

Promoting the Development of Executive Functions through Early Education
and Prevention Programs

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Promoting executive function (EF) skills is currently a “hot topic” in early childhood education. EF refers to a complex set of cognitive regulatory processes, including working memory and attention control skills which enable children to organize their thinking and behavior with increasing intentionality and flexibility (Barkley, 2001; Hughes & Graham, 2002). These skills develop rapidly during the preschool and early elementary years (ages 3-7) and provide a neural foundation to support school readiness, facilitating both self-regulated behavior and academic learning (Blair, 2002; McClelland, et al., 2007). At school entry, higher levels of EF skills promote accelerated literacy and math skills acquisition (Blair & Razza, 2007; Welsh, Nix, Blair, Bierman, & Nelson, 2010) and enhance the resilience of children who experience early adversity (e.g., reducing school difficulties among maltreated children; Pears, Fisher, Bruce, Kim, & Yoerger, 2010). EF development is often delayed among children growing up in poverty (Noble, McCandliss, & Farah, 2007), as are the learning behaviors that support academic achievement, reflected in low levels of classroom engagement and elevated teacher-rated attention problems (Bodovski & Youn, 2011; McClelland, et al., 2007).

Based on recent developmental neuroscience research, practitioners and policymakers alike are intrigued by the possibility of strengthening early education and preventive interventions by targeting EF development (Diamond & Lee, 2011). Most of the empirical

research on preschool education focuses on learning in domain-specific content areas (e.g., emergent literacy and numeracy skills). In contrast, EF-focused interventions target the development of domain-general skills that affect the pace and quality of children's learning capacity (e.g., attention control, memory, planning, persistence, and problem-solving). Promoting EF skills within early education and prevention programs may play a key role in reducing the substantial gaps in school readiness and later achievement that separate disadvantaged children from their more advantaged peers (Shonkoff & Phillips, 2000).

Yet, despite the excitement associated with EF-focused interventions, research evidence is sparse regarding what works to promote EF development and the impact of these interventions on social-emotional adjustment or academic progress in school. Only relatively recently have randomized-controlled trials been undertaken using both direct assessments of EF skill acquisition and "real-world" measures of impact on child behavior and learning in school contexts. This chapter provides an overview of intervention research that has tackled the task of improving EFs and associated self-regulated learning skills, especially in the preschool and early elementary years. We focus on strategies that have strong scientific evidence of efficacy, as documented by randomized-controlled trials, assess the current state of knowledge, and identify future directions for research and intervention program development and refinement. A wide array of intervention approaches is considered, grouped into those that focus on: 1) direct training of EF skills, 2) improving teacher-child relationships and positive classroom contexts, 3) using play as a central context for intervention, 4) promoting social-emotional learning, and 5) other promising approaches. In each section, the logic model describing the rationale for the approach is presented, along with studies assessing the impact of the approach.

Direct Training and Practice

One straightforward approach to intervention has been to foster EF skills with repeated practice sessions on specific EF tasks. The logic model supporting this intervention approach is straightforward. Parallel to the utility of strength training in sports, the approach focuses on targeting growth of the neural circuits that support EF, with the hope that these stronger circuits will support more well-regulated attention and behavior (Posner, Sheese, Odludas, & Tang, 2006).

In many cases, initial studies have demonstrated that practice improves performance on the specific tasks practiced and generalizes to closely-related tasks (Klingberg, Forssberg & Westerberg, 2002). The greater question for early education and prevention efforts is the extent to which gains on specific EF tasks generalize to improved performance on learning or behavioral tasks that use the targeted EF skills; that is, whether these gains support improved attention, behavior regulation, and achievement in the classroom context.

