behavioral control ($\beta = .13, p = .05$), attentional control ($\beta = .12, p = .09$) or problem solving ($\beta = .13, p = .10$). Continuous performance (sustained attention) efficiency scores were not significantly linked to any BASC2_{EF} factors ($\beta = [.03, .07, .12, .02] p = [.58, .32, .12, .78]$). Tower of Hanoi task (planning) efficiency scores were also not significantly linked to any BASC2_{EF} factors ($\beta = [.04, .03, .08, .09] p = [.19, .74, .29, .31]$).

In contrast, Model 1b (Figure 2) indicates strong links between the overall performance-based latent and each BASC2_{EF} factor: behavioral control ($\beta = .48, p = .002$), attentional control ($\beta = .59, p = .001$), problem solving ($\beta = .64, p = .002$), and emotional control ($\beta = .44 p = .01$).

Sample 2

Model 2a (Figure 2) indicates that many of the links between individual computerized performance-based tasks and BASC3_{EF} factors were not significant. Span task (working memory) efficiency scores were significantly linked with behavioral control ($\beta = .15, p = .03$) and emotional control ($\beta = .15, p = .03$), but not with problem solving ($\beta = .12, p = .09$) or attentional control ($\beta = .13, p = .06$). Hungry donkey (executive decision making) efficiency scores had significant inverse links with behavioral control ($\beta = -.16, p = .03$), attentional control ($\beta = -.17, p = .01$), problem solving ($\beta = -.18, p = .01$), and emotional control ($\beta = -.15, p = .04$). Figure matching (shifting) scores were significantly linked with behavioral control ($\beta = .15, p = .04$), attentional control ($\beta = .32, p < .001$), and problem solving ($\beta = .30, p < .001$), but not emotional control ($\beta = .04, p = .55$). Stop signal (inhibition) efficiency scores had significant inverse links with behavioral control ($\beta = -.15, p = .04$) and emotional control ($\beta = -.16, p = .03$) but not attentional control ($\beta = -.12, p = .11$) and problem solving ($\beta = -.07, p = .30$). Continuous performance (sustained attention) efficiency scores were not significantly linked to any BASC3_{EF} factors ($\beta = [.01, -.05, -.07, -.002] p = [.87, .42, .18, .97]$). The same was true for Tower of Hanoi task (planning) efficiency scores ($\beta = [-.04, -.005, .02, -.03] p = [.54, .93, .77, .69]$).

In contrast, Model 2b (Figure 2) indicates significant links between the overall performance-based latent with attentional control ($\beta = .37, p < .001$) and problem solving ($\beta = .39, p < .001$), but not with emotional control ($\beta = .03, p = .73$) or behavioral control ($\beta = .17, p = .08$).

Discussion

There is a dearth of executive function research with samples from high-poverty, ethnic minority communities. The results of this two-sample study are consistent with other studies using computerized performance-based tasks in more affluent schools (e.g., Ellefson et al. 2020; Xu et al., 2020) and contributes two key findings. First, BASC2_{EF} in its original form is an adequate, but not excellent measure of everyday executive function behaviors by children from schools in high-poverty communities; restricting analyses to only items included in BASC3_{EF} or using BASC3_{EF} is best practice. Second, BASC3_{EF} seems better able to capture the different components of performance-driven tasks, whereas BASC2_{EF} captures overall executive functioning better than individual tasks.

BASC3_{EF} is More Appropriate for High-Poverty, Ethnic Minority Samples

The post-hoc approach used with adapted BASC2_{EF} indicated that the better fitting models are more aligned with the structure of BASC3_{EF}, rather than BASC2_{EF}. In addition to the removal of several items that appear in BASC2_{EF}, BASC3_{EF} has some new items that were not included in earlier versions. The inclusion of new items and the removal of specific items from BASC2_{EF} improved the fit for data from these two age-adjusted, high-poverty, ethnic minority samples. This finding suggests that BASC2_{EF} in its original form might be a good fit for some populations, but it is not the best option for high-poverty samples.

