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Why doesn't executive function training improve academic achievement? Rethinking individual differences, relevance, and engagement from a contextual framework

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Abstract

Performance on lab assessments of executive functions predicts academic achievement and other positive life outcomes. A primary goal of research on executive functions has been to design interventions that

improve outcomes like academic achievement by improving executive functions. These interventions typically involve extensive practice on abstract lab-based tasks and lead to improvements on these practiced tasks. However, interventions rarely improve performance on non-practiced tasks and rarely benefit outcomes like academic achievement. Contemporary frameworks of executive function development suggest that executive functions develop and are engaged within personal, social, historical, and cultural contexts. Abstract lab-based tasks do not well-capture the real-world contexts that require executive functions and should not be expected to provide generalized benefits outside of the lab. We propose a perspective for understanding individual differences in performance on executive function assessments that focuses on contextual influences on executive functions. We extend this contextual approach to training executive function engagement, rather than training executive functions directly. First, interventions should incorporate task content that is contextually relevant to the targeted outcome. Second, interventions should encourage engaging executive functions through reinforcement and contextual relevance, which may better translate to real-world outcomes than training executive functions directly. While such individualized executive functions interventions do not address systemic factors that greatly impact outcomes like academic achievement, given the extensive resources devoted to improving executive functions, we hypothesize that interventions designed to encourage children's engagement of executive functions hold more promise for impacting real-world outcomes than interventions designed to improve executive function capacities.

Why Doesn't Executive Function Training Improve Academic Achievement? Rethinking individual differences, relevance, and engagement from a contextual framework

Jesse C. Niebaum & Yuko Munakata

Performance on lab-based assessments of executive functions improves dramatically across childhood and predicts concurrent and future academic achievement for children around the world (Ahmed et al., 2019; 2021; Cortés Pascual et al., 2019; de Santana et al., 2022; Robson et al., 2020; Spiegel et al., 2021). To leverage these associations, vast research and commercial efforts have been devoted to supporting the development and improvement of executive functions through cognitive training interventions, in hopes of improving academic achievement and other positive life outcomes. Interventions aimed at improving executive functions often involve extensive practice on lab-based executive function assessments (for reviews, see Diamond & Ling, 2019; Jacob & Parkinson, 2015; Kassai et al., 2019). For example, to train inhibitory control, children may repeatedly practice a Flanker task, in which they respond according to the direction of a central stimulus, such as a fish, that is surrounded by flanking stimuli pointing in the same or opposite direction. Such interventions make several assumptions about the nature and development of executive functions: 1) that executive functions are domain-general cognitive skills applied across a variety of contexts; 2) that executive functions can be improved by performing lab-based tasks that require executive function; and 3) that benefits derived from practicing lab-based executive function tasks will translate to benefits in everyday life. However, although individual studies have shown promise for impacting academic achievement (e.g., Judd & Klingberg, 2021), meta-analyses of decades of research have led to a disappointing conclusion: training executive functions improves performance on the tasks used for training but rarely leads to domain-general improvements in executive function capacities and rarely benefits academic achievement or outcomes in the real world (Aksayli et al., 2019; De Simoni & von Bastian, 2018; Friese et al., 2017; Gobet & Sala, 2022; Jacob & Parkinson, 2015; Kassai et al., 2019; Diamond & Ling, 2019; Melby-Lervåg et al., 2016; Nesbitt & Farran, 2021; Sala et al., 2018; Sala & Gobet, 2019; Simons et al., 2016; Takacs & Kassai, 2019). Thus, meta-

analyses suggest that the apparent promise of individual studies rests on idiosyncratic effects that do not hold consistently across studies. These failures suggest that improving domain-general executive function capacities through direct training is not an especially effective target for intervention.

