Published in final edited form as:
Annu Rev Dev Psychol. 2021 ; 3(1): 139–163. doi:10.1146/annurev-devpsych-121318-085005.

Executive Functions in Social Context: Implications for Conceptualizing, Measuring, and Supporting Developmental Trajectories

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Abstract

Success in life is linked to executive functions, a collection of cognitive processes that support goal-directed behaviors. Executive functions is an umbrella term related to cognitive control, self-control, and more. Variations in executive functioning predict concurrent success in schooling, relationships, and behavior, as well as important life outcomes years later. Such findings may suggest that certain individuals are destined for good executive functioning and success. However, environmental influences on executive function and development have long been recognized. Recent research in this tradition demonstrates the power of social contextual influences on children's engagement of executive functions. Such findings suggest new interpretations of why individuals differ in executive functioning and associated life outcomes, including across cultures and socioeconomic statuses. These findings raise fundamental questions about how best to conceptualize, measure, and support executive functioning across diverse contexts. Future research addressing real-world dynamics and computational mechanisms will elucidate how executive functioning emerges in the world.

Keywords

inhibition; delaying gratification; heritability; intervention; equity; causal inference

WILL THE REAL EXECUTIVE FUNCTION PLEASE STAND UP? ACTUALLY, ALL RISE

Executive function is an umbrella term that encompasses multiple cognitive processes. Executive functions are sometimes characterized in terms of "hot" executive functions that are engaged in emotional situations (e.g., when frustrated or angry, or when tempted by a reward) and "cool" executive functions that are engaged when emotions are not as

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DISCLOSURE STATEMENT
The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

involved. These executive function processes are related to a variety of other constructs in the literature, such as cognitive control, effortful control, self-control, and self-regulation. How these terms relate is a point of contention and an active area of research. As a case in point, a recent Twitter thread began with a scholar stating, “I triple dog dare someone to explain the difference between executive functioning and cognitive control” (Reilly 2021). Some respondents claimed that cognitive control is the broader term while executive functions are more specific. Other respondents argued the opposite. Yet others suggested that cognitive control and executive functions relate in a different way. Many people agreed that the terms are often used interchangeably, although they have had different histories and thus have different associations (e.g., Nigg 2017). For example, “executive function” has been used more in clinical and developmental research (e.g., Barkley 2012, Best & Miller 2010, Carlson 2005, Diamond 2013, Luria 1966, Moriguchi et al. 2016, Snyder 2013, Wiebe & Karbach 2017), and thus is associated with a focus on individual differences and changes across time. In contrast, “cognitive control” has been used more in cognitive neuroscience and computational research (e.g., Alexander & Brown 2010, Badre 2008, Botvinick & Braver 2015, Bunge & Crone 2009, Luna et al. 2010, Miller & Cohen 2001, Posner & Snyder 1975, Somerville & Casey 2010), and thus is associated with a focus on underlying mechanisms. “Effortful control,” “self-control” and “self-regulation” are often used in contexts relating to hot executive functions (Fujita et al. 2006, Rueda 2012, Vohs & Baumeister 2004).

One attempt to clarify these terms and other related terms is an online interactive visualization tool called Explore SEL (http://exploresel.gse.harvard.edu). This tool provides a taxonomy of frameworks that have explored skills related to social and emotional learning across disciplines (Figure 1). This taxonomy builds on a common coding system. The coding system was used to determine what skills are involved and how they are defined regardless of the terms used, given that the same skill can have different names (as in executive function and cognitive control) and the same term (e.g., curiosity) can be applied to different skills. This system has been used to produce a thesaurus. Terms such as executive functioning as defined by a given framework relate closely to terms as defined in other frameworks, such as self-management and persistence, in addition to other terms we have highlighted. Such efforts and tools should prove valuable to researchers, practitioners, and the general public in understanding points of overlap and connection across disciplines and frameworks. This type of effort could also support calls to develop a lingua franca across the social sciences, adopting the terms that describe ideas best from among the many terms in use, to formulate a common vocabulary across disciplines, support interdisciplinary collaboration, and advance understanding (Buyalskaya et al. 2021).

In this review, we have intentionally chosen to lump rather than split across the broad range of processes and terms related to executive functions, for two primary reasons. First, this is an active area of research and debate, spanning a plethora of measures and methods such as computerized, behavioral, and survey measures as well as individual difference, developmental, intervention, neuroimaging, and computational approaches. Any attempt to delineate a clear line around executive functions as distinct from related constructs would be debatable and could fill this entire review. Second, and more importantly, the points we make in this review apply across executive functions and related constructs. Specifically, these skills are important for children both in their day-to-day functioning and in predicting their longer-term outcomes, and social contexts influence whether and how children engage these skills. These findings highlight fundamental issues about how best to conceptualize, measure, and support these skills and their development, and suggest new interpretations of variations observed across individuals and groups, pointing toward important directions for future research. Thus, while we recognize the need for greater clarity in terminology and the value in attempts to delineate executive functions and related constructs, we use the term executive functions in a broad sense that includes rather than excludes other constructs related to goal-directed control processes.

EXECUTIVE FUNCTIONS PREDICT SUCCESS

Variations in executive functioning among individuals predict concurrent success with schooling, relationships, and behavior, as well as success in later years. For example, in the famous marshmallow test of delaying gratification, children are presented with one marshmallow and are told that they can it eat right away, or if they wait to eat it then they can have two marshmallows (Mischel et al. 1972, 1989). Although most children indicate that they would prefer to wait for the two marshmallows, many children nonetheless indulge in the one marshmallow at some point during the waiting period. Waiting for the delayed reward likely taps executive functions, given the need to inhibit the impulse to eat the available marshmallow and keep in mind the goal of obtaining two marshmallows. Indeed, performance on this task correlates with performance on measures of executive function such as inhibitory control (Eigsti et al. 2006, Hoffmann et al. 2009, O’Toole et al. 2018, Rodriguez et al. 1989). In addition, prefrontal cortical regions that support executive functioning are engaged during delay of gratification and related tasks (Figner et al. 2010, Luerssen et al. 2015, McClure et al. 2004). Importantly, children’s delaying of gratification in the marshmallow task predicts intelligence and academic, social, and behavioral skills in the short term (Duckworth et al. 2013, Razza & Raymond 2013), as well as academic success, socioemotional competence, and health in later years (Ayduk et al. 2000, Michaelson & Munakata 2020, Mischel et al. 1988, Schlam et al. 2012, Shoda et al. 1990, Watts et al. 2018).

Variations among individuals on computerized and tabletop task–based measures of executive function also predict concurrent and later success (Benson et al. 2013, Fox et al. 2021, Fuhs & Day 2011, Marcovitch et al. 2007, Miyake & Friedman 2012, Young et al. 2009). For example, response inhibition is the ability to stop a habitual, ongoing, or impulsive behavior. Task-based assessments of response inhibition include the following:

- the antisaccade test—participants must look in the opposite direction of a cue that appears on a monitor, rather than looking at the cue;
- the Stop-Signal Task—participants respond to stimuli on a monitor but must withhold that response if a signal appears rather than completing the response; and
- the Stroop test—participants must respond to stimuli in unusual ways (e.g., naming the color of ink that words are written in, or saying “night” in response

to a picture of a sun), rather than responding in learned ways (e.g., responding to words by reading them, or saying “day” in response to a picture of a sun).

Each measure of any particular skill such as response inhibition also taps other skills (e.g., visual processing), so executive functions can be difficult to measure. One approach to addressing this challenge is to use multiple measures and statistically extract a latent variable based on what is common across the measures. When response inhibition is measured during adolescence in this way using the antisaccade, Stop-Signal, and Stroop tasks, it predicts important behaviors such as substance use, novelty seeking, and measures relating to conduct disorder and attention-deficit/hyperactivity disorder (ADHD) (Young et al. 2009). Task-based measures of executive function also predict later educational outcomes from preschool into adolescence (Blair & Razza 2007, Blair et al. 2015, Cragg & Gilmore 2014, Huizinga et al. 2018, Lan et al. 2011, Matthews 2018, Schmitt et al. 2017).

Finally, questionnaire measures relating to executive function predict concurrent and later success as well. For example, in a well-known study of more than 1,000 children followed longitudinally, children’s self-control from 3 to 11 years of age was reported on by researchers, parents, teachers, and ultimately the children themselves. These questionnaires included persistence in reaching goals, maintaining attention, and inhibiting impulses. These measures were all positively correlated and were combined into a composite score. This composite score predicted the health, wealth, and public safety (lack of criminal convictions) of the individuals decades later (Moffitt et al. 2011).

Such longitudinal associations have been confirmed in a recent meta-analysis of 150 studies. Self-regulation measures at 4 years predicted social, academic, and behavioral outcomes in early school years, and self-regulation in early school years predicted behavioral, health, and academic/employment outcomes in later school years and beyond (Robson et al. 2020). Task-based assessments (e.g., the marshmallow test) and teacher reports tended to show stronger links than parent reports, a point we return to in the second-to-last section. Children’s executive functioning thus predicts their success across myriad domains in childhood and beyond (Figure 2, *right*).

ARE SOME INDIVIDUALS DESTINED FOR GOOD EXECUTIVE FUNCTIONING AND SUCCESS?

What children do—with a tempting marshmallow, on computerized tasks that challenge their ability to achieve goals, or in their daily behaviors that shape the impressions of adults around them—predicts their later success in school, relationships, health, wealth, work, and life. Such findings seem to suggest that certain individuals are simply destined for good executive functioning and success. Indeed, executive functioning is often defined as if it is an inherent aspect of an individual (see discussion in Doebel 2020). This emphasis aligns with a focus on the level of the individual within psychology more generally, which reflects and prioritizes the perspective of those who established the scientific culture of the discipline (Ledgerwood et al. 2021)—a point we return to in the second-to-last section.

From this perspective, it makes sense that executive functioning is often quantified via lab-based measures collected from an individual in isolation, or via reports about individuals considered in isolation. (Group-based measures of executive function in children have recently been developed, but these measures still focus on assessments at the level of the individual; Ahmed et al. 2021.) Moreover, variations in executive functioning among individuals show stability across development. That is, while children show dramatic improvements in executive function with development (Diamond 2013, Gathercole et al. 2004, Kave et al. 2008, Munakata et al. 2012), individuals who perform relatively well on measures of executive functioning at one point in time continue to perform well at later points in development (Friedman et al. 2007, 2011, 2016; Harms et al. 2014; Helm et al. 2020; Miyake & Friedman 2012). These developmentally stable variations across individuals can be explained to a substantial degree by genetic factors (Friedman et al. 2016, Miyake & Friedman 2012). For example, in a multivariate modeling study involving data from identical and fraternal twins, estimates of heritability—the portion of variability among individuals attributable to genetic effects—ranged from 0.75 to almost the maximum of 1 (Friedman et al. 2008). (Notably, the heritability estimates were much lower when based on single-task measures of executive function rather than latent variables; this contrast highlights the value of statistically extracting purer measures of processes of interest based on what is common across individual measures, which on their own reflect measurement error and additional nonexecutive processes specific to individual tasks that obscure relationships.) Such findings seem to suggest a trajectory from genetic variations to executive function capacities to life success.