Training working memory. Two randomized-controlled trials (RCT) showed that direct training improved the working memory skills of grade-school children, but provided only limited and mixed evidence regarding generalized impact on learning behavior and academic achievement. Both used the Cogmed computer program, which provides graduated practice on a set of working memory tasks, and compared outcomes to a control group that used the same program, set at the lowest level of challenge. In the first study, outcomes for 44 of the 53 randomized participants (those who completed at least 20 days of training) revealed significant effects for treatment on an untrained working memory task, as well as a set of broader tasks tapping other EF skills (attention inhibition, non-verbal reasoning), which were maintained at a 3-month follow-up (Klingberg et al., 2005). Parent ratings for 36 children (68% of the sample) also showed a significant reduction in attention deficit hyperactivity disorder (ADHD)

symptoms, although teacher ratings did not. A second RCT of Cogmed with grade-school children (aged 8 – 11) who had low pre-test working memory randomized children at three schools to the treatment condition ($n = 22$) and children at three different schools to the control group ($n = 20$) (Holmes, Gathercole, & Dunning, 2009). At post-intervention and 6-month follow-up assessments, the intervention group showed significantly better performance on working memory tasks than the control group. Although no intervention effects emerged on IQ measures, basic word reading, or math at the post-test, the intervention group had significantly higher scores than the control group on mathematical reasoning at the 6 month follow-up (Holmes et al., 2009). These findings suggest potential effects of the intervention on academic learning, although a limitation of the design was that intervention and control conditions were administered in different schools, which might also have affected math learning.

Two additional RCTs have examined training working memory skills in preschool children, each comparing this training with an alternative computer-based skill training program. In the first, Thorell, Lindqvist, Bergman Nutley, Bohlin, and Klingberg (2009) compared Cogmed training in visuo-spatial working memory ($n = 17$) with training in attention inhibition (go-no go, stop-signal, and flanker tasks) ($n = 18$). Children at two other preschools served as the control group ($n = 30$). Training included 15-minute sessions each day for 5 weeks. Compared to children at the control preschools, the children trained on working memory improved significantly on non-trained tests of spatial and verbal working memory, but did not improve on measures of attention inhibition. In contrast, children trained on inhibition showed no significant improvements relative to the control group on either type of task. In a second preschool study including 112 children (4.0-4.5 years of age), Bergman Nutley et al. (2011) compared the impact of Cogmed working memory training, training in non-verbal reasoning tasks, and a combination

of working memory and non-verbal reasoning, to a control group that used the combined program set to the lowest level of difficulty. Significant domain-specific effects were documented: children showed improvements in the domain they trained on (working memory or nonverbal reasoning), but not the other domain. The combined condition appeared to work least well, likely due to the dilution in practice time for each kind of task. Unfortunately, neither of these studies included measures of classroom behavior or academic learning, leaving unanswered the question of generalized impact of EF skill gains on school functioning.

Overall, these studies suggest that computerized training can enhance the working memory skills of children, including preschool children (see also the review by Morrison & Chein, 2011). However, the preschool studies show very specific effects on working memory, with a lack of generalized impact on related cognitive skills. In addition, evidence that the improvements in working memory generalize to promote learning engagement, attention control, or academic achievement in the classroom is currently lacking.

Training attention control. Attention training has also been evaluated as an intervention. Initial studies focused on grade-school children with ADHD. For example, Kerns, Eso, and Thomson (1999) randomly assigned children diagnosed with ADHD (ages 5-10) to a 16-session after-school program, where they played either games practicing attention control (such as sorting cards quickly into categories by color or picture, or pressing a buzzer in response to a certain word) ($n = 7$) or computer games ($n = 7$). At post-test, the intervention group outperformed the control group on measures of sustained attention, inhibitory control, mazes, and math efficiency (but not working memory). Intervention effects on teacher attention ratings were marginally significant. Although based on a very small sample, such findings galvanized efforts to examine the impact of attention training on younger children.

Focusing on normally developing 4-year-old ($n = 49$) and 6-year-old ($n = 24$) children, Rueda, Rothbart, McCandliss, Saccomanno, and Posner (2005) compared the impact of playing computer games designed to train attention control to doing nothing or watching children's movies. After five days of attentional training, the 4-year-old children in the intervention group showed significantly greater improvements than those in the control group on the visual matrices of the Kaufman Brief Intelligence Test (K-BIT); however the intervention-control group differences were not significant for the 6-year-olds. In addition, attention control, which was a central focus of the training and assessed using a flanker task, was not significantly improved relative to the control group at either age. No measures of classroom behavior or academic achievement were collected.