Contemporary frameworks of executive function development across childhood have shifted from viewing executive functions as domain-general cognitive processes to viewing executive functions as cognitive skills developed to meet specific demands in the environment. That is, children's executive functions develop and are engaged within personal, historical, social, and cultural contexts (Doebel et al., 2020; Munakata & Michaelson, 2021; Werchan & Amso, 2017). Abstract executive function tasks and the lab contexts in which they are administered do not well-capture executive functions in the real world (for discussions, see Miller-Cotto et al., 2021; Nketia et al., 2021; Zuilkowski et al., 2016). Instead, established lab-based assessments of executive functions are intentionally context-free, requiring participants to perform arbitrary tasks involving simple, static, and well-controlled stimuli in sterile lab settings with unfamiliar experimenters. The ubiquity of these kinds of established measures has contributed to a view of executive functions as reified entities that can be abstracted from the specific contexts in which they are developed and needed (for discussions, see Doebel, 2020; Moreau & Wiebels, 2022; Munakata & Michaelson, 2021). However, these types of tasks fail to capture the personal, historical, social, and cultural contexts that influence underlying processes contributing to performance on executive function assessments. Thus, extensive practice on executive function tasks in the lab should not be expected to improve domain-general executive functions or translate to benefits outside of the lab. We are not the first to suggest that contextualized executive function training programs could better generalize to outcomes in the real world, or that training programs that engage executive functions across broader contexts could lead to more generalized improvements in executive functioning (Diamond & Ling, 2019; Smith, 1982; Zelazo & Carlson, 2012).

However, in contrast to prior theoretical perspectives arguing for training executive function capacities, in this article, we propose a context-driven framework for training EF engagement. In this view, contextualized training programs are more likely to benefit real-world outcomes because they train the engagement of executive functions in the contexts that require them. Broader training programs are more likely to capture overlap between the training context and real-world outcomes. In either case, benefits for real-world outcomes are likely due to increased executive function engagement rather than increased capacities.

We build on contextual understanding of EF development to describe two distinct approaches for benefitting outcomes like academic achievement by training executive functions. First, we argue that interventions aiming to provide benefits outside of the lab by improving executive functions should include stimuli relevant to the real-world contexts that such interventions hope to benefit. Second, we argue that interventions targeting executive functions should focus on increasing children's willingness to engage executive functions instead of increasing children's executive function capacities. We focus our arguments on lab-based executive function tasks because these tools are frequently used as training materials in executive function training programs and as outcome measures to assess benefits from training (Diamond & Ling, 2019; von Bastian et al., 2022). Many longitudinal studies have also found relationships between executive functions and positive life outcomes using questionnaire measures of executive functioning (e.g., Moffitt et al., 2011). However, lab-based measures of executive function do not correlate well with questionnaire measures (Eisenberg et al., 2019), leading researchers to suggest that lab-based and questionnaire measures capture different aspects of executive function (Dang et al., 2020; Friedman & Gustavson, 2022; Ten Eycke & Dewey, 2016; Toplak et al., 2013).

Understanding the Relationship Between Executive Functions and Academic Achievement in Context

Several large-scale, longitudinal studies have found correlations between performance on executive function tasks and concurrent and future academic achievement (Ahmed et al., 2019; Cortés Pascual et al., 2019; de Santana et al., 2022; Robson et al., 2020). These relationships are typically interpreted as increasing executive function capacities supporting higher achievement in the classroom and beyond (Casey et al., 2011; Duckworth et al., 2013; Moffitt et al., 2011; Munakata et al., 2012; Spiegel et al., 2021; Young et al., 2009). For example, to succeed in school, children must maintain goals related to their learning in the face of interruptions and distractions, sustain their attention to stay on task through extended lessons, inhibit distracting sights and sounds in their classroom environment, and switch flexibly among different cognitive strategies, classroom activities and topics, and assignments (Zelazo & Carlson, 2012). A contextual framework for understanding executive functions and their development provides alternative and additional explanations for the correlations between executive functions and academic achievement beyond executive functions supporting higher academic achievement. Specifically, the ability to process the cues and stimuli used in established measures of executive function through increased familiarity with task content, through personal and cultural contexts, substantially contributes to task performance and may also contribute to academic achievement.

Individual executive function tasks often correlate poorly with each other, creating task-specific variance, even when tasks are designed to measure similar aspects of executive function (e.g., Friedman et al., 2006; Karr et al., 2018, 2022; Starr et al., 2022). Task-specific variance in performance on different executive function tasks is partially driven by differences in familiarity with the specific cues and stimuli used in different measures of executive function; that is, task-specific variation in performance is not only a consequence of the idiosyncratic differences