The original BASC2_{EF} might not have an excellent fit for a variety of reasons. One option could be that the items do not apply equivalently across all groups of children. Another is that the BASC3_{EF} items are more aligned with current understanding of behaviors related to

everyday executive functioning skills. Even though the BASC3 is the most up-to-date version of the BASC itself, the BASC2_{EF} is the more recent measure, established after BASC3_{EF}. Karr & Garcia-Barrera (2017) acknowledge that the existence of BASC3_{EF} could mean that the derived BASC2_{EF} is used less frequently than BASC3_{EF}. They derived the BASC2_{EF} because of its popularity and the likely existence of archived datasets that necessitate an embedded, psychometrically supported instrument for the assessment of executive functions.

Even though BASC2_{EF} is a reliable and valid measurement of executive function, those psychometric properties are based on a predominantly white, middle-income sample. The current study suggests these findings do not generalize to ethnic minority children in high-poverty contexts. Even though the BASC2_{EF} might be an outdated measure, it will likely continue to show up in archived datasets and longitudinal work, making this line of research on BASC2_{EF} important despite the existence of BASC3_{EF}. Based on our findings, we recommend that analyses of the BASC2_{EF} with archived or longitudinal datasets from high-poverty settings should use similar procedures to remove BASC2_{EF}, not found in BASC3_{EF}. Taken together, these findings have implications for how executive function skills are conceptualized and measured.

BASC3_{EF} is Better Able to Capture Distinct Elements of Performance-Based Tasks

Everyday executive functioning skills measured by BASC2_{EF}, are best linked to an overall latent of computerized performance-based tasks. This finding corroborates Duckworth and Yeager (2015), suggesting that behavior rating scales are likely looking at behaviors that require a combination of different executive function skills, so they are represented by a global ability. It is likely that classroom behaviors are mediated by multiple executive functions, so some behavior rating scales may not be as good at capturing the distinctive skills as well as performance-based tasks. For example, the attentional control subscale could involve working memory, inhibition, and switching skills. However, everyday settings do not make it obvious if those skills are working in harmony or tandem.

BASC2_{EF} seems best linked to an overall performance-based task latent, whereas BASC3_{EF} can capture distinctions across performance-based tasks. The changing emphasis of the items in BASC3_{EF} subscales could account for its ability to capture individual elements of everyday executive functioning better than BASC2_{EF}. The new BASC3_{EF} questions could be capturing more individual executive function elements, allowing the subscale to target self-control and distractibility. The attentional control subscale added more items about following directions and keeping focused in BASC3_{EF}. The BASC2_{EF} problem solving subscale contained items about good study routines, cooperating with classmates, staying organized, making decisions, and working in stressful settings that were excluded from BASC3_{EF}, allowing the subscale to target planning and analyzing problems. The BASC2_{EF} emotional control subscale included items about adapting to changing circumstances that were eliminated in BASC3_{EF}, shifting the subscale to target adjustment to stressful situations and propensity for anger.

Results for models depicting individual executive function tasks (Models 1a and 2a) remain consistent between the BASC2_{EF} and BASC3_{EF} for the cognitive flexibility, sustained attention, and planning tasks. However, there are differences in the working memory, executive decision-making, and inhibition tasks that could be explained by the changes in the subscales.

There are significant positive links between working memory (i.e., spatial span task) and all BASC2_{EF} subscales, but significant links only for the behavioral control and emotional control BASC3_{EF} subscales. The broader scope of BASC2_{EF} subscales could create stronger links with working memory, as each may be capturing multiple executive functions. Looking closely at how the items change between the BASC2_{EF} and BASC3_{EF}, it is possible that the items in the attentional control and problem solving BASC3_{EF} subscales do not capture the behaviors linked to working memory in the same way as BASC2_{EF}. In particular, the problem solving subscale excluded items that were not related to planning and problem solving, and the BASC3_{EF} attentional control subscale included more specific items about following directions and

maintaining focus. In both instances, the BASC3_{EF} subscales are more targeted, potentially weakening the links between problem solving and attentional control with working memory.

