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RESEARCH BRIEF

Executive Functioning Assessments in Early Childhood Screenings

Purpose of the Study

Early identification of academic challenges is essential to ensure that children receive the proper supports and intervention services to bolster their chances of long-term success. The current set of three studies evaluated whether including measures of executive function in early childhood screening increases our ability to predict later academic success across a diverse population of children. We then evaluated whether each measure of executive function worked as intended across different groups of children.

Background & Purpose

Executive function skills are foundational for learning and may provide unique insights into long term school success.

Over the last three decades, national and state level policies in Minnesota have mandated children be screened prior to entering kindergarten. Screening was instituted to identify children in need of early intervention services, and to reduce opportunity gaps and disparities in achievement. Early childhood is a period of rapid brain development that presents an opportunity for early intervention programs to promote long-term academic success (Graham, 2005). One set of neurocognitive skills that rapidly develop during this period is executive function (EF), which helps us follow directions, pay attention, ignore distractions, hold things like phone numbers or instructions in mind, and try different strategies to solve problems (Zelazo, 2020). EF skills are foundational for learning and are associated with long-term school success (Hendry et al., 2016; Hughes et al., 2020; McClelland et al., 2006; McHarg et al., 2020; Perez-Edgar et al., 2020). Measures of EF may also be less biased than traditional cognitive tests (read, count, hold a pencil, etc.) because they assess *how* children learn rather than *what* children know (Blair & Razza, 2007; Masten et al., 2012; Obradović, 2010). The research presented in this brief examined the value of adding EF assessments to early childhood screening.

The three studies included in this brief evaluate how EF assessments in early childhood screening relate to third grade benchmark tests of academic proficiency in math and reading. Third grade academic performance on such tests is important because it predicts future academic success, including school engagement, high school graduation, and college enrollment (Goldhaber et al., 2021; Hernandez, 2011; Lesnick et al., 2010). Identifying malleable early indicators of later academic challenges is important for designing early intervention efforts to bolster young children's likelihood of later academic success (Zelazo et al., 2016).

The current brief will present results from a series of three studies with the following primary research questions:

1. ***Study One:*** *Does measuring EF add value to existing screening protocols by increasing accuracy in predicting third grade academic achievement?*
2. ***Study Two:*** *How well does each computerized EF measure work across age, race, poverty status, and special education status in predicting third grade academic achievement?*
3. ***Study Three:*** *Does a brief parent report measure of EF predict later academic achievement similarly to direct measures of EF?*

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Participants

All three studies draw from a sample of 606 families in Minneapolis, Minnesota, who agreed to participate in a study during their early childhood screening with the Minneapolis Public School (MPS) district. Through Minn-LInK, participating children's screening and assessment data were integrated with data from the Minnesota Department of Education. At the time of screening, children who participated were 3 to 6.25 years old (M = 4.58, SD = 0.81). Children were screened at multiple community-based sites to ensure the sample was representative of children in MPS. Children were 37% White, 32% Black, 10% Asian, 6% Native, and 9% Multiracial. Approximately 13% of the sample identified as Hispanic. Many children spoke more than one language, and 18% of the sample completed screening in a language other than English. Approximately 12% (n = 70) of the sample was screened while staying in emergency homeless shelters, and the mean income based on census tract data for children not screened in shelters was $53,645 (SD = $25,309) U.S. dollars.

Study One

The central question of study one was to evaluate whether measuring EF during early childhood screening adds to long-term predictive utility of existing screening procedures. It addressed this question through four aims:

Aim One:	Does EF predict third grade academic achievement?
Aim Two:	How well do the screening measures typically used by Minneapolis Public Schools predict third grade academic achievement?
Aim Three:	Does evaluating EF add predictive value to existing screening tools?
Aim Four:	Do EF and the existing screening measures predict to academic achievement similarly across age at screening, sex, and racial/ethnic background?

Participants and Methods

Study one included 471 children (53% Female; M_{age} = 4.54 years) who completed at least one EF task and were English speaking. Children primarily identified as Black (36%) or White (52%). EF tasks included: (1) Peg-Tapping (Diamond & Taylor, 1996), which assesses a child's ability to hold different rules in mind and inhibit the natural tendency to directly copy an administrator's actions. Children were told to tap a dowel once when the administrator tapped twice and to tap twice when the administrator tapped once. This occurred across 16 counterbalanced trials. This task has been found to work well with children experiencing low-income (e.g., Blair & Raza, 2007) and homelessness (e.g., Masten et al., 2012; Obradović, 2010). (2) Flanker Inhibitory Control and Attention Task with Developmental Extension (Flanker-Dext; Anderson et al., 2021) is a computer-based measure that assess a child's ability to pay attention and ignore distractions (Rueda et al., 2004). Children are presented with five fish on a screen and told to touch an arrow that matches the way the middle fish is pointing. The flanking fish either point in the same or opposite direction as the middle fish. The developmental extension includes easier levels that add more space between the middle and flanking fish, increase the size of the middle fish, or make the fish different colors. (3) Dimensional Change Card Sort with Developmental Extension (DCCS-Dext; Carlson et al., 2021) is a computer-based measure that assesses a child's ability to flexibly follow different rules. Children are presented with pairs of pictures that can vary by shape and color. Children are asked to first sort pictures by shape and then directed to sort pictures by color. If children successfully sort by the two rules, they are then asked to switch back and forth between sorting by shape and color. If children cannot pass the initial rounds of the task, they are given easier levels, such as sorting by animal type (elephant and fish) or size (big kitty and little kitty).