between particular tasks but also due to a child's personal, historical, and cultural experiences with task content, which eases the cognitive demands associated with processing task cues and stimuli. For example, cross-cultural studies of Dutch and Iranian adults performing a range of choice tasks involving target detection, working memory, and relational reasoning found that Dutch participants responded faster than Iranian participants across all tasks when geometric figures were used as task stimuli; however, when the task stimuli were replaced with Arabic alphabet characters, Iranian participants responded faster than Dutch participants (Sonke et al., 2020). This perspective can provide additional explanations for findings in research on the development of executive functions. For example, 5-year-old children performed significantly better on cued task-switching paradigms with contextually relevant sorting cues (e.g., a rainbow for color sorting and palette of shapes for shape sorting) compared with abstract cues (e.g., a black square for color sorting and gray circle for shape sorting) (Chevalier et al., 2011; Chevalier & Blaye, 2009). Children aged 7 and 9 years do not show the same magnitude of performance differences between arbitrary and more semantically related task cues, suggesting that performance differences across age could be driven by an individual's ability to process relevant cues or experience with abstract stimuli as cues for task operations (Chevalier & Blaye, 2009; Scribner & Cole, 1973). Greater familiarity with reflecting on objects according to dimensions like shape and color could also explain why Montessori preschool children outperform their similarly aged peers on card sorting tasks that require sorting arbitrary stimuli by color and shape (Doebel, 2020; Lillard, 2017). Contextually relevant stimuli and familiarity with task content can help younger children overcome the perseverative errors on flexibility tasks characteristic for their age (Yerys & Munakata, 2006; Holt & Deák, 2015).

Children exposed to poverty and violence typically perform worse on measures of executive function than their peers (Duncan et al., 2017; Ellis et al., 2022; Ursache et al., 2016). These lines of research typically use

measures of executive function with abstract stimuli that may be unfamiliar to children who experience poverty or violence as they grow up (for discussions, see Ellis et al., 2022; Frankenhuis et al., 2020; Frankenhuis & de Weerth, 2013). When executive function tasks incorporated more contextually relevant stimuli, such as faces and money instead of abstract stimuli like colored shapes (Caughy, Owen, & Deluna, 2016), performance differences in working memory updating between seventh and eighth grade U.S. children exposed to violence and poverty and their peers greatly diminished or disappeared (although group differences in attentional shifting remained; Young et al., 2022).

Cross-cultural differences in performance on established lab-based measures of executive function have also been observed (for review, see Schirmbeck et al., 2020). For example, 3-7-year-old children from South Africa performed worse than similarly aged children from the United States on a three-dimensional card sorting task, a standard measure of cognitive flexibility that uses more abstract stimuli (e.g., a small blue dog or large yellow snake); however, performance was similar across cultural groups on a flexible induction of meaning paradigm, another measure of cognitive flexibility in which participants must infer the meaning of words based on semantic cues from an experimenter describing arrays of pictures (Legare et al., 2018). South African children were tested in Tswana, their primary language, and United States children were tested in English. United States children performed worse when switching from trials with stronger semantic cues for word meaning (e.g., “is a…”) to trials with weaker semantic cues (e.g., “holds a…”), a commonly observed performance difference for this task; however, South African children did not show this typical semantic order effect, suggesting that task difficulty was driven by the differences in relative semantic strength of the specific cues used for each task across languages. Across these various studies, task content systematically influenced executive function task performance across children at different

ages and across different groups in ways that may not fully reflect differences in executive function capacities.

To address task-specific variance across assessments of executive functions, longitudinal studies investigating executive functions and their relationship to academic achievement often use composite variables that average performance across different executive function tasks or latent variables that extract shared variance across different executive function tasks (e.g., Ahmed et al., 2019; Blair et al., 2015; Robson et al., 2020). Composite and latent variables are thought to be purer and more reliable measures of executive functioning (Carlson & Moses, 2001), because individual executive function tasks require different aspects of executive function, as well as other cognitive skills (i.e., the “task-impurity problem”) (Miyake & Friedman, 2012). However, the composite and latent variables vary greatly depending on their constituent tasks, which could explain why results from investigations into the structure of executive functions have varied greatly across childhood (Doebel, 2020; Karr et al., 2018; 2022). Given that measures of executive function tend to correlate poorly with each other, latent factors of executive function may be inappropriate, especially across development (Rhemtulla et al., 2020). In addition to removing variance due to idiosyncratic task differences, composite or latent factors may also attenuate or remove meaningful and informative variance in performance related to a child’s familiarity with task content, which can influence relationships with outcomes like academic achievement.