However, individual differences can show stability across development and high heritability even if they are not inherent aspects of an individual and are influenced by the environmental and social context. This is in part because factors that influence executive function both in the moment and in the long term over time—such as character, connection, and trust in parents, peers, and other adults—also tend to be stable across the life span. For example, the Five Cs (competence, confidence, character, connection, and caring) model of positive youth development demonstrates structural equivalence across multiple time points throughout adolescence, suggesting relative continuity across time (Bowers et al. 2010). Relative stability is also observed in multidimensional measures of well-being, including self-esteem, self-efficacy, and social support, from adolescence through adulthood (Schulenberg et al. 2004); only 17% of participants demonstrated evidence of "considerable change." Moreover, growth mixture modeling research suggests that adolescents' prosocial behavior toward family and friends is generally stable over time (Padilla-Walker et al. 2015). Cross-sectional studies involving multiple age groups indicate that the degree to which we trust others is relatively unaffected by age (Harbaugh et al. 2003, Rotter 1971). These factors also tend to be correlated with executive functions, and may therefore represent continuous forces on executive function that partially explain its apparent developmental stability and heritability. That is, individuals who grow up with sound character, strong social connections, and adequate trust in others may also tend to have the necessary environmental resources to develop strong executive functions (Doebel et al. 2020).

Moreover, high heritability does not mean immutability, as the authors of the studies showing high heritability of executive functions emphasize (Miyake & Friedman 2012).

Heritability addresses how much of the variation across a particular set of individuals at a particular point in time can be attributed to genetic effects. Heritability can be high even if the environment plays a major role in shaping variations among individuals (Scarr-Salapatek 1971, Tucker-Drob et al. 2013, Turkheimer 2000). For example, height is influenced by environmental factors such as nutrition, as evidenced by the fact that the average height of 11-year-old boys in Japan today is 5 inches greater than it was 50 years ago. However, in some samples, the heritability of height has been estimated to be 80% (Dubois et al. 2012). How can that be, if nutrition has such a clear impact? This can happen if nutrition did not vary sufficiently within the particular set of individuals studied to make a significant impact on differences in height among them. As a result, variations in height in that particular sample reflect other factors to a greater degree, such as genetic factors. Similar patterns have been observed with measures of intelligence (which are correlated with executive functions; Brydges et al. 2012, Conway et al. 2003, Friedman et al. 2006). Specifically, estimates of the heritability of IQ have varied across studies and samples, with relatively high heritability of IQ observed in studies conducted in Western Europe and Australia, and in the United States with individuals of high socioeconomic status, but with lower heritability of IQ observed in studies conducted in the United States with individuals of low socioeconomic status (Tucker-Drob & Bates 2016). Individuals in the studies yielding high heritability estimates may have experienced more similar environmental conditions relevant to performance on measures of intelligence (e.g., in terms of schooling, nutrition, and health care), such that variations in their environments do not lead to significant variations in IQ. The power of these environmental factors can only be revealed in samples that have significant variations in them. Such variations in the quality of schooling and other environmental factors may be more prevalent across individuals with lower socioeconomic status in the United States, and less common across individuals in countries that provide high-quality public options for all and across higher–socioeconomic status individuals in the United States who can access high-quality options. This situation has led one behavioral geneticist to quip, “If you want to decrease the role of genes in determining destiny, increase inequality. Then the environment will play a bigger role, and the role of genes will shrink” (R. Olson, personal communication).

While estimates of the stability and heritability of executive function can be high, longitudinal studies also show changes. For example, estimates of the heritability of some aspects of executive function decreased substantially between late adolescence and early adulthood, when many twins moved out of their homes and started to live separately (Friedman et al. 2016). These findings highlight the influence of nonshared environmental factors—that is, environmental influences that led twins to become different from one another.

So, are some individuals simply destined for good executive functioning and success—on a flourishing track based on inherent aspects of themselves? The evidence suggests otherwise. Although individual differences in executive functioning can predict concurrent and later success in life, and although such individual differences in executive function can show stability across development and high heritability, environmental factors still play a major shaping role.

ENVIRONMENTAL INFLUENCES ON EXECUTIVE FUNCTION AND DEVELOPMENT

Environmental influences on development, and on executive function development in particular, have long been recognized. Children are shaped by the people, settings, and objects with which they interact (Bronfenbrenner & Evans 2000, Bronfenbrenner & Morris 1998, Cole 1995, Evans 2021, Rogoff 1990, Vygotsky 1978). Influences can be physical as well as social. For example, crowding, noise, and chaos experienced in the home and in learning environments elevate children's chronic physiological stress, as indicated through objective markers including blood pressure, skin conductance, and neuroendocrine stress hormones (Basner et al. 2014, Evans et al. 1998, McEwen 1998). Influences can also be both direct and indirect, operating via the children's exposure or via parents' and other caregivers' exposure, for example (Ackerman & Brown 2010, Repetti et al. 2002). Fragmented and unpredictable patterns from the environment can cause aberrant synaptic connectivity that disrupts crucial cognitive and emotional brain circuit maturation (Davis et al. 2017, Glynn & Baram 2019). Environmental effects of physical and social circumstances on children's executive functioning may be pronounced as a result of the protracted structural and functional development of the prefrontal cortical areas that support them in comparison to other neurocognitive functions (Noble et al. 2005, Werchan & Amso 2017). Furthermore, apparent failures to engage executive functions may reflect an adaptive response to the regularities of one's environment (Lee & Carlson 2015, McGuire & Kable 2013, Pepper & Nettle 2017).

Correlational studies have highlighted reliable links between children's environments and outcomes across domains. For example, inconsistent discipline from caregivers predicts higher negative affect and behavioral problems in children (Acker & O'Leary 1996, Doan & Evans 2020, Sawin & Parke 1979), and regular family routines (such as consistent meal- and bedtimes) are associated with positive developmental outcomes (Fiese 2006). Verbal and nonverbal parent–child interaction quality at 24 months accounts for nearly a third of the variance in child expressive language 1 year later (Hirsh-Pasek et al. 2015). Better childhood executive function is associated with parenting that is classified as more positive (e.g., in terms of warmth and responsiveness), less negative (e.g., in terms of control and intrusiveness), and more cognitive (e.g., in terms of autonomy support and scaffolding) (Valcan et al. 2018). Children with more unstructured time to practice engaging executive functions in their daily lives display better self-directed executive functioning on laboratory tasks (Barker et al. 2014). On the flip side, unpredictable and unreliable behavior from parents and other adults in children's lives is associated with worse executive functioning on delay of gratification and temporal discounting tasks (Mauro & Harris 2000, Schneider et al. 2014). Household chaos is also associated with worse executive functioning in children (Andrews et al. 2021, Berry et al. 2016, Schmitt et al. 2015, Sturge-Apple et al. 2017). Cultures also differ in the value associated with, and propensity to engage, executive functions (Lamm et al. 2018, Lan et al. 2011, Legare et al. 2018, Roos et al. 2017, Yanaoka et al. 2021).

Recent experimental research in this tradition demonstrates the power of social contextual influences on children's engagement of executive functions across cultures. Children engage more cognitive control on a computerized task when they are told they are competing or cooperating with another person in the room, relative to a neutral context where another person is similarly present and participating, but in neither a competitive nor a cooperative manner (Fischer et al. 2018). Children also perform less impulsively in a delay-of-gratification task when their outcomes are interdependently linked to other participants' rewards, relative to when they perform the same task alone (Koomen et al. 2020). Furthermore, children are more willing to wait for a delayed reward when they are told their in-group waited (and their out-group did not), relative to when they are told their in-group did not wait (and their out-group did), across both Western and Japanese samples (Doebel & Munakata 2018, Munakata et al. 2020). Children are less likely to delay gratification when the adult promising the delayed rewards behaves in an unreliable or untrustworthy way (Kidd et al. 2013, Michaelson & Munakata 2016, Moffett et al. 2020). Schooling also shapes children's executive functioning and associated brain regions, as revealed through studies comparing children of similar ages who enroll or do not enroll in school on the basis of birthdate cutoffs (Brod et al. 2017, Burrage et al. 2008) and studies experimentally manipulating aspects of the classroom environment (Fisher et al. 2014).

Social contextual influences can also explain why executive functioning in childhood predicts life outcomes. Longitudinal links between preschool delaying gratification and adolescent academic and behavioral outcomes disappear after accounting for factors like social support (Michaelson & Munakata 2020). Effects of early executive function on preschoolers' academic readiness are fully mediated by social adjustment (Baptista et al. 2016). Such findings suggest that children who grow up with social support may be more willing to engage executive functions because of social norms (Doebel & Munakata 2018, Lamm et al. 2018, Pepper & Nettle 2017) and because they trust that the rewards of exerting executive functions will pay off (Kidd et al. 2013, Michaelson & Munakata 2016). These early experiences may in turn lead to greater opportunities for children to practice using and benefiting from their executive functions (Doebel et al. 2020, Michaelson & Munakata 2020). Thus, performance on measures of executive function reflects not only stable core capacities but also a variety of social contextual factors that influence whether individuals engage executive functions, which may in turn shape the further development of executive functions.

Many other contextual factors such as rewards influence performance on executive function tasks and have shifted conceptualization of executive functions as stable core capacities in other realms as well. For example, individuals who are characterized as high span in their working memory capacity can typically remember a longer string of digits than individuals characterized as low span. However, when rewards are increased, high-span and low-span individuals perform more comparably (Adam & Vogel 2016). Similarly, rewards can change the extent to which individuals engage executive functioning proactively, in anticipation of needing it, versus reactively, as needed in the moment (Chiew & Braver 2013, 2014, 2016; Hefer & Dreisbach 2016). Such findings highlight the potential role of motivational and other factors in the differences observed among individuals in their executive functioning (Botvinick & Braver 2015). Similar ideas have been explored in understanding variations in executive functioning observed in developmental disorders, such as ADHD (Haenlein & Caul 1987, Johansen et al. 2009, Volkow et al. 2011). Thus, individuals may weigh the relative benefits and costs of engaging executive functions such that behaviors reflect not only core capacities but also decisions regarding whether and when it is worth engaging executive functions. These ideas have been formalized in the expected value of control framework (Shenhav et al. 2013, 2017) and demonstrated in people's choices of tasks and skills engaged in those tasks across development (Chevalier 2018; Kool et al. 2010; McGuire & Botvinick 2010; Niebaum et al. 2019, 2021; Niebaum & Munakata 2020; Westbrook et al. 2013).

This research highlights the potential power of environmental influences on executive functioning and its development, and the importance of conceptualizing executive functioning and development in context. The left side of Figure 2 captures these influences and many other forces influencing executive functioning both in the moment and in the longer term.

CONCEPTUALIZING, MEASURING, AND SUPPORTING EXECUTIVE FUNCTIONS ACROSS DEVELOPMENT

The influence of environmental factors on the engagement and development of executive functions raises fundamental questions about how to best conceptualize, measure, and support executive functions across development. Environmental influences (*a*) may explain why different measures of executive function often do not correlate well and differentially predict success in the world; (*b*) suggest new interpretations about what differences in executive function and associated life outcomes across diverse groups reflect, with implications for comparisons across groups and cultures and for intervention efforts; and (*c*) highlight distinct perspectives on how to address environmental influences in the measurement and conceptualization of executive function.

First, different measures of executive function—such as lab tasks, parent report, teacher report, and self-report—often do not correlate well and differentially predict success in the world (e.g., Duckworth & Kern 2011, Duckworth & Yeager 2015, Eisenberg et al. 2019, Enkavi et al. 2019, Robson et al. 2020). Each of these measures could index meaningful aspects of executive function, but performance on them and their predictiveness may vary, given variations in the social and contextual influences at play across them. Individuals may appear to have poor executive functioning when instead they have determined that it is not worth engaging executive functions in that moment in time, in that particular context—in their home with their family, in school with their friends, or out in the world in their particular cultural setting. For example, one child may perform best on executive function measures administered in a quiet lab room, but prioritize talking with friends over focusing on the teacher in the classroom. Another child may see no point in performing an arbitrary executive function task on a computer but prioritize switching flexibly among challenging responsibilities at home. Which executive function measures correlate with and predict success in the world may depend on the match between the contexts in which they are measured and the relevant contexts in the world. For example, latent variables of cool executive functions formulated from computerized tasks in isolation may best predict an individual's behavior in the real world when that person is acting alone; measures of hot executive function under more emotional circumstances may best predict real-world behaviors with other people. Variations in measurement error, bias in reporting, and so forth may also contribute to measures not correlating well and differentially predicting success in the world (see the sidebar titled Tell Me About Your Executive Function).