There are significant negative links between executive decision-making (i.e., hungry donkey task) and the BASC2_{EF} problem solving and emotional control subscales and non-significant links for the BASC2_{EF} behavioral control and attentional control subscales. In contrast, there were significant negative links between executive decision making and all BASC3_{EF} subscales. The removal of BASC2_{EF} items about disruptive and harmful behavior towards other children in the BASC3_{EF} behavioral control subscale and new items about following directions and keeping focused in the BASC3_{EF} attentional control subscale could have elicited stronger negative links to executive decision making.

The links between inhibition (i.e., stop signal task) and BASC2_{EF} subscales are positive and significant. In contrast, they are negative (or non-significant) for BASC3_{EF}. Looking at the specific items, some new BASC3_{EF} items could capture post-error slowing behaviors. Briefly, post-error slowing is the inclination for participants to slow down on the current trial after committing an error on the previous trial (Rabbitt, 1966); this speed-accuracy trade-off reflects an intent to increase accuracy (e.g., Botvinick et al., 2001). The design of the stop signal task allows children to be more aware of their errors and the efficiency metric is more sensitive to post-error slowing than the other performance-based tasks in this study. Students might use a similar strategy in classrooms by reflecting on their mistakes, thinking critically, and controlling their negative emotions when making errors (de Mooij et al., 2022). Several new items in the BASC3_{EF} target these types of behaviors. Specifically, attentional control (following directions and keeping focused) taps into reflecting on mistakes. Problem solving (planning and analyzing problems) taps into thinking critically. Emotional control (adjusting to stressful situations and propensity for anger) taps into controlling negative emotions when making errors. The inclusion of new items that emphasize these classroom behaviors may be the reason why there are both

negative links between the stop signal task and these BASC3_{EF} subscales and why the link between the overall performance-based latent and these scales is smaller than for BASC3_{EF}.

Variation also exists between the overall executive function models and BASC subscales (Models 1b and 2b). All paths between overall executive function and the adapted BASC2_{EF} subscales show significant links. Paths between overall performance-based executive function and BASC3_{EF} attentional control and problem solving subscales show significant links, but paths between overall executive function and behavioral control and emotional control are non-significant. The changed BASC3_{EF} subscale items may have weakened those links, as the target of each subscale became narrower and encompassed fewer classroom behaviors.

Our findings suggest that researchers with archived or longitudinal BASC2_{EF} datasets from high-poverty settings wanting to compare BASC2_{EF} responses to performance-based tasks should use a composite score (or single latent variable) of that task performance rather than looking at links between individual tasks and BASC2_{EF} subscales to reduce Type II errors. Researchers planning new projects with BASC3_{EF} should be able to explore direct performance-based task links or use composite scores. However, they should consider the specific performance-based tasks they are measuring and how each task maps onto the BASC3_{EF} items.

Finally, these findings indicate that teachers are appropriately identifying where children are in terms of executive functioning based on their observations of everyday behaviors. As the field gets better at working with teachers to develop effective ways of incorporating executive function research into classroom practice, it is worth remembering that teachers already have knowledge surrounding everyday executive function behaviors, even if they don't have the same vocabulary that is used in cognitive psychology contexts (Perry et al., 2015). It is important for researchers to work with teachers collaboratively, rather than from the top down to build upon their existing expertise (Ellefson et al., 2019). Teachers are already in a good position to implement well-designed curriculum centered on building executive function skills, especially

when researchers recognize that teachers bring a sophisticated understanding of everyday executive functioning to the table (Faith et al., 2022).

Limitations and Future Directions

Although these findings make a unique contribution to the field by comparing teacher ratings of everyday behaviors with computerized performance-based tasks, there are some limitations and areas where further research is needed.