The measures used to assess academic achievement capture necessary skills for success in the classroom but are also often far removed from the classroom environments in which executive functions are engaged. In longitudinal studies investigating relationships between executive functions and academic achievement, academic achievement is almost exclusively measured by subscales of intelligence tests, like the Applied Problems or Letter-Word Identification subscales from the Woodcock Johnson Tests of Cognitive Abilities (e.g., Best et al., 2011; Blair et al., 2015; Blair &

Razza, 2007; Daucourt et al., 2018; Fuhs & Day, 2011; Lawson & Farah, 2017; Rose et al., 2012; cf. St Clair-Thompson & Gathercole, 2006; Waber et al., 2006). These assessments are delivered by the same kinds of unfamiliar experimenters that administer lab-based measures of executive functioning and are often administered individually in the same sterile lab settings (e.g., Ahmed et al., 2019; Best, Miller, & Naglieri, 2011; Willoughby et al., 2012). Children who are comfortable in an isolated lab environment following instructions from an unfamiliar experimenter for assessments of executive function may be the same children willing to follow instructions from an unfamiliar experimenter on intelligence test subscales. For example, 4-year-old children's trust in an experimenter influences their willingness to wait on delay of gratification tests (Kidd, Palmeri, & Aslin, 2013; Michaelson & Munakata, 2016), and social trust may explain longitudinal links between 4-year-old's willingness to delay gratification and academic achievement at 15 years (Michaelson & Munakata, 2020). This view could explain why individual lab-based measures of executive function may correlate better with academic achievement measures also administered individually than executive function measures assessed while children are interacting in social groups (e.g., marching to music together, Ahmed et al., 2021). In a longitudinal study of third, fourth, and fifth graders in the United States, measures of executive function were administered individually in a separate quiet space in the school and in groups within children's classrooms (Obradovic et al., 2019). Measures of executive function correlated well with each other and with state-administered standardized test scores (Obradovic et al., 2019); however, only the executive function assessments administered in the classroom, where children's executive functions are needed for learning, predicted improvements in standardized test scores over time. Thus, overlap between the contexts in which lab-based measures of executive function and academic achievement are administered, as well as trust in study administrators, could influence the strengths of association between executive function and academic achievement.

Working memory updating, which is often considered a core component of executive functioning (Karr et al., 2018; Miyake & Friedman, 2012), may be more strongly correlated with academic assessments of literacy and mathematics than other components of executive functioning (e.g., Ahmed et al., 2019; Dekker et al., 2017; Jacob & Parkinson, 2015; Spiegel et al., 2021; St Clair-Thompson & Gathercole, 2006; Van der Ven et al., 2012). Such relationships have provided a foundation for targeting working memory specifically in executive functioning training programs. However, a contextual understanding of executive function and its development provides an alternative explanation for these relationships. Executive function tasks, especially those used to assess working memory, often include stimuli relevant for assessments of academic achievement (e.g., Alloway & Alloway, 2010). For example, working memory can be assessed with digit span tasks that use numbers or span tasks that use words, shapes, or letters as stimuli. Academic achievement measures used in longitudinal studies primarily include assessments that involve operating on, remembering, and solving problems that use numbers, shapes, letters, and words. Familiarity with processing such stimuli could drive stronger relationships between measures of working memory and academic achievement.

Individual differences in familiarity with task cues also explain variation in correlations between cognitive flexibility and math achievement. For example, correlations between cognitive flexibility and math achievement may be stronger when flexibility is measured with the Plus-Minus task, which requires participants to switch between adding and subtraction numbers (St. Clair-Thompson & Gathercole, 2006), compared with studies in which flexibility is measured with card sorting tasks, which require participants to switch between color and shape rules to sort stimuli (Willoughby et al., 2019; Morgan et al., 2019). Thus, familiarity with the overlapping stimuli used in measures of working memory and cognitive flexibility could drive stronger

correlations between working memory and academic achievement, independently of executive function capacities.

Our aim in presenting the above evidence is to demonstrate that children's familiarity with and ability to process the contents of established measures of executive function, including those used to demonstrate links between executive functions and academic achievement, substantially influences performance on measures of executive function. We are not claiming that executive functions are unimportant or that individual differences in executive function do not exist or matter for academic achievement and other important outcomes. We acknowledge that several other factors could also contribute to the pattern of results described above. For example, methodological concerns, including poor test-retest reliability and low variability in interindividual performance differences, could drive task-specific variance (Enkavi et al., 2019; Dang et al., 2020). Working memory may more strongly correlate with academic outcomes because measures of working memory typically use accuracy as outcome variables instead of response times, which may increase the reliability of these assessments (Draheim et al., 2021; Enkavi et al., 2019). However, the above evidence suggests that in addition to executive function capacities and the psychometric properties of different tasks, familiarity with task content may be an underappreciated aspect driving variation in performance on measures of executive function and relationships with academic achievement.