Second, environmental influences on executive function highlight the need to rethink why individuals vary in their executive functioning and life outcomes across diverse groups and how best to support them. For example, if variations in children's delaying gratification and later life outcomes reflect social support (e.g., the trustworthiness of others in providing delayed rewards, group norms around valuing the delay of gratification), then increasing these social supports may be a promising approach. Considering individual differences in additional relevant factors (such as the tendency to trust others) may provide a more complete understanding of executive functioning (Ma et al. 2018). Social factors may also explain variations in executive functioning that have been observed between groups (e.g., racial and ethnic groups; Rea-Sandin et al. 2021) or across other dimensions. For example, socioeconomic status predicts executive function, with individuals from higher socioeconomic backgrounds performing better across a range of measures (Lawson et al. 2018, Noble et al. 2005). Socioeconomic status is a multifaceted construct that can include education, occupation, income, and other factors that can be meaningfully distinguished (DeJoseph et al. 2021). Such factors and associated experiences may influence the extent to which it is rational and valuable for an individual to trust others, view an arbitrary experimental task as sensible or worth exerting effort on, and so forth, which can then influence engagement of executive function (e.g., Pepper & Nettle 2017) and its development (e.g., Michaelson & Munakata 2020).

This perspective highlights the possibility that traditional measures of executive function have not been equitable in measuring cognitive processes across participants. Instead, traditional measures may be biased to elicit better performance from individuals who resemble the people who designed the tasks and whose experiences support being comfortable with arbitrary testing situations focused on individual performance, motivation to do well on arbitrary tasks, and so on. Typical measures have been designed within a tradition of psychology built on the perspective of White, Western, wealthy males (Ledgerwood et al. 2021), such that the measures may favor performance from those whose experiences best align with this tradition. As the rapper MC Hammer (2021) put it in his viral tweet: "When you measure include the measurer." A measure of executive function may be more likely to reveal full executive function capabilities if steps are taken to explicitly address potential biasing elements (e.g., by discussing with participants the inherent challenge and potential fun of arbitrary, unfamiliar tasks), or if support around these biasing elements is provided (e.g., by making tasks more familiar or gamelike, or by measuring executive function in natural contexts with social support and a greater purpose for learning). Such steps to address bias may diminish variations in executive functioning observed between groups or across dimensions like socioeconomic status, as has been observed with other cognitive and academic measures (Camilli & Shepard 1994, Good et al. 2003, May et al. 1993, Pennebaker et al. 2013, Rogoff et al. 2002).

Moreover, variations in the social contextual environment across cultures may shape differences in executive functioning and the processes involved (Lamm et al. 2018, Yanaoka et al. 2021). For example, children in Japan routinely wait to begin eating until after everyone is served, from early in life and across contexts (home, school, restaurants), whereas children in the United States may have more regular experiences of waiting in the context of opening gifts relative to children in Japan. Japanese children wait much longer than American children in the classic marshmallow test, whereas American children wait much longer than Japanese children when the reward is a wrapped present rather than a food treat (Yanaoka et al. 2021). In addition, while children's delaying times were overall predicted by parent reports of children's self-control and sensitivity to social conventions, self-control seemed less relevant in the context of cultural habits (when Japanese children waited for two marshmallows or American children waited for two gifts), while sensitivity to social conventions seemed more relevant in those contexts (Yanaoka et al. 2021). These patterns highlight how sociocultural factors may shape children's behaviors and the processes involved. More generally, such findings highlight the importance of extending beyond WEIRD (Western, educated, industrialized, rich, democratic) and other narrow populations of study—to reveal behavioral patterns and causal forces that might otherwise be missed—and they highlight the value of considering who measures were designed for and whether they are appropriate across groups and contexts (Correa-Chávez et al. 2015, Goodenough 1936, Henrich et al. 2010, Nielsen et al. 2017, Nsamenang 1995).

Finally, what do these findings mean for how best to conceptualize and measure executive functions? We draw two contrasts that such findings have highlighted and explain the reasoning behind our position in these debates. One contrast concerns measurement and interpretation, what variables should be controlled for when measuring executive functions, and how resulting findings should be interpreted. On the one hand, some researchers have argued for and taken the approach of measuring and controlling for multiple variables such as socioeconomic status in an attempt to purify measures of executive function by removing variance that can be attributed to co-occurring constructs (e.g., Ahmed et al. 2019, Watts & Duncan 2020, Watts et al. 2018). From this perspective, the more controls there are, the better, with the idea being that the resulting measure will best isolate executive functions and highlight their unique roles. If a correlation is observed with executive function and life outcomes and it becomes insignificant when the controls are included, then the correlation with executive function is dismissed as reflecting separable factors. On the other hand, we agree with other researchers who have argued that controls should be used for testing theories rather than purifying relationships (e.g., Meehl 1970, Newcombe 2003, Spector & Brannick 2011, Wysocki et al. 2020), and that extensive covariate adjustment can inflate false-positive rates (e.g., Westfall & Yarkoni 2016) or inadvertently remove the true causal effect (Doebel et al. 2020, Falk et al. 2020, Rohrer 2018, Spencer et al. 2005). Including controls may lead to throwing the baby out with the bathwater, or to muddying the bathwater so it is harder to see the baby. From this perspective, because social support is a crucial component in the engaging and development of executive function, controlling for it does not purify measures of executive function, but likely removes variance of interest (see the sidebar titled Covariates for Executive Function: Too Much Control?).

The second contrast concerns conceptualization of executive functions, and whether it is useful to consider executive functions as cognitive processes internal to the individual, separable from external influencing factors. On the one hand, some researchers have argued that context is everything, so it is inappropriate to reify executive functions as if they are stable internal capacities (Buss & Spencer 2014, Doebel 2020, Perone et al. 2021). From this perspective, one should not view executive functions as processes that could be strengthened in one particular setting (e.g., on a standard lab task), similar to a muscle, and then transferred to other settings. Instead, what matters is the factors that influence performance in one particular setting (e.g., comfort in a lab setting, motivation to perform well in front of an experimenter). Executive functioning may not exist in a way that can be abstracted from these specific instantiations. On the other hand, we argue that while context matters, executive functions are nonetheless real processes, which can be understood in terms of underlying mechanisms, computations, and cognitive processes that can be meaningfully delineated (Banich 2009, Botvinick & Braver 2015, Miyake & Friedman 2012). Influences on these processes are considerable and should not be discounted, but we also should not discount the executive functions themselves. This too would be like throwing the baby out with the bathwater (see the sidebar titled Context and Executive Functions Matter).

ELUCIDATING HOW EXECUTIVE FUNCTIONING EMERGES IN THE WORLD

Many studies have highlighted the potential of a rich interplay between social context and executive function development; however, they are open to multiple possible interpretations about whether and how social factors support and shape executive function in the wild. Correlational studies with measures of real-world social context and outcomes have been an important step in exploring how executive functioning emerges in the world. Longitudinal studies and genetically informative studies have added valuable information about timing and sources of influence. Targeted experimental studies have identified causal influences. However, such studies have typically been narrow in scope—focusing on the short-term effects of brief experiences in the lab. Such experimental studies have also tended to focus on explaining the average person, for example, estimating group tendencies rather than understanding variability within and between people. Future research building on all of these foundations will elucidate the complexity of how executive functioning emerges in the world. We highlight four promising directions.

First, targeted interventions can address whether causal effects in the lab matter in the world. Although these interventions can be time intensive and costly to implement and evaluate, existing examples suggest they may be worth the effort. A 2-year community trust intervention in rural Bangladesh significantly reduced myopic decision-making among members of communities in which volunteers had been trained to act as intermediaries with the local government, relative to communities that did not have these volunteers (Jachimowicz et al. 2017). The effectiveness of such interventions highlights how social factors may provide a powerful psychological lever through which targeted interventions can lessen long-standing inequalities in income and achievement. Longitudinal, field-based, randomized controlled studies have also been conducted to test whether preschool curricula or instructional models such as the Montessori program improve children's executive functions; the answer was no for the preschool curriculum tested (Nesbitt & Farran

2021), but the findings were more promising for the Montessori program (Lillard & Else-Quest 2006, Lillard et al. 2017). Research–practice partnerships provide another promising approach. Such partnerships involve researchers and community members as equal collaborators in developing and investigating research questions of mutual interest in real-world contexts (Penuel & Gallagher 2017). EF+Math is an initiative that is funding large-scale researcher–educator partnerships to support students' executive functioning by addressing school social context and other factors (https://www.efmathprogram.org). Such real-world programs may ultimately yield greater benefits than more narrow executive function training that does not show benefit beyond the training context (see the sidebar titled Training Executive Function: Teaching to the Test?).

Second, studies that target processes as they unfold in real time may shed light on how executive functioning emerges in the world. Consider research in another domain, language learning. Infants who produce more adult-like sounds evoke more social responsiveness from adults (Goldstein & West 1999). Moreover, when parents are coached to alter their behaviors to be more contingent in response to their infants' vocalizations, those vocalizations become more adult-like (Goldstein & Schwade 2008, Goldstein et al. 2003). Such studies have revealed how language learning and related processes are shaped in real time through interaction with the environment (Abney et al. 2020, Suarez-Rivera et al. 2019). Biobehavioral synchrony in parent–child interactions may support children's functioning across a range of domains (Feldman 2012, Parenteau et al. 2021). In the domain of executive function, children's performance is correlated with parent behaviors such as scaffolding to support children in solving challenging tasks with assistance (Valcan et al. 2018). Scaffolding of children's goal-directed activities can support their learning and experiences solving problems they could not reach on their own, which may in turn support the engagement and development of executive functions (Bodrova et al. 2013, Vygotsky 1978). These naturalistic findings can be built on, as in the domain of language, to experimentally test the causal role of such dynamics in the emergence of executive function (Moreno et al. 2017, Bodrova & Leong 2018; cf. Nesbitt & Farran 2021).

Third, computational modeling approaches should yield insight into how experiences in social contexts shape emerging executive function and how to support children's development. Computational models provide a valuable framework for specifying and testing hypotheses and bridging brain, behavior, and experience. Such models have proven useful for exploring many aspects of development (e.g., Elman et al. 1996, Mareschal & Thomas 2007, Munakata & McClelland 2003, Schöner et al. 2016, Shultz 2013, Smith & Thelen 1996, Ullman & Tenenbaum 2020), including executive function (Buss & Spencer 2014, Munakata et al. 2013). An established neural network modeling framework incorporates information about frontostriatal circuitry to simulate performance on a range of executive function tasks; this research has led to insights into underlying mechanisms as well as detailed predictions that have been confirmed across a variety of methods and populations (e.g., Chatham et al. 2011, Collins & Frank 2013, O'Reilly & Frank 2006). The simulated learning environments of such models can be manipulated to test the impact on developing executive function (e.g., Rougier et al. 2005). Such manipulations often focus on the basic content of the learning environment, such as the objects observed and the words heard. However, these simulations could be extended to explore how models learn and adapt in their trajectories of executive function development in response to different social contexts, such as those relating to trust and norms that have been shown to influence children's engagement of executive function. Such computational approaches can provide insight into the mechanisms underlying the effects of social contexts on developing executive function, and into ways to support children's executive function at different points in development and given different social contexts and histories. Such advances could parallel and build on advances in the field of computational psychiatry, which uses models as a tool to explore the complexities of the brain and the environment in order to advance understanding, prediction, and treatment of mental illness (Huys et al. 2016). Computational approaches can also inform ongoing debates about relationships among executive function, self-control, and related processes, by highlighting how common and distinct mechanisms contribute to goal-directed processes as explored across a multitude of methods and contexts.