A particularly important study examining attention training in early elementary school was conducted by Rabiner, Murray, Skinner, and Malone (2010). This study used a more rigorous research design than other direct training studies, by 1) comparing computerized attention training with an alternative, potentially potent intervention (e.g., computerized academic tutoring), as well as with a wait-list control group, 2) using intent-to-treat analyses, rather than analyzing only those children who completed the training, thus avoiding selection biases, 3) randomizing to condition within school and using a nested design that accounted for teacher and school influences, rather than assigning schools to different conditions, 4) examining teacher ratings of classroom behavior and standardized achievement measures to assess the generalized impact of intervention on school progress, and 5) including a 6-month follow-up assessment. The sample included 77 first-grade students, selected on the basis of elevated teacher-rated inattention, randomly assigned to one of three after-school groups (the *Captain's Log* computerized attention training program ($n = 25$), the *Destination Reading* and *Destination*

Math computerized tutoring programs ($n = 27$) or a wait-list control group ($n = 25$).

Intervention sessions were held twice per week for 14 weeks. At post-treatment assessments, students who received any of the computerized trainings were more likely than wait list controls to show significant improvements in teacher-rated attention skills. However, only students who received the computerized reading and math tutoring showed significant gains in reading fluency and improved teacher ratings of academic performance. No group differences were sustained at the second-grade follow-up assessment, although post-hoc analyses suggested long-term benefits associated with intervention for children who had more serious attention problems at baseline.

This study is important because it suggests that domain-specific training (i.e., computerized tutoring in reading and math) may be as beneficial as domain-general training (i.e., computerized attention training) at promoting growth in attention skills, but the domain-specific training has the added advantage of promoting achievement in the targeted domain (e.g., in this study, improving reading fluency). However, in this study, the impact on EF skills was not assessed directly.

Summary. Although these studies suggest that direct training of EF skills (working memory or attention inhibition) can promote skill acquisition in specific domains, the results are variable across studies. In addition, there is little evidence that this kind of training has effects that generalize to substantially affect school learning behavior or achievement (see also Owen et al., 2010). The Rabiner et al. (2010) findings are particularly provocative because they suggest that other types of interventions might improve EF functioning, but have stronger academic relevance and more potential to close the school achievement gap than those focused only on direct training of EF skills. For example, Siegler and Ramani (2008) found that they could significantly reduce the numerical knowledge gap shown by low-income preschool children

relative to their advantaged peers by having them play a simple numerical board game over four 15-minute sessions. Playing games that substituted colors for numbers did not have this effect. Although Siegler and Ramani did not measure EF skills, their findings raise the question of whether selected math games might serve the dual purpose of improving numeracy understanding and fostering EF skill development.

Improving Teacher-Child Relationships and Positive Classroom Climates

A second approach to promoting EF skills in early education settings focuses on improving the quality of teacher-child interactions and providing more predictable, supportive, sensitive, and responsive classroom climates. The logic model for this intervention approach has roots in developmental research that suggests that high-quality early caregiving plays a key role in promoting EF development (Bernier, Carlson, Deschenes, & Matte-Gagne, 2012). In particular, sensitive-responsive caregiving, language stimulation, and adult support that fosters guided exploration of the social and physical environment (joint attention and scaffolding) have been implicated in the development of EF skills (Bernier et al., 2012; Lengua, Honorado, & Bush, 2007). Conversely, instability or non-responsiveness in adult-child relationships associated with maternal depression, neglect, or exposure to violence predicts delays in EF development (Cicchetti, 2002; Lengua et al., 2007). The implication for early childhood education is that the provision of high-quality adult-child interactions and a predictable, supportive school context might facilitate EF development, particularly among children who have experienced early poverty or adversity.