Future research should test additional theoretical models that are suited to the complexity of the executive function constructs, investigating whether the current findings generalize to other computerized performance-based executive function tasks and observer reports of executive function in children, completed by teachers and parents alike. The current battery of computerized performance-based tasks are themselves only one metric of a different aspect of executive function skills (e.g., inhibition, working memory). Research designs using additional tasks could be used to test how robust these findings are for different types of performance-based tasks measuring the same executive function skills. If three different performance-based tasks were used for each of the three key aspects of executive function (i.e., inhibition, shifting, working memory) commonly presented in the literature (Miyake et al., 2000; Riggs et al., 2006), then a theoretical evaluation of the unity and diversity of executive function could be tested across performance-based and behavior rating scales. Furthermore, it is important for computerized performance-based tasks to be standardized and full psychometric evaluations conducted, especially with older children. Such work would enable better comparison with other executive function metrics developed in clinical, developmental, or neuropsychology settings.

It is possible that some differences in the findings between the two samples could be driven by participant demographics. Future work could specifically sample across ethnic minority groups to investigate whether there are any systematic biases in behavior rating scales that might distinctively affect children from diverse minoritized backgrounds.

Additionally, nested models were not included in the current study as the teacher was not an appropriate predictor and the sample lacked sufficient statistical power. Though much of the existing literature does not include nested models (e.g., McAuley et al., 2010; Miranda et al., 2015, Van Tetering & Jolles, 2017), it would be useful for future research with larger sample sizes to include nesting of teachers in schools to better understand whether there are any response biases, especially when studying children from high-poverty and/or ethnic minority families.

Recent work by Camerota et al. (2020) highlights the need for critical evaluation of the best way to represent executive functions in measurement models. While the current study aligns with a common reliance on confirmatory factor analysis or structural equation models to represent the construct of executive functions (e.g., Miyake et al., 2000; Miyake & Friedman, 2012; Wiebe et al., 2008), Camerota et al. warn against accepting these measurement models as the default without implementing a reasoned approach for selecting them because interpretational differences can occur depending on the measurement model selected to represent executive functions. Our BASC3_{EF} results substantiate their advice. Future research would benefit from the implementation and comparison of different models (e.g., formative latent variable models) that may represent executive functions differently.

Conclusions

Results from the current study indicate a robust link between the performance-based tasks and both versions of the BASC_{EF}. Children's performance on these computerized performance-based tasks does appear to be linked to the behaviors that teachers report on BASC_{EF} rating scales. However, BASC2_{EF} in its original form is not a good representation of everyday executive function behaviors by children from schools in high-poverty communities. Given the popularity of BASC2, it is likely that future research using this measure will continue to extend from archived datasets and longitudinal work. As such, it is important to recognize that

the derivation of BASC2_{EF} could be useful as an embedded executive function screener for many archived BASC2 datasets. However, it is not an appropriate screener for data from children from ethnic minority families from low-income communities without removing items that are not in BASC3_{EF}. When given the choice, BASC3_{EF} is more appropriate for children from high-poverty, ethnic minority populations.

This work opens a window for exploring the links between computerized executive function tasks and observer reports of children within the context of low-income, urban communities. Our findings indicate that it may not be appropriate in some cases to use the same assessments with individuals of various racial/ethnic minority groups and socio-economic backgrounds. This reaffirms the importance of including diverse samples in executive function research and exploring the utility of different versions of executive function screeners that continue to be used in longitudinal research or archived datasets.

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Table 1

Correlations Amongst the Performance-Based Tasks and Teacher Rating Subscales (using Age-Adjusted Data)