Finally, given the complexity of understanding how executive function emerges in the world, advances in theory, measurement, and analysis will be central to this endeavor. Many rigorous research methods remain underused across the developmental sciences (Rioux & Little 2020), but studies of the development of executive function are increasingly applying these innovative methods. Intensive longitudinal and ambulatory assessment studies measure child executive functions on many occasions over a short time period to understand intraindividual fluctuations in addition to interindividual differences (Könen et al. 2015, Neubauer et al. 2019, Yu et al. 2021). Such designs can support idiographic analytic techniques, such as dynamic structural equation modeling, to reveal unique individual trajectories of executive function development that are obscured in traditional variable-centered analyses (e.g., Yu et al. 2020). Invariance testing can be used to explore whether the latent structure of executive function differs between sample subgroups and how it changes across development (Montroy et al. 2019, Wiebe et al. 2011, Willoughby et al. 2012). These methods feature variability within individuals and groups as an interesting and often overlooked source of research questions in its own right, to complement our well-established techniques for studying aggregates and means. Additionally, contemporary family designs such as children of twins and sibling fixed-effect studies can help tease out causal effects of the environment on child outcomes while accounting for genetic influences (D'Onofrio et al. 2003, Jaffee et al. 2012, McAdams et al. 2018).

Studies that span multiple aspects of these promising directions, such as longitudinal intervention studies measuring real-world dynamics and consequences and computational mechanisms, will likely play a key role in understanding the richness of how social context influences the development of executive function. Such research will advance the understanding and supporting of children's success both in the moment and in the long term.

ACKNOWLEDGMENTS

We thank Jane Barker, Sabine Doebel, Nathan Fox, Ben Katz, Akira Miyake, Jesse Niebaum, Diego Placido, Priti Shah, Hilary Traut, Jack White, Jade Yonehiro, Winnie Zhuang, and members of the Cognition in Context Lab for valuable feedback and discussion. The writing of this article was supported by the National Institute of Child Health and Human Development (R01HD078532, R01HD086184) and the American Institutes for Research publication program.

LITERATURE CITED

Abney DH, Suanda SH, Smith LB, Yu C. 2020. What are the building blocks of parent–infant coordinated attention in free-flowing interaction? Infancy 25(6):871–87 [PubMed: 33022842]

Acker MM, O'Leary SG. 1996. Inconsistency of mothers' feedback and toddlers' misbehavior and negative affect. J. Abnorm. Child Psychol 24(6):703–14 [PubMed: 8970905]

Ackerman BP, Brown ED. 2010. Physical and psychosocial turmoil in the home and cognitive development. In Chaos and Its Influence on Children's Development: An Ecological Perspective, ed. Evans GW, Wachs TD, pp. 35–47. Washington, DC: Am. Psychol. Assoc.

Adam KCS, Vogel EK. 2016. Reducing failures of working memory with performance feedback. Psychon. Bull. Rev 23(5):1520–27 [PubMed: 26961905]

Ahmed S, Grammer J, Morrison F. 2021. Cognition in context: validating group-based executive function assessments in young children. J. Exp. Child Psychol 208:105131 [PubMed: 33878609]

Ahmed S, Tang S, Waters NE, Davis-Kean P. 2019. Executive function and academic achievement: longitudinal relations from early childhood to adolescence. J. Educ. Psychol 111(3):446–58

Alexander WH, Brown JW. 2010. Computational models of performance monitoring and cognitive control. Top. Cogn. Sci 2(4):658–77 [PubMed: 21359126]

Andrews K, Atkinson L, Harris M, Gonzalez A. 2021. Examining the effects of household chaos on child executive functions: a meta-analysis. Psychol. Bull 147(1):16–32 [PubMed: 33151702]

Ayduk O, Mendoza-Denton R, Mischel W, Downey G, Peake PK, Rodriguez M. 2000. Regulating the interpersonal self: strategic self-regulation for coping with rejection sensitivity. J. Personal. Soc. Psychol 79(5):776–92

Badre D 2008. Cognitive control, hierarchy, and the rostro-caudal organization of the frontal lobes. Trends Cogn. Sci 12(5):193–200 [PubMed: 18403252]

Baillargeon R, Spelke ES, Wasserman S. 1985. Object permanence in five-month-old infants. Cognition 20(3):191–208 [PubMed: 4064606]

Banich M 2009. Executive function: the search for an integrated account. Curr. Dir. Psychol. Sci 18(2):89–94

Baptista J, Osório A, Martins EC, Verissimo M, Martins C. 2016. Does social-behavioral adjustment mediate the relation between executive function and academic readiness? J. Appl. Dev. Psychol 46:22–30

Barker JE, Semenov AD, Michaelson L, Provan LS, Snyder HR, Munakata Y. 2014. Less-structured time in children's daily lives predicts self-directed executive functioning. Front. Psychol 5:593 [PubMed: 25071617]

Barkley RA. 2012. Executive Functions: What They Are, How They Work, and Why They Evolved. New York: Guilford

Basner M, Babisch W, Davis A, Brink M, Clark C, et al. 2014. Auditory and non-auditory effects of noise on health. Lancet 383(9925):1325–32 [PubMed: 24183105]

Benson JE, Sabbagh MA, Carlson SM, Zelazo PD. 2013. Individual differences in executive functioning predict preschoolers' improvement from theory-of-mind training. Dev. Psychol 49(9):1615–27 [PubMed: 23244411]

Berry D, Blair C, Willoughby M, Garrett-Peters P, Vernon-Feagans L, Mills-Koonce WR. 2016. Household chaos and children's cognitive and socio-emotional development in early childhood: Does childcare play a buffering role? Early Child. Res. Q 34:115–27 [PubMed: 29720785]

Best JR, Miller PH. 2010. A developmental perspective on executive function. Child Dev. 81(6):1641–60 [PubMed: 21077853]

Blair C, Razza RP. 2007. Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. Child Dev. 78(2):647–63 [PubMed: 17381795]

Blair C, Ursache A, Greenberg M, Vernon-Feagans L, Fam. Life Proj. Investig. 2015. Multiple aspects of self-regulation uniquely predict mathematics but not letter-word knowledge in the early elementary grades. Dev. Psychol 51(4):459–72 [PubMed: 25688999]

Bodrova E, Germeroth C, Leong DJ. 2013. Play and self-regulation: lessons from Vygotsky. Am. J. Play 6(1):111–23

Bodrova E, Leong DJ. 2018. Tools of the mind: a Vygotskian early childhood curriculum. In International Handbook of Early Childhood Education, ed. Fleer M, van Oers B, pp. 1095–111. Dordrecht, Neth.: Springer

Bogartz RS, Shinskey JL, Schilling T. 2000. Object permanence in five-and-a-half month old infants? Infancy 1:403–28 [PubMed: 32680304]

Botvinick M, Braver T. 2015. Motivation and cognitive control: from behavior to neural mechanism. Annu. Rev. Psychol 66:83–113 [PubMed: 25251491]

Bowers E, Li Y, Kiely M, Brittian A, Lerner J, Lerner R. 2010. The Five Cs model of positive youth development: a longitudinal analysis of confirmatory factor structure and measurement invariance. J. Youth Adolesc 39:720–35 [PubMed: 20397040]

Brod G, Bunge SA, Shing YL. 2017. Does one year of schooling improve children's cognitive control and alter associated brain activation? Psychol. Sci 28(7):967–78 [PubMed: 28489500]

Bronfenbrenner U, Evans GW. 2000. Developmental science in the 21st century: emerging questions, theoretical models, research designs and empirical findings. Soc. Dev 9(1):115–25

Bronfenbrenner U, Morris PA. 1998. The ecology of developmental processes. In Handbook of Child Psychology, Vol. 1: Theoretical Models of Human Development, ed. Damon W, Lerner RM, pp. 993–1028. Hoboken, NJ: Wiley. 5th ed.

Brydges CR, Reid CL, Fox AM, Anderson M. 2012. A unitary executive function predicts intelligence in children. Intelligence 40(5):458–69

Bunge SA, Crone EA. 2009. Neural correlates of the development of cognitive control. In Neuroimaging in Developmental Clinical Neuroscience, ed. Rumsey JM, Ernst M, pp. 22–37. Cambridge, UK: Cambridge Univ. Press

Burrage MS, Ponitz CC, McCready EA, Shah P, Sims BC, et al. 2008. Age- and schooling-related effects on executive functions in young children: a natural experiment. Child Neuropsychol. 14(6):510–24 [PubMed: 18982508]

Buss AT, Spencer JP. 2014. The emergent executive: a Dynamic Field theory of the development of executive function. Monogr. Soc. Res. Child Dev 79(2):1–11

Buyalskaya A, Gallo M, Camerer CF. 2021. The golden age of social science. PNAS 118(5):e2002923118

Camilli G, Shepard LA. 1994. Methods for Identifying Biased Test Items, Vol. 4. Thousand Oaks, CA: SAGE

Carlson SM. 2005. Developmentally sensitive measures of executive function in preschool children. Dev. Neuropsychol 28(2):595–616 [PubMed: 16144429]

Cepeda NJ, Blackwell KA, Munakata Y. 2013. Speed isn't everything: Complex processing speed measures mask individual differences and developmental changes in executive control. Dev. Sci 16(2):269–86 [PubMed: 23432836]

Chatham CH, Herd SA, Brant AM, Hazy TE, Miyake A, et al. 2011. From an executive network to executive control: a computational model of the *n*-back task. J. Cogn. Neurosci 23:3598–619 [PubMed: 21563882]

Chevalier N 2018. Willing to think hard? The subjective value of cognitive effort in children. Child Dev. 89(4):1283–95 [PubMed: 28397991]

Chiew KS, Braver TS. 2013. Temporal dynamics of motivation–cognitive control interactions revealed by high-resolution pupillometry. Front. Psychol 4:15 [PubMed: 23372557]

Chiew KS, Braver TS. 2014. Dissociable influences of reward motivation and positive emotion on cognitive control. Cogn. Affect. Behav. Neurosci 14(2):509–29 [PubMed: 24733296]

Chiew KS, Braver TS. 2016. Reward favours the prepared: Incentive and task-informative cues interact to enhance attentional control. J. Exp. Psychol. Hum. Percept. Perform 42(1):52–66 [PubMed: 26322689]

Cole M 1995. Culture and cognitive development: from cross-cultural research to creating systems of cultural mediation. Cult. Psychol 1(1):25–54

Collins AGE, Frank MJ. 2013. Cognitive control over learning: creating, clustering, and generalizing task-set structure. Psychol. Rev 120(1):190–229 [PubMed: 23356780]

Conway ARA, Kane MJ, Engle RW. 2003. Working memory capacity and its relation to general intelligence. Trends Cogn. Sci 7(12):547–52 [PubMed: 14643371]

Correa-Chávez M, Mejía-Arauz R, Rogoff B. 2015. Children Learn by Observing and Contributing to Family and Community Endeavors: A Cultural Paradigm. Adv. Child Dev. Behav Vol. 49. Amsterdam: Elsevier. 1st ed.