The *Incredible Years Teacher Training Program* focuses specifically on improving the quality of teacher-student interactions, and promoting positive classroom management strategies (Webster-Stratton, Reid, & Hammond, 2001). The intervention is delivered via monthly teacher

workshops that involve the review of modeling videotapes, group discussion, practice assignments, and consultation provided in response to the ongoing program experiences of the participating teachers. Five core teaching skills are targeted: 1) supporting positive child behavior with specific, contingent attention, encouragement, and praise, 2) motivating learning effort and engagement with incentives and rewards, 3) preventing behavior problems by structuring the classroom effectively and planning for transitions, 4) decreasing inappropriate behavior with non-punitive consequences (e.g., planned ignoring, time out), and 5) building positive relationships with students. Research by the developer demonstrated positive effects on teachers (e.g., increased use of praise, reduced levels of harsh and critical interactions in the classroom) and improvements in children's learning behavior (e.g., higher levels of learning engagement and on-task behavior), but did not include direct measures of child EF skills (Webster-Stratton et al., 2001).

More recently, however, the *Incredible Years Teacher Training Program* was incorporated by Raver and colleagues (2008) into the *Chicago School Readiness Project (CSR)*, in a study that included direct measures of EF skills as well as academic skill acquisition and classroom behavioral adjustment. The CSR provided Head Start teachers with five 6-hour training sessions in the *Incredible Years* program. In addition, the program provided teachers with a mental health consultant, who met with them weekly to support their implementation of the *Incredible Years* classroom management skills and to provide emotional support for their own stress reduction. Mental health consultants also implemented individualized management plans for children displaying high levels of disruptive behavior in the classroom.

The CSR was evaluated in the context of a cluster-randomized trial that included 35 Head Start classrooms (18 randomly assigned to receive treatment) and 543 children.

Approximately 17 children (age 3-4) participated from each classroom. Analyses used an intent-to-treat model (to avoid selection biases associated with level of treatment participation) and hierarchical linear modeling (HLM) that accounted for nesting of children in classrooms and classrooms in sites (Raudenbush & Bryk, 2002). The intervention had the expected impact on the quality of teacher-child interactions, with intervention teachers showing significantly higher levels of positive climate, teacher sensitivity, and positive behavior management than the teachers in the “usual practice” control group (Raver et al., 2008). In terms of the impact on child outcomes, significant intervention effects were documented on two EF measures that utilize attention and inhibitory control (peg tapping, balance beam), with an effect size of .37 (Raver et al., 2011). Examiners also rated children in the intervention condition as more focused and less distractible during the testing sessions relative to children in the control condition, $d = .43$. Importantly, the intervention also had significant effects on academic learning (vocabulary scores, letter learning, math skills) (Raver et al., 2011), and classroom behavior (lower levels of observed aggressive and disruptive behavior) (Raver et al., 2009). Additional analyses suggested that the improved academic skills associated with the intervention were mediated largely by the intervention impact on improved EF (Raver et al., 2011).

This study suggests that improving the quality of teacher-child interactions in ways that provide more contingent positive support, reduce negative exchanges, and improve instructional support has benefits for EF skill development, child learning engagement, and academic achievement. The only caveat is that the Head Start programs that participated in this study were drawn from very high risk neighborhoods (selected for high neighborhood poverty and crime rates), and it is not yet clear whether a program focused on behavior management such as this

one would have the same transformative impact in preschool programs serving children in lower-risk neighborhoods with lower base rates of problem behavior in the classroom.

Fostering the Power of Play

A third approach to early intervention is based upon developmental research that suggests that socio-dramatic play provides a particularly powerful context for the promotion of EF skills in early childhood (Blair & Diamond, 2008; Vygotsky, 1967). Normatively, young children begin to seek each other out for social play during the preschool years, forming their first friendships, and taking great pleasure in cooperative and shared fantasy play with peers. In order to sustain friendly exchanges, children must learn to negotiate, cooperate, and compromise. In order to contribute to elaborated play, they must mentally represent and enact complementary social roles and social routines (Bodrova & Leong, 2007). Thus, interactions with peers motivate and support the development of the emotional and social skills that provide a foundation for effective social collaboration (empathy, cooperation, role coordination) and stimulate the development of the cognitive skills that underlie effective social exchange, including inhibitory control, perspective taking, and flexible problem solving (Bierman et al., 2009). Indeed, Barkley (2001) has postulated that the EF system evolved primarily to support advanced social collaboration skills, and that socio-dramatic play represents the primary “natural” context for its development. Conceptually, pretend social play requires children to exercise all three of the core executive function skills (Blair & Diamond, 2008); role-playing requires holding one’s own character role and those of others in mind, exercising working memory; successful social play requires inhibiting behavioral impulses to act out of character and employing attentional set-shifting skills to flexibly adapt to unexpected changes in play scenarios. The elaborated play of older preschool children – including their ability to sustain synchronized, thematic play, and