Reinterpreting Results from Executive Function Interventions in Context

Benefits from executive function training programs are quantified by improvements in performance on lab-based measures of executive functioning and transfer tasks intended to assess outcomes like academic achievement. Meta-analyses of executive function training programs have demonstrated that such programs result in improved performance on executive function tasks used for training and similar executive function

tasks but do not improve performance on transfer tasks capturing academic achievement (Sala & Gobet, 2017; 2019; Simons et al., 2016). Quantifying benefits from training in terms of improvements in performance (e.g., improved accuracy and response time) does not allow examination of the mechanisms underlying changes in task performance (for discussion, see Smid et al., 2021).

Better processing of task cues and stimuli through increased familiarity could explain many findings in the executive function training literature, including performance benefits from training. For example, meta-analyses of high-quality executive function training studies have found that participants who perform worse on baseline assessments of executive functions show the largest improvements in performance as a result of training (Karbach et al., 2017; Sala & Gobet, 2022; Traut, Guild, & Munakata, 2021). Transfer of training-related gains is modulated by overlap in task stimuli. A meta-analysis of transfer effects from working memory training showed that correspondence between stimuli across training and transfer tasks moderated transfer-related gains across different working memory tasks (Gathercole et al., 2019). Such findings provide a complementary mechanism of training-related skill transfer, in addition to the development of task-specific strategies that explain training-related improvements on superficially similar tasks (Simons et al., 2016; Souder et al., 2017), in addition to factors like regression to the mean and outsized gains during initial skill acquisition. Thus, we suggest that improvements in performance due to executive function training interventions are partially driven by improvements in processing task-specific stimuli, as well as the refinement of task-specific strategies (for discussion, von Bastian et al., 2022).

Training Executive Function Engagement with Contextually Relevant Stimuli

A contextual understanding of executive function development and results from interventions aimed at improving executive function support an

important inference for changing how executive functions are engaged in the real world. In addition to improving children's relevant knowledge about the processes involved for executive function tasks (Doebel, 2020), we suggest that executive function training should incorporate stimuli that are relevant to the contexts in which executive functions are needed. The impact of executive function training on real-world behavior will be determined by the correspondence between training stimuli and the targeted outcomes. For example, training children in cognitive flexibility tasks using mathematical operations as rules should benefit math performance more than interventions that train flexibility with shape and color rules. Training children in cognitive flexibility tasks using magnitude rules and numbers as stimuli should benefit fraction understanding more than in tasks that use abstract stimuli like colored shapes. Generalizing from successful transfer between lab-based assessments of executive function that use similar cues and stimuli to contexts in the real-world with similar cues and stimuli may seem like a logical leap; however, this approach has empirical support.

For example, about ten hour-long sessions of speed of processing training in older adults decreased the number of reckless maneuvers in a driving simulator compared with a driving simulator training group and passive control group (Roenker et al., 2003) and decreased the number of actual at-fault motor vehicle collisions compared with a no-contact control group and a working memory training group (at-fault collisions also decreased in a group undergoing relational reasoning training, but only in models with many control variables; Ball et al., 2010). Notably, the speed of processing training involved practicing detecting stimuli relevant for the target behavior: Older adults practiced detecting simple depictions of cars and trucks, as well as other stimuli, amongst many different distractor stimuli. Such training could lead to better engagement of control in target real-world contexts through rehearsing the detection of relevant stimuli (although speed of processing training without relevant stimuli would be

needed to support strong claims about the necessity of task-relevant stimuli).

A meta-analysis investigating the impact of training inhibitory control on health-related behaviors found a small, short-term benefit for training on health-related outcomes like alcohol consumption and healthy eating choices (Allom et al., 2016). However, this effect was fully moderated by the type of stimuli used during training. Interventions that used contextually relevant stimuli for the targeted behavioral outcome (e.g., pictures of chocolate in a go-/no-go paradigm to reduce less healthy eating decisions) had a medium-sized analytic effect on targeted health-related behaviors over the short-term, whereas interventions that used abstract stimuli had a null effect. For example, interventions to decrease alcohol intake in college-aged U.S. students that paired no-go responses in a go-/no-go paradigm with photos of alcohol decreased self-report alcohol intake over the subsequent week compared with a condition that paired photos of alcohol with a go response in a go-/no-go paradigm (Houben et al., 2012). Similar results have been observed with in-laboratory drinking after a single training session with alcohol-related stimuli (Jones & Field, 2013). These studies typically included within-session outcome variables, like taste tests or self-report for health-related behaviors; however, these tasks may have better potential for transfer to relevant real-world outcomes than finding improved performance on similar digital paradigms used to measure executive functions.