Cragg L, Gilmore C. 2014. Skills underlying mathematics: the role of executive function in the development of mathematics proficiency. Trends Neurosci. Educ 3(2):63–68

Davis EP, Stout SA, Molet J, Vegetabile B, Glynn LM, et al. 2017. Exposure to unpredictable maternal sensory signals influences cognitive development across species. PNAS 114(39):10390–95 [PubMed: 28893979]

DeJoseph ML, Sifre RD, Raver CC, Blair CB, Berry D. 2021. Capturing environmental dimensions of adversity and resources in the context of poverty across infancy through early adolescence: a moderated nonlinear factor model. Child Dev. 92(4):457–75

Diamond A 2013. Executive functions. Annu. Rev. Psychol 64:135–68 [PubMed: 23020641]

Diamond A, Lee K. 2011. Interventions shown to aid executive function development in children 4–12 years old. Science 333(6045):959–64 [PubMed: 21852486]

Doan SN, Evans GW. 2020. Chaos and instability from birth to age three. Future Child. 30(2):93–113

Doebel S 2020. Rethinking executive function and its development. Perspect. Psychol. Sci 15(4):942–56 [PubMed: 32348707]

Doebel S, Michaelson LE, Munakata Y. 2020. Good things come to those who wait: Delaying gratification likely does matter for later achievement (a commentary on Watts, Duncan, & Quan, 2018). Psychol. Sci 31(1):97–99 [PubMed: 31850827]

Doebel S, Munakata Y. 2018. Group influences on engaging self-control: Children delay gratification and value it more when their in-group delays and their out-group doesn’t. Psychol. Sci 29(5):738–48 [PubMed: 29625014]

D’Onofrio BM, Turkheimer EN, Eaves LJ, Corey LA, Berg K, et al. 2003. The role of the children of twins design in elucidating causal relations between parent characteristics and child outcomes. J. Child Psychol. Psychiatry 44(8):1130–44 [PubMed: 14626455]

Draheim C, Tsukahara JS, Martin JD, Mashburn CA, Engle RW. 2021. A toolbox approach to improving the measurement of attention control. J. Exp. Psychol. Gen 150(2):242–75 [PubMed: 32700925]

Dubois L, Kyvik KO, Girard M, Tatone-Tokuda F, Pérusse D, et al. 2012. Genetic and environmental contributions to weight, height, and BMI from birth to 19 years of age: an international study of over 12,000 twin pairs. PLOS ONE 7(2):e30153 [PubMed: 22347368]

Duckworth AL, Kern ML. 2011. A meta-analysis of the convergent validity of self-control measures. J. Res. Personal 45(3):259–68

Duckworth AL, Tsukayama E, Kirby TA. 2013. Is it really self-control? Examining the predictive power of the delay of gratification task. Personal. Soc. Psychol. Bull 39(7):843–55

Duckworth AL, Yeager DS. 2015. Measurement matters: assessing personal qualities other than cognitive ability for educational purposes. Educ. Res 44(4):237–51 [PubMed: 27134288]

Eigsti I-M, Zayas V, Walter M, Shoda Y, Ayduk O, et al. 2006. Predicting cognitive control from preschool to late adolescence and young adulthood. Psychol. Sci 17(6):478–84 [PubMed: 16771797]

Eisenberg IW, Bissett PG, Enkavi AZ, Li J, MacKinnon DP, et al. 2019. Uncovering the structure of self-regulation through data-driven ontology discovery. Nat. Commun 10:2319 [PubMed: 31127115]

Elman JL, Bates EA, Johnson MH, Karmiloff-Smith A, Parisi D, Plunkett K. 1996. Rethinking Innateness: A Connectionist Perspective on Development. Cambridge, MA: Bradford

Enkavi AZ, Eisenberg IW, Bissett PG, Mazza GL, MacKinnon DP, et al. 2019. Large-scale analysis of test–retest reliabilities of self-regulation measures. PNAS 116(12):5472–77 [PubMed: 30842284]

Evans GW. 2021. The physical context of child development. Curr. Dir. Psychol. Sci 30(1):41–48

Evans GW, Bullinger M, Hygge S. 1998. Chronic noise exposure and physiological response: a prospective study of children living under environmental stress. Psychol. Sci 9(1):75–77

Falk A, Kosse F, Pinger P. 2020. Re-revisiting the marshmallow test: a direct comparison of studies by Shoda, Mischel, and Peake 1990 and Watts, Duncan, and Quan 2018. Psychol. Sci 31(1):100–4 [PubMed: 31850833]

Feldman R 2012. Parent–infant synchrony: a biobehavioral model of mutual influences in the formation of affiliative bonds. Monogr. Soc. Res. Child Dev 77(2):42–51

Fiese BH. 2006. Family Routines and Rituals. New Haven, CT: Yale Univ. Press

Figner B, Knoch D, Johnson EJ, Krosch AR, Lisanby SH, et al. 2010. Lateral prefrontal cortex and self-control in intertemporal choice. Nat. Neurosci 13(5):538–39 [PubMed: 20348919]

Fischer P, Camba L, Ooi SH, Chevalier N. 2018. Supporting cognitive control through competition and cooperation in childhood. J. Exp. Child Psychol 173:28–40 [PubMed: 29656106]

Fisher AV, Godwin KE, Seltman H. 2014. Visual environment, attention allocation, and learning in young children: when too much of a good thing may be bad. Psychol. Sci 25(7):1362–70 [PubMed: 24855019]

Fox NA, Buzzell GA, Morales S, Valadez EA, Wilson M, Henderson HA. 2021. Understanding the emergence of social anxiety in children with behavioral inhibition. Biol. Psychiatry 89(7):681–89 [PubMed: 33353668]

Friedman NP, Haberstick BC, Willcutt EG, Miyake A, Young SE, et al. 2007. Greater attention problems during childhood predict poorer executive functioning in late adolescence. Psychol. Sci 18(10):893–900 [PubMed: 17894607]

Friedman NP, Miyake A, Altamirano LJ, Corley RP, Young SE, et al. 2016. Stability and change in executive function abilities from late adolescence to early adulthood: a longitudinal twin study. Dev. Psychol 52(2):326–40 [PubMed: 26619323]

Friedman NP, Miyake A, Corley RP, Young SE, Defries JC, Hewitt JK. 2006. Not all executive functions are related to intelligence. Psychol. Sci 17(2):172–79 [PubMed: 16466426]

Friedman NP, Miyake A, Robinson JL, Hewitt JK. 2011. Developmental trajectories in toddlers' self-restraint predict individual differences in executive functions 14 years later: a behavioral genetic analysis. Dev. Psychol 47(5):1410–30 [PubMed: 21668099]

Friedman NP, Miyake A, Young SE, Defries JC, Corley RP, Hewitt JK. 2008. Individual differences in executive functions are almost entirely genetic in origin. J. Exp. Psychol. Gen 137(2):201–25 [PubMed: 18473654]

Fuhs MW, Day JD. 2011. Verbal ability and executive functioning development in preschoolers at head start. Dev. Psychol 47(2):404–16 [PubMed: 21142363]

Fujita K, Trope Y, Liberman N, Levin-Sagi M. 2006. Construal levels and self-control. J. Personal. Soc. Psychol 90(3):351–67

Gathercole SE, Pickering SJ, Ambridge B, Wearing H. 2004. The structure of working memory from 4 to 15 years of age. Dev. Psychol 40(2):177–90 [PubMed: 14979759]

Glynn LM, Baram TZ. 2019. The influence of unpredictable, fragmented parental signals on the developing brain. Front. Neuroendocrinol 53:100736 [PubMed: 30711600]

Goldstein MH, King AP, West MJ. 2003. Social interaction shapes babbling: testing parallels between birdsong and speech. PNAS 100:8030–35 [PubMed: 12808137]

Goldstein MH, Schwade JA. 2008. Social feedback to infants' babbling facilitates rapid phonological learning. Psychol. Sci 19(5):515–23 [PubMed: 18466414]

Goldstein MH, West MJ. 1999. Consistent responses of human mothers to prelinguistic infants: the effect of prelinguistic repertoire size. J. Comp. Psychol 113(1):52–58 [PubMed: 10098268]

Good C, Aronson J, Inzlicht M. 2003. Improving adolescents' standardized test performance: an intervention to reduce the effects of stereotype threat. J. Appl. Dev. Psychol 24(6):645–62

Goodenough FL. 1936. The measurement of mental functions in primitive groups. Am. Anthropol 38(1):1–11

Haenlein M, Caul WF. 1987. Attention deficit disorder with hyperactivity: a specific hypothesis of reward dysfunction. J. Am. Acad. Child Adolesc. Psychiatry 26(3):356–62 [PubMed: 3597291]

Hammer MC (@MCHammer). 2021. You bore us. If science is a “commitment to truth” shall we site all the historical non-truths perpetuated by scientists ? Of course not. It’s not science vs Philosophy … It’s Science + Philosophy. Elevate your Thinking and Consciousness. When you measure include the measurer Twitter, Febr. 21, 9:50 AM. https://twitter.com/mchammer/status/1363908982289559553

Harbaugh W, Krause K, Liday S, Vesterlund L. 2003. Trust and Reciprocity: Interdisciplinary Lessons for Experimental Research. New York: Russell Sage Found.

Harms MB, Zayas V, Meltzoff AN, Carlson SM. 2014. Stability of executive function and predictions to adaptive behavior from middle childhood to pre-adolescence. Front. Psychol 5:331 [PubMed: 24795680]

Hefer C, Dreisbach G. 2016. The motivational modulation of proactive control in a modified version of the AX-continuous performance task: evidence from cue-based and prime-based preparation. Motiv. Sci 2(2):116–34

Helm AF, McCormick SA, Deater-Deckard K, Smith CL, Calkins SD, Bell MA. 2020. Parenting and children’s executive function stability across the transition to school. Infant Child Dev. 29(1):e2171 [PubMed: 32617081]

Henrich J, Heine SJ, Norenzayan A. 2010. The weirdest people in the world? Behav. Brain Sci 33(2/3):61–83 [PubMed: 20550733]

Hirsh-Pasek K, Adamson LB, Bakeman R, Owen MT, Golinkoff RM, et al. 2015. The contribution of early communication quality to low-income children’s language success. Psychol. Sci 26(7):1071–83 [PubMed: 26048887]

Hoffmann W, Friese M, Roefs A. 2009. Three ways to resist temptation: the independent contributions of executive attention, inhibitory control, and affect regulation to the impulse control of eating behavior. J. Exp. Psychol 45(2):431–35

Holmes J, Gathercole SE, Dunning DL. 2009. Adaptive training leads to sustained enhancement of poor working memory in children. Dev. Sci 12(4):F9–15 [PubMed: 19635074]

Huizinga M, Baeyens D, Burack JA. 2018. Executive function and education. Front. Psychol 9:1357 [PubMed: 30123163]

Huys QJM, Maia TV, Frank MJ. 2016. Computational psychiatry as a bridge from neuroscience to clinical applications. Nat. Neurosci 19(3):404 [PubMed: 26906507]

Jachimowicz JM, Chafik S, Munrat S, Prabhu JC, Weber EU. 2017. Community trust reduces myopic decisions of low-income individuals. PNAS 114(21):5401–6 [PubMed: 28400516]

Jaffee SR, Strait LB, Odgers CL. 2012. From correlates to causes: Can quasi-experimental studies and statistical innovations bring us closer to identifying the causes of antisocial behavior? Psychol. Bull 138(2):272–95 [PubMed: 22023141]

Johansen EB, Killeen PR, Russell VA, Tripp G, Wickens JR, et al. 2009. Origins of altered reinforcement effects in ADHD. Behav. Brain Funct 5:7 [PubMed: 19226460]

Kail R 2000. Speed of information processing: developmental change and links to intelligence. J. Sch. Psychol 38(1):51–61

Kassai R, Futo J, Demetrovics Z, Takacs ZK. 2019. A meta-analysis of the experimental evidence on the near-and far-transfer effects among children’s executive function skills. Psychol. Bull 145(2):165–88 [PubMed: 30652908]

Katz B, Matthews JS, Shah P, Munakata Y. 2021. Executive functions and education: progress and potential. Work. Pap., Dep. Hum. Dev. Fam. Sci, Va. Tech., Blacksburg

Kave G, Kigel S, Kochva R. 2008. Switching and clustering in verbal fluency tasks throughout childhood. J. Clin. Exp. Neuropsychol 30(3):349–59 [PubMed: 17852609]