	Stop Signal	Continuous Performance	Spatial Span	Figure Matching	Tower of Hanoi	Hungry Donkey	Behavioral Control	Attentional Control	Problem Solving	Emotional Control
Stop Signal	--	.05	.18*	.47***	.10	-.04	-.05	.06	.09	-.10
Continuous Performance	.21*	--	.13*	.03	.06	-.05	.03	-.02	-.04	.02
Spatial Span	.17*	.11	--	.34***	.38***	-.14*	.17**	.22***	.23***	.17*
Figure Matching	.12	.08	.13	--	.23**	-.07	.13	.31***	.32***	.02
Tower of Hanoi	.05	.04	.17*	.12	--	-.12	.05	.12	.14*	.05
Hungry Donkey	.09	.17*	.20***	.00	.20**	--	-.17*	-.20*	-.21**	-.18**
Behavioral Control	.21**	.09	.29***	.19**	.09	.00	--	.80***	.56***	.83***
Attentional Control	.19**	.12	.35***	.23**	.10	-.02	.76***	--	.81***	.62***
Problem Solving	.20**	.18**	.33***	.26***	.15*	.00	.59***	.81***	--	.49***
Emotional Control	.17*	.01	.23***	.17*	.12	-.08	.68***	.63***	.65**	--

Notes. BASC2_{EF} (n = 243) below the diagonal; BASC3_{EF} (n = 229) above the diagonal, with * $p < .05$, ** $p < .01$, *** $p < .001$. Correlations are large effect sized for values $> .50$, medium effect sized for values $> .30$ and small effect sized for values $> .10$.

Table 2*Structural Equation Models Goodness-of-fit Statistics*

<i>Model</i>	<i>χ^2</i>	<i>df</i>	<i>RMSEA</i>	<i>CFI</i>	<i>TLI</i>	<i>SRMR</i>	<i>AIC</i>	<i>BIC</i>
Sample 1								
Individual Performance-Based Tasks with original BASC2 _{EF}								
	1400.24 ^{<.001}	663	.07	.86	.85	.07	19811	20348
Single Latent for Performance-Based Tasks with original BASC2 _{EF}								
	1440.90 ^{<.001}	692	.07	.86	.85	.07	19790	20227
Model 1a: Individual Performance-Based Tasks with adapted BASC2 _{EF}								
	565.33 ^{<.001}	285	.07	.91	.89	.05	14069	14482
Model 1b: Single Latent for Performance-Based Tasks with adapted BASC2 _{EF}								
	602.99 ^{<.001}	314	.06	.91	.90	.06	14045	14358
Sample 2								
Model 2a: Individual Performance-Based Tasks with BASC3 _{EF}								
	1167.09 ^{<.001}	590	.07	.92	.91	.05	15697	16210
Model 2b: Single Latent for Performance-Based Tasks with BASC3 _{EF}								
	1220.80 ^{<.001}	619	.07	.92	.91	.07	15692	16106

Notes. Scaled values are reported for all fit indices because the data were non-normally distributed. *p*-values for χ^2 are listed as superscripts; *df* = degrees of freedom; *RMSEA* = scaled root mean square of approximation; *CFI* = scaled comparative fit indices; *TLI* = scaled Tucker and Lewis' index; *SRMR* = Standardized Root Mean Square Residual using Bentler's formula; *AIC* = Akaike information criterion; *BIC* = Bayesian information criterion (sample-size adjusted). Data presented here have been adjusted for age. Full results are openly available from <https://osf.io/whzrg/>.

Figure 1

SEM Models Testing the Links Between Performance-Based Computerized Tasks and Behavior Rating Scales

Model 1a - Individual EF Tasks with adapted BASC2_{EF}

Model 2a - Individual EF Tasks with BASC3_{EF}

Model 1b- Overall EF with adapted BASC2_{EF}

Model 2b- Overall EF with BASC3_{EF}

Notes. Numbers in the boxes on the right-hand side of each model are the item numbers in the BASC2_{EF}/BASC3_{EF}. ^R Indicates reverse coded item.

Figure 2

Links Between Performance-Based and Behavior Ratings of Executive Functions

Model 1a - Individual EF Tasks with adapted BASC-2

(Sample 1)

Model 2a - Individual EF Tasks with BASC-3

(Sample 2)

Model 1b- Overall EF with adapted BASC-2

(Sample 1)

Model 2b- Overall EF with BASC-3

(Sample 2)

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$. ^R Indicates reverse coded item. For simplicity, only latent variable predictions included here. Full results are openly available from <https://osf.io/whzrg/>.