Although cognitive training aimed at improving executive function capacities has largely failed to improve real-world outcomes, training executive functions with stimuli relevant to targeted real-world behaviors holds promise for relevant behavior outside of the lab. Such effects are likely small and transient; however, extended or consistent training could result in larger benefits for real-world outcomes. Although the interventions described above were not implemented in children, potential mechanisms for such effects have been put forth within the framework of executive function development. For example, training effects could be driven by freeing up

cognitive resources devoted to processing task content, which better enable an individual to engage executive functions (e.g., Doebel & Lillard, 2022). We suggest that pairing contextually relevant stimuli within contexts in which executive functions are needed encourages the engagement of executive functions across similar or overlapping contexts. In either case, we hypothesize that training that encourages the engagement of executive functions holds promise for benefitting real-world outcomes, rather than training to increase executive function capacities.

Reinforcing Executive Function Engagement Within Contexts

Executive functions are inherently goal-driven cognitive processes. In the lab, goals are provided by an experimenter (e.g., to sort pictures by their shape or color). Outside of the lab, goals, and an individual's motivation to achieve them, are also driven by personal, historical, social, and cultural contexts (e.g., Doebel, 2020; Michaelson & Munakata, 2021). Executive functions are not automatically engaged; students must want to complete school assignments, follow a teacher, and avoid distracting their classmates. Even if interventions aimed at improving executive function capacities were successful, children's decisions to engage executive functions could remain unchanged, preventing transfer to outcomes in the classroom or the real world.

Engaging executive functions takes effort, and children do not always perform executive functions tasks at maximum effort. For example, manipulations designed to increase children's willingness to engage executive function through competition, collaboration, other social factors, and reward improve children's performance on direct measures of executive function and lab-based tasks believed to require executive function (Atkinson et al., 2019; Doebel & Munakata, 2018; Jin et al., 2020; Koomen et al., 2020; Lertladaluck et al., 2020; Michaelson & Munakata, 2016; Munakata et al., 2020; Qu et al., 2013; Tarullo et al., 2018). Even 7–11-month-old infants' performance on measures of executive function is moderated by apparent

differences in motivation for potential rewards (Diamond, 1983). These findings suggest that standard measures of executive function do not fully capture children's capacities but instead capture some confluence of capacity and the willingness to engage executive function. Children's decisions to engage executive functions on measures in the lab may contribute to links with outcomes like academic achievement. For example, a child willing to give maximum effort on a lab task of executive functions or other lab-based assessments of cognitive functions administered by an experimenter may also be more likely to give maximum effort on tasks assessing academic achievement administered by a teacher or experimenter. We propose that willingness to give maximum effort likely matters most for challenging tasks, such as executive function and academic tasks; willingness to give maximum effort should matter less for simpler tasks that can be completed successfully even without exerting maximum effort, which may account for the specificity of correlations between EFs and academic achievement.

Older children are sensitive to the costs of engaging control and meaningfully vary in their willingness to engage executive functions. Like adults, 11-year-old U.S. children will avoid completing more demanding lab-based executive function tasks when given the choice (Niebaum et al., 2019; Niebaum & Munakata, 2020). Decisions about which tasks to take on explain variation in children's and adults' executive function task performance and explain how self-control is engaged outside of the lab (Chevalier, 2018; Kool et al., 2010; Kramer et al., 2021; Niebaum et al., 2019; Wolff et al., 2016). For example, 11-year-old children's preferences for avoiding tasks high in rule-switching demands correlate with their rule-switching task accuracy (Niebaum et al., 2019). Such correlations have typically been interpreted as worse executive function capacity motivating individuals to avoid tasks that require engaging executive functions (e.g., Niebaum et al., 2019; Kool et al., 2010); however, alternative interpretations are possible. Unwillingness to engage executive functions could lead to worse performance on executive

function tasks due to decreased motivation to engage executive functions to perform well. For example, young children may be unmotivated to perform well in the lab and in the classroom because they do not trust that their efforts will pay off or they do not see the activities as relevant to their lives (Matthews, 2018; Michaelson & Munakata, 2021). Children, like adults, may not find the effort required to perform well on assessments of executive function meaningful (Campbell et al., 2022). An extension of this interpretation is that relationships between executive function task performance and academic achievement are partially driven by a willingness to engage executive functions, rather than executive function capacities directly.