Keen R 2003. Representation of objects and events: Why do infants look so smart and toddlers look so dumb? Curr. Dir. Psychol. Sci 12(3):79–83

Kidd C, Palmeri H, Aslin RN. 2013. Rational snacking: Young children’s decision-making on the marshmallow task is moderated by beliefs about environmental reliability. Cognition 126(1):109–14 [PubMed: 23063236]

Könen T, Dirk J, Schmiedek F. 2015. Cognitive benefits of last night’s sleep: Daily variations in children’s sleep behavior are related to working memory fluctuations. J. Child Psychol. Psychiatry 56(2):171–82 [PubMed: 25052368]

Kool W, McGuire JT, Rosen ZB, Botvinick M. 2010. Decision making and the avoidance of cognitive demand. J. Exp. Psychol. Gen 139(4):665–82 [PubMed: 20853993]

Koomen R, Grueneisen S, Herrmann E. 2020. Children delay gratification for cooperative ends. Psychol. Sci 31(2):139–48 [PubMed: 31916904]

Lamm B, Keller H, Teiser J, Gudi H, Yovsi RD, et al. 2018. Waiting for the second treat: developing culture-specific modes of self-regulation. Child Dev. 89(3):e261–77 [PubMed: 28586087]

Lan X, Legare CH, Ponitz CC, Li S, Morrison FJ. 2011. Investigating the links between the subcomponents of executive function and academic achievement: a cross-cultural analysis of Chinese and American preschoolers. J. Exp. Child Psychol 108(3):677–92 [PubMed: 21238977]

Lawson GM, Hook CJ, Farah MJ. 2018. A meta-analysis of the relationship between socioeconomic status and executive function performance among children. Dev. Sci 21(2):e12529

Ledgerwood A, Hudson STJ, Lewis N, Maddox K, Pickett C, et al. 2021. The pandemic as a portal: reimagining psychological science as truly open and inclusive. PsyArXiv gdzue. 10.31234/osf.io/gdzue

Lee WSC, Carlson SM. 2015. Knowing when to be “rational”: flexible economic decision making and executive function in preschool children. Child Dev. 86(5):1434–48 [PubMed: 26264807]

Legare CH, Dale MT, Kim SY, Deák GO. 2018. Cultural variation in cognitive flexibility reveals diversity in the development of executive functions. Sci. Rep 8:16326 [PubMed: 30397235]

Lillard AS, Else-Quest N. 2006. The early years: evaluating Montessori education. Science 313(5795):1893–94 [PubMed: 17008512]

Lillard AS, Heise MJ, Richey EM, Tong X, Hart A, Bray PM. 2017. Montessori preschool elevates and equalizes child outcomes: a longitudinal study. Front. Psychol 8:1783 [PubMed: 29163248]

Luerssen A, Gyurak A, Ayduk O, Wendelken C, Bunge SA. 2015. Delay of gratification in childhood linked to cortical interactions with the nucleus accumbens. Soc. Cogn. Affect. Neurosci 10(12):1769–76 [PubMed: 26048177]

Luna B, Padmanabhan A, O’Hearn K. 2010. What has fMRI told us about the development of cognitive control through adolescence? Brain Cogn 72(1):101–13 [PubMed: 19765880]

Luria AR. 1966. Higher Cortical Functions in Man. London: Tavistock

Ma F, Chen B, Xu F, Lee K, Heyman GD. 2018. Generalized trust predicts young children’s willingness to delay gratification. J. Exp. Child Psychol 169:118–25 [PubMed: 29357990]

Mak C, Whittingham K, Cunnington R, Boyd RN. 2018. Efficacy of mindfulness-based interventions for attention and executive function in children and adolescents—a systematic review. Mindfulness 9(1):59–78

Marcovitch S, Boseovski JJ, Knapp RJ. 2007. Use it or lose it: examining preschoolers’ difficulty in maintaining and executing a goal. Dev. Sci 10:559–64 [PubMed: 17683342]

Mareschal D 2000. Object knowledge in infancy: current controversies and approaches. Trends Cogn. Sci 4(11):408–16 [PubMed: 11058818]

Mareschal D, Thomas M. 2007. Computational modeling in developmental psychology. IEEE Trans. Evol. Comput 11(2):137–50

Matthews JS. 2018. When am I ever going to use this in the real world? Cognitive flexibility and urban adolescents’ negotiation of the value of mathematics. J. Educ. Psychol 110(5):726–46

Mauro CF, Harris YR. 2000. The influence of maternal child-rearing attitudes and teaching behaviors on preschoolers’ delay of gratification. J. Genet. Psychol 161(3):292–306 [PubMed: 10971908]

May CP, Hasher L, Stoltzfus ER. 1993. Optimal time of day and the magnitude of age differences in memory. Psychol. Sci 4(5):326–30

McAdams TA, Hannigan LJ, Eilertsen EM, Gjerde LC, Ystrom E, Rijsdijk FV. 2018. Revisiting the Children-of-Twins design: improving existing models for the exploration of intergenerational associations. Behav. Genet 48(5):397–412 [PubMed: 29961153]

McClure SM, Laibson DI, Loewenstein G, Cohen JD. 2004. Separate neural systems value immediate and delayed monetary rewards. Science 306(5695):503–7 [PubMed: 15486304]

McEwen BS. 1998. Stress, adaptation, and disease. Allostasis and allostatic load. Ann. N. Y. Acad. Sci 840:33–44 [PubMed: 9629234]

McGuire JT, Botvinick MM. 2010. Prefrontal cortex, cognitive control, and the registration of decision costs. PNAS 107(17):7922–26 [PubMed: 20385798]

McGuire JT, Kable JW. 2013. Rational temporal predictions can underlie apparent failures to delay gratification. Psychol. Rev 120(2):395–410 [PubMed: 23458085]

Meehl PE. 1970. Nuisance variables and the ex post facto design. Minn. Stud. Philos. Sci 4:373–402

Michaelson LE, Munakata Y. 2016. Trust matters: Seeing how an adult treats another person influences preschoolers' willingness to delay gratification. Dev. Sci 19(6):1011–19 [PubMed: 26799458]

Michaelson LE, Munakata Y. 2020. Same data set, different conclusions: Preschool delay of gratification predicts later behavioral outcomes in a preregistered study. Psychol. Sci 31(2):193–201 [PubMed: 31961773]

Miller EK, Cohen JD. 2001. An integrative theory of prefrontal cortex function. Annu. Rev. Neurosci 24:167–202 [PubMed: 11283309]

Mischel W, Ebbesen EB, Raskoff Zeiss A. 1972. Cognitive and attentional mechanisms in delay of gratification. J. Personal. Soc. Psychol 21(2):204–18

Mischel W, Shoda Y, Peake PK. 1988. The nature of adolescent competencies predicted by preschool delay of gratification. J. Personal. Soc. Psychol 54(4):687–96

Mischel W, Shoda Y, Rodriguez ML. 1989. Delay of gratification in children. Science 244(4907):933–38 [PubMed: 2658056]

Miyake A, Friedman NP. 2012. The nature and organization of individual differences in executive functions: four general conclusions. Curr. Dir. Psychol. Sci 21(1):8–14 [PubMed: 22773897]

Moffett L, Flannagan C, Shah P. 2020. The influence of environmental reliability in the marshmallow task: an extension study. J. Exp. Child Psychol 194:104821 [PubMed: 32169745]

Moffitt TE, Arseneault L, Belsky D, Dickson N, Hancox RJ, et al. 2011. A gradient of childhood self-control predicts health, wealth, and public safety. PNAS 108(7):2693–98 [PubMed: 21262822]

Montroy JJ, Merz EC, Williams JM, Landry SH, Johnson UY, et al. 2019. Hot and cool dimensionality of executive function: model invariance across age and maternal education in preschool children. Early Child. Res. Q 49:188–201

Moreno AJ, Shwayder I, Friedman ID. 2017. The function of executive function: everyday manifestations of regulated thinking in preschool settings. Early Child. Educ. J 45(2):143–53

Moriguchi Y, Chevalier N, Zelazo PD. 2016. Development of executive function during childhood. Front. Psychol 7:6 [PubMed: 26834679]

Munakata Y, Chatham C, Snyder H. 2013. Mechanistic accounts of frontal lobe development. In Principles of Frontal Lobe Function, ed. Knight RT, Stuss DT, pp. 185–206. Oxford, UK: Oxford Univ. Press

Munakata Y, McClelland JL. 2003. Connectionist models of development. Dev. Sci 6(4):413–29

Munakata Y, McClelland JL, Johnson MH, Siegler RS. 1997. Rethinking infant knowledge: toward an adaptive process account of successes and failures in object permanence tasks. Psychol. Rev 104(4):686–713 [PubMed: 9337629]

Munakata Y, Snyder HR, Chatham CH. 2012. Developing cognitive control: three key transitions. Curr. Dir. Psychol. Sci 21(2):71–77 [PubMed: 22711982]

Munakata Y, Yanaoka K, Doebel S, Guild RM, Michaelson LE, Saito S. 2020. Group influences on children's delay of gratification: testing the roles of culture and personal connections. Collabra Psychol. 6(1):1

Nesbitt KT, Farran DC. 2021. Effects of prekindergarten curricula: Tools of the Mind as a case study. Monogr. Soc. Res. Child Dev 86(1):7–119

Neubauer AB, Dirk J, Schmiedek F. 2019. Momentary working memory performance is coupled with different dimensions of affect for different children: a mixture model analysis of ambulatory assessment data. Dev. Psychol 55(4):754–66 [PubMed: 30556707]

Newcombe NS. 2003. Some controls control too much. Child Dev. 74(4):1050–52 [PubMed: 12938700]

Niebaum J, Chevalier N, Guild R, Munakata Y. 2021. Developing adaptive control: age-related differences in task choices and awareness of proactive and reactive control demands. Cogn. Affect. Behav. Neurosci 21(3):561–72 [PubMed: 33009653]

Niebaum J, Munakata Y. 2020. Deciding what to do: developments in children's spontaneous monitoring of cognitive demands. Child Dev. Perspect 14(4):202–7 [PubMed: 37162814]

Niebaum JC, Chevalier N, Guild RM, Munakata Y. 2019. Adaptive control and the avoidance of cognitive control demands across development. Neuropsychologia 123:152–58 [PubMed: 29723599]

Nielsen M, Haun D, Kärtner J, Legare CH. 2017. The persistent sampling bias in developmental psychology: a call to action. J. Exp. Child Psychol 162:31–38 [PubMed: 28575664]

Nigg JT. 2017. On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. J. Child Psychol. Psychiatry 58(4):361–83 [PubMed: 28035675]

Noble KG, Norman MF, Farah MJ. 2005. Neurocognitive correlates of socioeconomic status in kindergarten children. Dev. Sci 8(1):74–87 [PubMed: 15647068]

Nsamenang AB. 1995. Theories of developmental psychology for a cultural perspective: a view from Africa. Psychol. Dev. Soc 7(1):1–19

O'Reilly RC, Frank MJ. 2006. Making working memory work: a computational model of learning in the prefrontal cortex and basal ganglia. Neural Comput. 18(2):283–328 [PubMed: 16378516]

O'Toole S, Monks CP, Tsermentseli S. 2018. Associations between and development of cool and hot executive functions across early childhood. Br. J. Dev. Psychol 36(1):142–48 [PubMed: 29226486]

Padilla-Walker LM, Dyer WJ, Yorgason JB, Fraser AM, Coyne SM. 2015. Adolescents' prosocial behavior toward family, friends, and strangers: a person-centered approach. J. Res. Adolesc 25(1):135–50

Parenteau AM, Hostinar CE, Vacaru SV, Lustermans H, Dimanova P, et al. 2021. Does biobehavioral synchrony promote learning? A systematic review and meta-analysis. Paper presented at the Society for Research in Child Development, online, Apr. 8

Pennebaker JW, Gosling SD, Ferrell JD. 2013. Daily online testing in large classes: boosting college performance while reducing achievement gaps. PLOS ONE 8(11):e79774 [PubMed: 24278176]

Penuel WR, Gallagher DJ. 2017. Creating Research–Practice Partnerships in Education. Cambridge, MA: Harvard Educ.