Figure 1: Example Flanker Fish Developmental Extension Screenshots

Study one also included screening measures that are already a part of the standard early childhood screening protocol for the district. This includes the Minneapolis Preschool Screening Instrument-Revised (MPSI-R; Minneapolis Public Schools, 2007), which the MPS

district developed and use as their primary developmental screener. This assessment measures developmental skills that are foundational to future learning including: motor skills, cognitive skills, language, and literacy. The screener also includes a report from primary caregivers on their children's social and emotional skills via the Ages and Stages Questionnaire – Social and Emotional (ASQ-SE; Squires et al., 2002). This is a validated and non-diagnostic screening tool aimed at identifying children with social-emotional challenges. It covers a wide skill set including: self-regulation (i.e., the ability to adjust to new environmental conditions), compliance with directives, ability to initiate communication, adaptive functioning (e.g., basic skills like sleeping and eating), the ability to respond to situations without guidance, affect expression, and general social skills.

Figure 2: MCA 3rd Grade Math Achievement by EF Performance at Pre-Kindergarten Screening

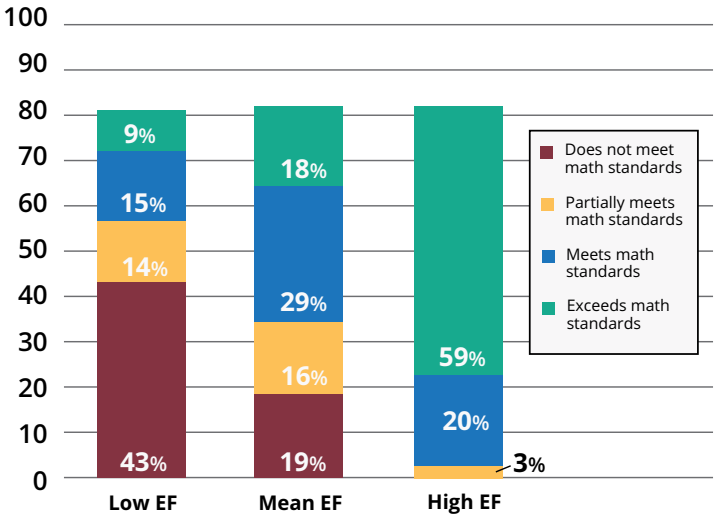
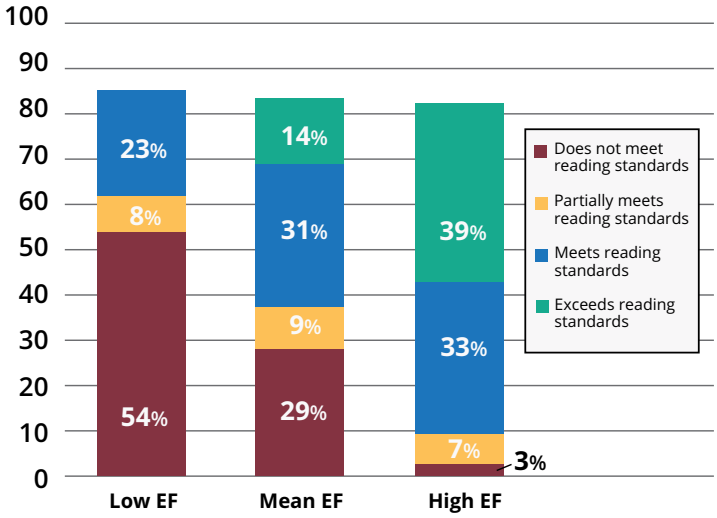


Figure 3: MCA 3rd Grade Reading Achievement by EF Performance at Pre-Kindergarten Screening



Third grade academic achievement data were integrated through administrative data collection and measured via the Minnesota Comprehensive Assessments (MCAs). The MCAs are Minnesota's state wide online adaptive tests in reading and mathematics that are used to meet federal and state legislative requirements for education. Children in this sample were in the third grade from the 2015-2016 through the 2018-2019 academic year. Scores ranged from 1 to 99 on reading with a mean score of 48.02, and ranged from 15 to 92 on math with a mean of 52.25. Study one questions were assessed using a series of structural equation models. A single latent factor for EF was created using all three task-based measures of EF and demonstrated adequate model fit.