Reinforcing the engagement of executive functions is possible in principle and could better transfer to unrelated tasks. For example, reinforcing engaging executive functions on a traditional lab-based measure by linking monetary rewards with engaging executive functions led to increased engagement of executive functions on a new, unrelated task compared with a control group receiving random rewards, even after rewards were no longer offered (Clay et al., 2022; Lin et al., 2021). Individuals with rewards contingent upon engaging executive functions also reported greater achievement motivation after the intervention compared with a group that received random rewards (Clay et al., 2022). Importantly, these interventions distinguish between rewards for engaging this type of mental effort and rewards for good task performance. Rewards solely for task performance could decrease intrinsic motivation over time (e.g., Deci, Koestner, & Ryan, 1999; Lepper & Henderlong, 2000; Werneken & Tomasello, 2008); however, repeatedly rewarding effort could make putting forth effort a secondary reinforcer, such that engaging executive functions becomes more rewarding. Such findings support learning theories for engaging executive functions and the potential for transferring preferences for engaging executive functions to novel tasks and contexts (Eisenberger, 1992; Lieder et al., 2018). A child’s willingness to engage cognitive control

may be a product of individual learning histories, as well as social and cultural contexts (Doebel, 2020; Lucca et al., 2020; Munakata & Michaelson, 2021). Interventions that positively reinforce executive function engagement should transfer better to real-world outcomes compared with increasing executive function capacity.

Interventions designed to improve executive function that have successfully benefitted academic achievement also improve third variables, including self-confidence and teacher-student relationships (for review, see Jacob & Parkinson, 2015; Ling & Diamond, 2019). These factors may simultaneously improve executive function task performance and academic achievement by improving executive function engagement rather than improving executive functions directly. For example, the Chicago School Readiness Program implemented a school-based intervention to train response inhibition and attentional control and observed improvements on measures of executive function and academic outcomes (Bierman et al., 2008). This intervention involved teacher training to improve student-teacher relationships and classroom management, which may increase academic achievement independently of improvements in executive function capacities due to the intervention.

Other interventions designed to improve academic achievement have shown that success may depend on peers' willingness to engage executive functions, broadly construed. For example, a national intervention in the United States designed to teach ninth-grade students that cognitive skills can be developed through practice observed the strongest effects on improving GPA when students were surrounded by peers who supported taking on challenging cognitive tasks (Yeager et al., 2019). These results indicate that interventions aimed at improving academic outcomes should focus on increasing students' mental effort, like the effect associated with engaging executive functions. Interventions that target executive function engagement within specific contexts, like classrooms, should be more likely to benefit targeted outcomes like academic achievement.

Conclusion

Efforts to increase executive function capacities directly through training have failed to yield generalized improvements in executive function and have failed to benefit important outcomes like academic achievement. We provide a contextual perspective for understanding individual differences in performance on lab-based measures of executive function. Children's familiarity with the content used in measures of executive function and their willingness to engage executive functions influence task performance, in addition to executive function capacities. We describe a contextual approach to training executive function engagement, rather than training executive functions directly. Interventions should incorporate task content that is contextually relevant to the targeted behavioral outcomes, such as specific aspects of academic achievement. Interventions should also reinforce the engagement of executive functions across different tasks and contexts. We acknowledge that these kinds of individualized interventions do not address systemic factors such as racism, sexism and gender stereotypes, and income and wealth inequality, which greatly impact outcomes like academic achievement and are critical targets for intervention (Cheryan et al. 2017; Lacour & Tissington, 2011; Sosina & Weathers, 2019). In addition, much of the cognitive training literature has been limited to investigations in Europe and the United States, limiting the generalizability of findings. However, given the resources devoted to individualized interventions designed to improve life outcomes through training executive function, we argue that these interventions should focus on increasing engagement rather than capacity. We hypothesize that such contextually driven interventions hold more promise for impacting real-world outcomes than interventions aiming to improve executive function capacities.

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