Pepper GV, Nettle D. 2017. The behavioural constellation of deprivation: causes and consequences. Behav. Brain Sci 40:e314 [PubMed: 28073390]

Perone S, Simmering VR, Buss AT. 2021. A dynamical reconceptualization of executive-function development. Perspect. Psychol. Sci In press. 10.1177/1745691620966792

Posner MI, Snyder CRR. 1975. Attention and cognitive control. In Information Processing and Cognition, ed. Solso RL, pp. 55–85. Hillsdale, NJ: Erlbaum

Razza RA, Raymond K. 2013. Associations among maternal behavior, delay of gratification, and school readiness across the early childhood years. Soc. Dev 22(1):180–96

Rea-Sandin G, Korous KM, Causadias JM. 2021. A systematic review and meta-analysis of racial/ethnic differences and similarities in executive function performance in the United States. Neuropsychology 35(2):141–56 [PubMed: 33764108]

Reilly J (@JamieReilly_cog). 2021. I triple dog dare someone to explain the difference between executive functioning and cognitive control. Twitter, Jan. 22, 5:17 AM. https://twitter.com/JamieReilly_cog/status/1352606309951172609

Repetti RL, Taylor SE, Seeman TE. 2002. Risky families: family social environments and the mental and physical health of offspring. Psychol. Bull 128(2):330–66 [PubMed: 11931522]

Rioux C, Little TD. 2020. Underused methods in developmental science to inform policy and practice. Child Dev. Perspect 14(2):97–103

Robson DA, Allen MS, Howard SJ. 2020. Self-regulation in childhood as a predictor of future outcomes: a meta-analytic review. Psychol. Bull 146(4):324–54 [PubMed: 31904248]

Rodriguez ML, Mischel W, Shoda Y. 1989. Cognitive person variables in the delay of gratification of older children at risk. J. Personal. Soc. Psychol 57(2):358–67

Rogoff B 1990. Apprenticeship in Thinking: Cognitive Development in Social Context. New York: Oxford Univ. Press

Rogoff B, Turkanis CG, Bartlett L. 2002. Learning Together: Children and Adults in a School Community. Oxford, UK: Oxford Univ. Press

Rohrer JM. 2018. Thinking clearly about correlations and causation: graphical causal models for observational data. Adv. Methods Pract. Psychol. Sci 1(1):27–42

Roos L, Beauchamp K, Flannery J, Fisher P. 2017. Cultural contributions to childhood executive function. J. Cogn. Cult In press

Rotter JB. 1971. Generalized expectancies for interpersonal trust. Am. Psychol 26(5):443–52

Rougier NP, Noelle D, Braver TS, Cohen JD, O’Reilly RC. 2005. Prefrontal cortex and the flexibility of cognitive control: rules without symbols. PNAS 102(20):7338–43 [PubMed: 15883365]

Rueda MR. 2012. Effortful control. In Handbook of Temperament, ed. Zenter M, Shiner RL, pp. 145–67. New York: Guilford

Salthouse TA. 1996. The processing-speed theory of adult age differences in cognition. Psychol. Rev 103:403–28 [PubMed: 8759042]

Sawin DB, Parke RD. 1979. Inconsistent discipline of aggression in young boys. J. Exp. Child Psychol 28(3):525–38 [PubMed: 533842]

Scarr-Salapatek S 1971. Race, social class, and IQ. Science 174(4016):1285–95 [PubMed: 5167501]

Schlam TR, Wilson NL, Shoda Y, Mischel W, Ayduk O. 2012. Preschoolers’ delay of gratification predicts their body mass 30 years later. J. Pediatr 162(1):90–93 [PubMed: 22906511]

Schmitt SA, Finders JK, McClelland MM. 2015. Residential mobility, inhibitory control, and academic achievement in preschool. Early Educ. Dev 26(2):189–208

Schmitt SA, Geldhof GJ, Purpura DJ, Duncan R, McClelland MM. 2017. Examining the relations between executive function, math, and literacy during the transition to kindergarten: a multi-analytic approach. J. Educ. Psychol 109(8):1120–40

Schneider S, Peters J, Peth JM, Büchel C. 2014. Parental inconsistency, impulsive choice and neural value representations in healthy adolescents. Transl. Psychiatry 4(4):e382 [PubMed: 24736798]

Schöner G, Spencer JP, DFT Res. Group. 2016. Dynamic Thinking: A Primer on Dynamic Field Theory. Oxford, UK: Oxford Univ. Press

Schulenberg JE, Sameroff AJ, Cicchetti D. 2004. The transition to adulthood as a critical juncture in the course of psychopathology and mental health. Dev. Psychopathol 16(4):799–806 [PubMed: 15704815]

Shenhav A, Botvinick MM, Cohen JD. 2013. The expected value of control: an integrative theory of anterior cingulate cortex function. Neuron 79(2):217–40 [PubMed: 23889930]

Shenhav A, Musslick S, Lieder F, Kool W, Griffiths T, et al. 2017. Toward a rational and mechanistic account of mental effort. Annu. Rev. Neurosci 40:99–124 [PubMed: 28375769]

Shinskey JL, Munakata Y. 2005. Familiarity breeds searching: Infants reverse their novelty preferences when reaching for hidden objects. Psychol. Sci 16(8):596–600 [PubMed: 16102061]

Shoda Y, Mischel W, Peake PK. 1990. Predicting adolescent cognitive and self-regulatory competencies from preschool delay of gratification: identifying diagnostic conditions. Dev. Psychol 26(6):978–86

Shultz TR. 2013. Computational models in developmental psychology. In The Oxford Handbook of Developmental Psychology, Vol. 1: Body and Mind, ed. Zelazo PD. New York: Oxford Univ. Press. 10.1093/oxfordhb/9780199958450.013.0017

Smith LB, Thelen E. 1996. A Dynamic Systems Approach to the Development of Cognition and Action. Cambridge, MA: Bradford

Smith LB, Thelen E, Titzer B, McLin D. 1999. Knowing in the context of acting: the task dynamics of the A-not-B error. Psychol. Rev 106(2):235–60 [PubMed: 10378013]

Snyder HR. 2013. Major depressive disorder is associated with broad impairments on neuropsychological measures of executive function: a meta-analysis and review. Psychol. Bull 139(1):81–132 [PubMed: 22642228]

Somerville LH, Casey B. 2010. Developmental neurobiology of cognitive control and motivational systems. Curr. Opin. Neurobiol 20(2):236–41 [PubMed: 20167473]

Spector PE, Brannick MT. 2011. Methodological urban legends: the misuse of statistical control variables. Organ. Res. Methods 14(2):287–305

Spelke E, Breinlinger K, Macomber J, Jacobson K. 1992. Origins of knowledge. Psychol. Rev 99(4):605–32 [PubMed: 1454901]

Spencer SJ, Zanna MP, Fong GT. 2005. Establishing a causal chain: why experiments are often more effective than mediational analyses in examining psychological processes. J. Personal. Soc. Psychol 89(6):845–51

Sturge-Apple ML, Davies PT, Cicchetti D, Hentges RF, Coe JL. 2017. Family instability and children's effortful control in the context of poverty: Sometimes a bird in the hand is worth two in the bush. Dev. Psychopathol 29(3):685–96 [PubMed: 27580955]

Suarez-Rivera C, Smith LB, Yu C. 2019. Multimodal parent behaviors within joint attention support sustained attention in infants. Dev. Psychol 55(1):96–109 [PubMed: 30489136]

Takacs ZK, Kassai R. 2019. The efficacy of different interventions to foster children's executive function skills: a series of meta-analyses. Psychol. Bull 145(7):653–97 [PubMed: 31033315]

Tucker-Drob EM, Bates TC. 2016. Large cross-national differences in gene × socioeconomic status interaction on intelligence. Psychol. Sci 27(2):138–49 [PubMed: 26671911]

Tucker-Drob EM, Briley DA, Harden KP. 2013. Genetic and environmental influences on cognition across development and context. Curr. Dir. Psychol. Sci 22(5):349–55 [PubMed: 24799770]

Turkheimer E 2000. Three laws of behavior genetics and what they mean. Curr. Dir. Psychol. Sci 9(5):160–64

Ullman TD, Tenenbaum JB. 2020. Bayesian models of conceptual development: learning as building models of the world. Annu. Rev. Dev. Psychol 2:533–58

Valcan DS, Davis H, Pino-Pasternak D. 2018. Parental behaviours predicting early childhood executive functions: a meta-analysis. Educ. Psychol. Rev 30(3):607–49

Verburgh L, Königs M, Scherder EJA, Oosterlaan J. 2014. Physical exercise and executive functions in preadolescent children, adolescents and young adults: a meta-analysis. Br. J. Sports Med 48(12):973–79 [PubMed: 23467962]

Vohs KD, Baumeister RF. 2004. Handbook of Self-Regulation: Research, Theory, and Applications. New York: Guilford

Volkow ND, Wang G-J, Newcorn JH, Kollins SH, Wigal TL, et al. 2011. Motivation deficit in ADHD is associated with dysfunction of the dopamine reward pathway. Mol. Psychiatry 16(11):1147–54 [PubMed: 20856250]

Vygotsky LS. 1978. Mind in Society: Development of Higher Psychological Processes. Cambridge, MA: Harvard Univ. Press

Watts TW, Duncan GJ. 2020. Controlling, confounding, and construct clarity: responding to criticisms of "Revisiting the marshmallow test" by Doebel, Michaelson, and Munakata 2020 and Falk, Kosse, and Pinger 2020. Psychol. Sci 31(1):105–8 [PubMed: 31850825]

Watts TW, Duncan GJ, Quan H. 2018. Revisiting the marshmallow test: a conceptual replication investigating links between early delay of gratification and later outcomes. Psychol. Sci 29(7):1159–77 [PubMed: 29799765]

Werchan DM, Amso D. 2017. A novel ecological account of prefrontal cortex functional development. Psychol. Rev 124(6):720–39 [PubMed: 29106267]

Westbrook A, Kester D, Braver TS. 2013. What is the subjective cost of cognitive effort? Load, trait, and aging effects revealed by economic preference. PLOS ONE 8(7):e68210 [PubMed: 23894295]

Westfall J, Yarkoni T. 2016. Statistically controlling for confounding constructs is harder than you think. PLOS ONE 11(3):e0152719 [PubMed: 27031707]

Wiebe SA, Karbach J, eds. 2017. Executive Function: Development Across the Life Span. New York: Routledge

Wiebe SA, Sheffield T, Nelson JM, Clark CAC, Chevalier N, Espy KA. 2011. The structure of executive function in 3-year-olds. J. Exp. Child Psychol 108(3):436–52 [PubMed: 20884004]

Willoughby MT, Wirth RJ, Blair CB. 2012. Executive function in early childhood: longitudinal measurement invariance and developmental change. Psychol. Assess 24(2):418–31 [PubMed: 22023561]

Wysocki A, Lawson KM, Rhemtulla M. 2020. Statistical control requires causal justification. PsyArXiv j9vw4. 10.31234/osf.io/j9vw4

Yanaoka K, Michaelson L, Guild RM, Dostart G, Yonehiro J, et al. 2021. Cultures crossing: the power of habit in delaying gratification. Work. Pap., Grad. Sch. Educ., Kyoto Univ, Jpn.