Findings

Results for aim one suggested that, when controlling for child sex and race, EF was a significant and strong predictor of reading (B = 0.54, SE = 0.05, p < .001) and math (B = 0.58, SE = 0.05, p< .001). EF, sex, and child race predict 52% of variance in third grade math scores and 48% of variance in reading scores. Results for aim two suggested that the MPSI-R, controlling for child sex and race, also was a strong predictor of later academic achievement (reading: B = 0.55, SE = 0.04, p< .001; math: B = 0.54, SE = 0.04, p < .001). Those variables explained 51% of the variance in math and 52% of the variance in reading. The ASQ-SE was not related to third grade academic achievement. When we included the EF measures and the MPSI-R together to address aim three, EF explained an additional 4% of the variance in third grade math achievement and 2% of the variance in reading. Finally, to address aim four we examined whether these associations differed by child age at screening, Black or White race, and sex; we did not find any significant differences, suggesting that EF and the MPSI-R are unbiased predictors across these subgroups of children.

Study Two

The results from study one indicated that incorporating EF measures into early childhood screening provides additional predictive value to third grade achievement when administered alongside routine screening measures. In study two, we focused more specifically on how each of the two computerized measures of EF—the Flanker-Dext and DCCS-Dext—were functioning. Honing in on

whether individual measures have predictive value to third grade achievement can guide decisions about adopting a particular assessment. Previous research with the same data set has already shown that both tasks have excellent concurrent and short-term predictive validity to kindergarten (Kalstabakken et al., 2021), but their independent long-term utility in predicting academic achievement had yet to be explored. The two aims of the study were as follows:

Aim One: Do the Flanker-Dext and DCCS-Dext (both together and separately) predict third grade academic achievement?

Aim Two: Does age at the time of screening, poverty status, racial/ethnic background, or special education status affect the strength of the relation between Flanker-Dext or DCCS-Dext and third grade academic achievement?

Participants and Methods

Participants included 402 children (51% Female; M_{age} = 4.59 years) drawn from the full population of children described above who completed both Flanker-Dext and DCCS-Dext measures, as well as the language subtest of the MPSI-R, during routine early childhood screening. Children primarily identified their race as Black (36%) and White (52%). Over half of the children in the sample qualified for free or reduced lunch and 16% of children were eligible for special education services at some point between kindergarten and the third grade. All other variables are the same as described in study one. To assess aims we used a series of hierarchical linear regression models.

Findings

For aim one we found that the DCCS-Dext and Flanker-Dext predicted both math (DCCS-Dext: B = 1.42, SE = 0.32, p< .001; Flanker-Dext: B = 2.02, SE = 0.39, p< .001) and reading (DCCS-Dext: B = 2.01, SE = 0.46, p< .001; Flanker-Dext: B = 2.46, SE = 0.56, p< .001) achievement, controlling for age, gender, and language skills. Each Dext EF measure was a significant predictor of third grade math and reading when both were entered in the same regression model; together they accounted for 15% of the variability in math scores and 13% of the variability in reading scores. We then examined the DCCS-Dext and Flanker-Dext independently of one another and found that each measure, alone, explained a considerable portion of the variation in both math (DCCS-Dext = 10%; Flanker-Dext = 12%) and reading (DCCS-Dext = 9%; Flanker-Dext = 8%). These findings suggest there is added value in administering both Dext measures to children to gain a more comprehensive picture of their EF skills. However, as it may not be feasible for researchers, educators, or practitioners to administer both measures due to time constraints or other logistical challenges, using just one measure still offers significant predictive utility to later achievement. Through analyses evaluating aim two, we found that both the DCCS-Dext and Flanker-Dext were equally predictive of math and reading across children's poverty status, racial/ethnic background, and special education status. However, there was some evidence that the Flanker-Dext was less predictive of third grade math performance for 3-year-olds compared to older children. The DCCS-Dext did not significantly vary in strength of prediction by child age at screening.

Study Three

Both study one and study two provided strong evidence that task-based measures of EF can be administered effectively in routine early childhood screening, but these measures may present practical challenge that impede implementation in some settings. A potential alternative to task-based measures are parent report questionnaires. Questionnaires can minimize logistical barriers including administration time and training requirements while still gathering accurate and predictive information. The purpose of study three was to evaluate whether a newly developed parent report measures of EF—the Short Executive Functioning Questionaire (SEFQ)—accurately captures children's EF skills and could be a useful alternative to more intensive task-based measures of EF. The three aims of the study were:

Aim One: Does the SEFQ measure EF similarly across child age, gender, racial/ethnic background, and income?