Young SE, Friedman NP, Miyake A, Willcutt EG, Corley RP, et al. 2009. Behavioral disinhibition: liability for externalizing spectrum disorders and its genetic and environmental relation to response inhibition across adolescence. J. Abnorm. Psychol 118(1):117–30 [PubMed: 19222319]

Yu D, Yang P-J, Geldhof GJ, Tyler CP, Gansert PK, et al. 2020. Exploring idiographic approaches to children's executive function performance: an intensive longitudinal study. J. Personal. Oriented Res 6(2):73–87

Yu D, Yang P-J, Michaelson LE, Geldhof GJ, Chase PA, et al. 2021. Understanding child executive functioning through use of the Bornstein specificity principle. J. Appl. Dev. Psychol 73:101240

ACHIEVING GOALS

How do children develop the ability to achieve their goals? Whether negotiating a toy from a playmate, completing an assignment for school, mastering a sport or hobby, or planning an event, success relies upon a collection of cognitive processes known as executive functions. Executive functions include processes such as the following:

- goal maintenance—for example, keeping in mind that you want to learn how to kick-flip a skateboard, even through the frustration of failed attempts;
- inhibitory control—for example, stopping yourself from grabbing a toy out of someone else's hands;
- shifting—for example, switching flexibly between addition and subtraction problems in a math assignment; and
- updating information in working memory—for example, keeping track of the most recent options discussed during a conversation about where to go for dinner, what time to meet, and how to get there, with multiple options considered for each topic and with the topics interspersed.

Executive functions are measured in a multitude of ways, including computerized tasks, behavioral measures, and questionnaires administered to the individuals of interest or to others who know them, such as parents or teachers.

TELL ME ABOUT YOUR EXECUTIVE FUNCTION

When people report on their executive functioning and success, they may take a hard look in the mirror—or they may not. Biases in such self-reports may partially explain why different measures of executive function often do not correlate well (in addition to social and contextual forces leading to genuine variations in executive functioning). For example, one paper found that self-report- and task-based measures of executive function did not correlate well and that self-report measures better predicted success in the world than task-based measures (Enkavi et al. 2019). Measures of success in the world were based on self-report. Thus, the stronger correlation observed with self-report measures of executive function may in part reflect bias in participant reporting—those who claim to be high on executive function also claim to be doing well in life, with higher scores reflecting additional factors such as greater confidence and desire to impress when describing oneself. More objective task-based measures of executive function might better predict more objective measures of success in the world. This potential influence of bias in reporting may also explain why task-based measures (and teacher reports) are more predictive of children's real-world outcomes than parent reports (Robson et al. 2020).

COVARIATES FOR EXECUTIVE FUNCTION: TOO MUCH CONTROL?

Commonly used covariates may remove variance of interest related to control processes. For example, processing speed is characterized as the rate of perceiving, interpreting, and responding to information, reflecting low-level factors like neural myelination (Kail 2000, Salthouse 1996). However, many processing speed measures are complex. They correlate with and likely reflect executive functions such as goal maintenance and shifting (Cepeda et al. 2013). Similarly, executive functions correlate with intelligence (Brydges et al. 2012, Conway et al. 2003, Friedman et al. 2006), likely as a result of overlap in measures and the role of executive functioning in intelligence and vice versa. While it may be tempting to include measures of intelligence to control for certain participants “just being smarter,” such controls can be problematic because executive functions may be a fundamental aspect of being smarter, as assessed by intelligence tests (Draheim et al. 2021, Friedman et al. 2006). Similar issues arise when controlling for concurrently measured cognitive and behavioral skills in an attempt to purify measures of executive function (as in Watts et al. 2018). Thus, when it comes to control variables, we argue that more is not merrier, and careful analysis is needed to target relevant constructs and measures.

CONTEXT AND EXECUTIVE FUNCTIONS MATTER

The contrast between "executive functions are influenced by context" and "context is primary and executive functions may be superfluous" is reminiscent of debates about emerging conceptual knowledge in infancy. Some researchers took signs of knowledge in infancy as evidence of innate or rapidly learned principles (e.g., of object permanence, that objects continue to exist when no longer perceived; Baillargeon et al. 1985, Spelke et al. 1992). Other researchers (including dynamic systems theorists) argued against reifying early signs of knowledge, because infants' successes in such studies depended on testing context, measures, and familiarity (e.g., Bogartz et al. 2000, Smith & Thelen 1996, Smith et al. 1999). These factors might explain infant behavior without any need to appeal to knowledge. In these debates too, we and other researchers found it productive to explore a middle ground, with the contextual variability observed in children's behaviors guiding theorizing about the nature of early knowledge representations (e.g., Keen 2003, Mareschal 2000, Munakata et al. 1997). For example, infants could develop graded (rather than all-or-nothing) representations of objects with experience, and certain situations require stronger representations than others. This framework led to the prediction that infants' well-established preferences for novelty should reverse when searching for hidden objects, which was confirmed (Shinskey & Munakata 2005).

TRAINING EXECUTIVE FUNCTION: TEACHING TO THE TEST?

Many interventions have been developed to enhance executive function. Computerized training programs are among the most popular: Children engage in gamified versions of cognitive tasks that engage skills such as working memory, selective attention, and inhibition, with gradual increases in difficulty (e.g., CogMed; Holmes et al. 2009). Noncomputerized games and activities that traditionally emphasize self-discipline and control, including martial arts, mindfulness, yoga, and physical exercise, have also been tested (e.g., Mak et al. 2018, Verburgh et al. 2014). Most available evidence pertains to targeted training of executive function skills through computerized training, where intervention effects rarely transfer outside the training environment (Diamond & Lee 2011, Kassai et al. 2019). Children may advance through levels of increasing working-memory demand in a computerized game but are no better at retaining instructions conveyed by their teacher. Providing new strategies for self-regulation (e.g., through mindfulness training) may be more promising, though further research on long-term effects is warranted (Takacs & Kassai 2019). Targeting multiple executive functions, and doing so in a naturalistic environment that resembles the contexts in which these skills are engaged in everyday life, may be crucial for more successful interventions with effects that generalize to the real world.

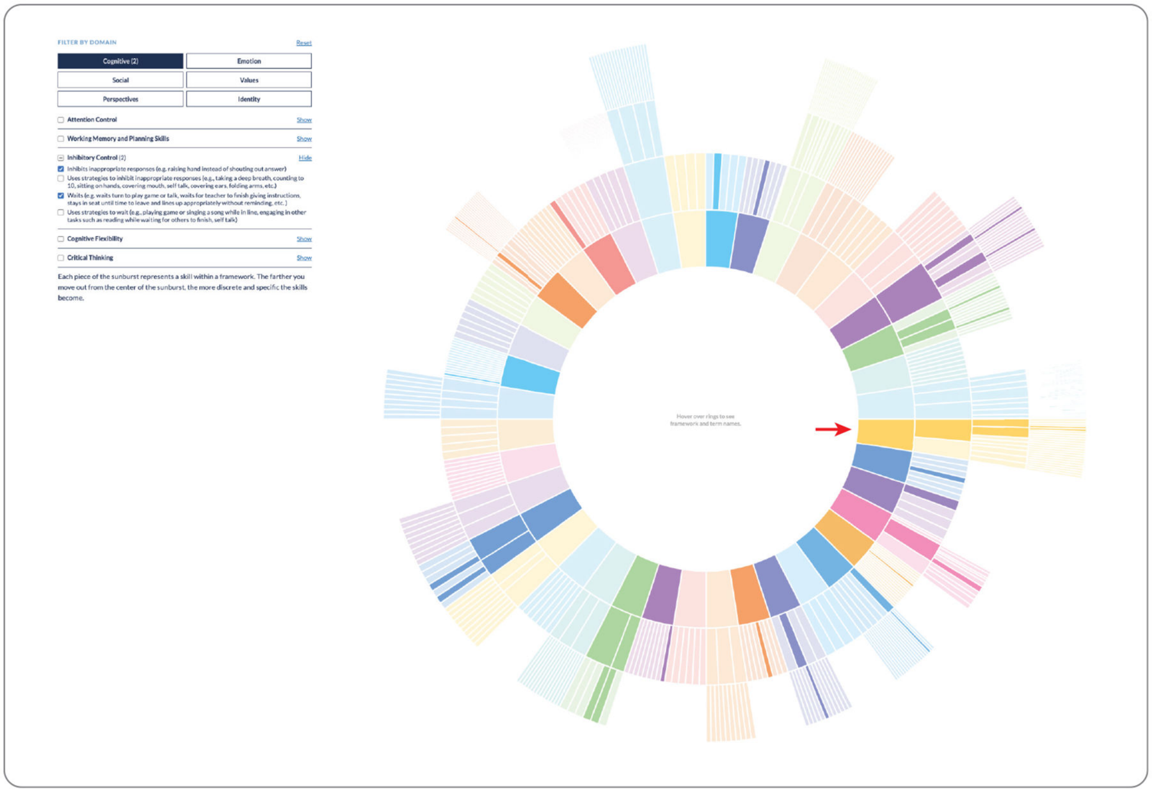

Figure 1.
Explore SEL attempts to clarify executive functions and related processes by organizing and connecting them across different frameworks. Two aspects of inhibitory control have been selected in the figure—inhibiting inappropriate responses and waiting. The sunburst diagram shows where these skills appear across frameworks regardless of how they are labeled. For example, the orange framework at the 3:00 central location is Head Start (*red arrow*). Moving out from the center, the skills described become increasingly discrete and specific, from "approaches to learning" to cognitive, emotional, and behavioral self-regulation, to "child manages actions, words, and behavior with increasing independence" and "child demonstrates an increasing ability to control impulses." Such tools highlight the complexity of understanding and supporting executive functioning and provide a foundation for unpacking this complexity. Image taken as a screen shot from http://exploresel.gse.harvard.edu/.

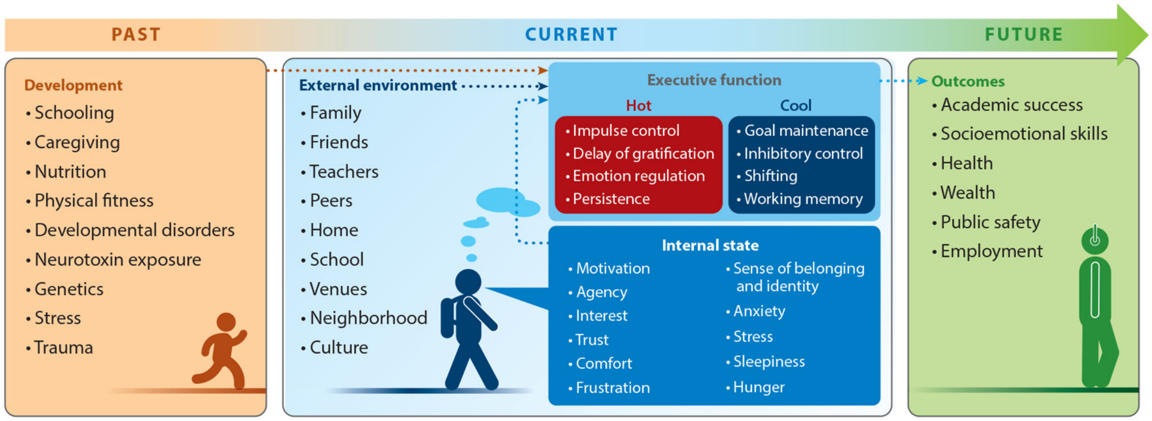

Figure 2.

Multiple forces from the past and present influence executive functioning in the moment and in the longer term, and executive functioning affects behavior in the moment and predicts future outcomes. For example, a child's delaying of gratification (shown under hot executive function in *red*) and inhibitory control (shown under cool executive function in *dark blue*) can be influenced by what other children are doing (shown under external environment) and by how much trust the child feels (shown under internal state), as well as by factors that shaped the child's past development, such as caregiving. Executive functions in childhood in turn predict academic, behavioral, health, and other outcomes years later. Figure concept from Katz et al. (2021).