Aim Two: Is the SEFQ related to task-based measures of EF?

Aim Three: Does the SEFQ predict to third grade academic achievement?

Participants and Methods

Participants for the current study included 380 children (54% Female) from the sample of 606 children described above who received all measures in English, self-identified their race as Black (n = 169; 43%) or White (n = 211; 57%), and were three to five years old (M_{age} = 4.51 years). There were not enough children who spoke other languages (Spanish = 49; Hmong = 36; Somali = 23), identified as another race (Asian = 59; American Indian/Alaska Native = 37; Multiracial = 55), or were six years old (n = 4) to examine whether the SEFQ worked differently in those groups.

In addition to the measures described in studies one and two, study three also included the SEFQ (a newly developed parent report questionnaire of children's EF skills). This scale included questions about how well children could pay attention, ignore distractions, delay the fulfillment of their wants/desires, remember instructions, regulate their emotions, and flexibly use different rules. Parents were

asked to rate their children on a scale from 1 (extremely untrue of your child) to 7 (extremely true of your child) on 14 items. Overall, the SEFQ had an alpha of 0.79 suggesting that the items worked well together.

We tested if the measure worked the same way across census-tract estimated income, race, age, and sex and then adjusted for any differences using a statistical technique called moderated non-linear factor analysis. We then assessed if the SEFQ was related to other EF measures and screening measures in expected ways using correlations. We also tested if the SEFQ predicted to third grade academic achievement using hierarchical linear regression models.

Findings

We found that the SEFQ worked best as two separate subscales—one comprising of reverse worded items that tap into children's EF challenges and the other with positively worded items that tap into children's EF skills. Results for aim one suggested that four items on the positively worded EF skills scale and two items on negatively worded EF challenges scale functioned differently for children depending on age and race. After adjusting for measurement differences across race and age, results for aim two suggested that the EF challenges subscale was most related to task-based measures of EF (significant partial correlations = 0.20 to 0.29). Finally, in addressing aim three we found that the EF challenges scale predicted third grade math achievement (B = 2.98, SE = 0.89, p< .001), even while controlling for demographic variables and the MPSI-R (B = 2.00, SE = 0.85, p< .05). However, the EF challenges subscale only explained about 1% of the variability in third grade math scores and did not predict third grade reading scores. These results suggest that parent reports of EF could be useful in settings that do not have established protocols for child assessment, however, they do not provide as much information as task-based measures of EF and are less related to long term academic achievement.

Executive functioning in early childhood is important for later academic success. Measures of executive functioning added predicative value to existing screening protocols by increasing prediction to third grade academic achievement outcomes. This may be because executive functioning assessments measure malleable skills and add more information about learning readiness by systematically measuring how well children pay attention, follow instruction, flexibly shift their behaviors, and ignore distractions..

Conclusion

Overall, the results presented in this brief support the inclusion of EF assessments in routine early childhood screening. The three studies found that:

- The developmental screening tool (MPSI-R) that is currently used in the Minneapolis Public Schools and many other Minnesota school districts has strong associations with third grade math and reading scores, and showed no evidence of bias by children's age at screening, race, or sex in how well it predicts to achievement.
- Children's EF skills in early childhood predicted later academic achievement. As shown in Figure 1 and 2, children with strong EF skills at screening were much more likely to exceed the standards assessed in the MCAs compared to those with weaker EF skills. Moreover, cumulative EF measures and each computer-based task had unique predictive value as part of a standard screening battery.
- The task-based measures of EF were less likely than the parent report measure (SEFQ) to demonstrate bias across children's age and race, although one of the computerized measures of EF (Flanker-Dext) had less predictive value for three year old children.
- The task-based measures of EF were better predictors of third grade achievement than the parent report measure of EF, but when logistical barriers to administration are high, short parent report measures may still be a useful way to capture a child's EF skills

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Limitations

The findings from this series of studies should be interpreted in light of several limitations. Our results may not generalize to children who speak languages other than English. Despite having translations of questionnaire measures, computer task-based measures were only programed in English. The current series of studies did not evaluate the individual contribution of the table-top measure, Peg-Tapping, but given higher examiner burden of task training and administration for this task, inclusion of this measure in routine screening is not likely. Further, due to the small number of participants in this study who were Asian, Native American, Hispanic, or Multiracial, we could not assess the effect of race/ethnicity beyond that of Black and White children. Additionally, the EF measures included here were not yet normed, so there are no specific cutoff scores representing atypical functioning. Finally, it should be noted that the parent report EF measure (SEFQ) is in an earlier stage of development and requires additional research to establish its reliability for use in broader educational or health settings.

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