negotiate turn taking and resource sharing – reflects their growing capacity to mentally represent and follow social scripts, while simultaneously tracking social exchange (Barkley, 2001).

During the preschool years, collaborative play thus represents a context in which children are motivated to be “effortful” in their attempts to initiate and sustain engagement with peers, which in turn requires the application of working memory, inhibitory control, and attention set-shifting in the service of emotion regulation and social collaboration.

A number of studies have documented significant correlations between the frequency and complexity of a child’s socio-dramatic play, particularly the use of symbolic representation in play, and concurrent measures of IQ, problem-solving skills, language acquisition, social competence, and self-regulation (see Hanline, Milton, & Phelps, 2003). In a short term longitudinal study, Elias and Berk (2002) found that impulsive preschool children who engaged in higher levels of complex socio-dramatic play with peers in the fall of the year showed improved self-regulated functioning in the spring. Solitary socio-dramatic play was not associated with improved self-regulation, suggesting that the social interactive component of this play may be critical for its positive developmental influence on growth in self-regulation skills.

The use of socio-dramatic play as a preschool intervention to promote social and cognitive skills was first tested empirically by Smilansky (1968), who examined the impact of teaching economically-disadvantaged children how to engage in pretend play. Several quasi-experimental studies followed, with results that suggested that engaging children systematically in socio-dramatic play might enhance their language, social interaction, and problem-solving skills (Rosen, 1974). One of the most well-designed of these studies was conducted by Saltz, Dixon, and Johnson (1977). Working with 146 low-income preschool children (age 3-4.5 years) in an urban setting, they randomly assigned classrooms to 4 different treatment conditions: 1)

fantasy play (acting out fairy tales, such as *Three Billy Goats Gruff*, *Little Red Riding Hood*), 2) socio-dramatic play (acting out scenes from everyday life, e.g. trips to the grocery store or doctor's office), 3) listening to and discussing fairy tales, or 4) paper-and-pencil crafts and artwork. The interventions were conducted 15 minutes per day in the preschool context, three days per week, for about 6 months, by undergraduate students or research staff who worked with children in groups of 3-4. The goal was to compare the effects of different kinds of socio-dramatic play (e.g., using fantasy stories or real-life activities) with fantasy exposure that did not involve a motor/enactment or social interaction component (listening and discussing the stories) and the art-work activity control. Over the course of the year, the two socio-dramatic play conditions (fantasy or real-life enactment) as compared with non-play conditions produced greater improvements on tests of vocabulary (PPVT) , delay of gratification (inhibiting the touch of a forbidden toy) and matching figures, suggesting a direct effect on EF skills associated with attention control.

More recently, socio-dramatic play has been embedded as a central feature of a comprehensive preschool and early elementary school curriculum, *Tools of the Mind (Tools)* (Bodrova & Leong, 2006). In *Tools*, teachers are taught how to introduce and support complex dramatic play themes in the classroom, and children spend time each day in planning and enacting sustained, collaborative socio-dramatic peer play in prepared play centers. Specific techniques include having children develop "play plans" that articulate a social role and planned behavior, preparing specific play centers, and requiring sustained socio-dramatic play daily. *Tools* includes other activities designed to enhance the development of child self-regulation skills: it restructures learning activities, replacing large-group activities and passive waiting time with small-group and peer-pairing activities that keep children more actively engaged in the

learning process, and includes motor games and activities designed to practice self-regulation skills, such as pacing motor activity in time to fast or slow music, and games that require behavioral inhibition, such as *Simon Says*.

In an initial randomized-controlled trial, teachers and preschool children (aged 3- and 4-years-old) were assigned to classrooms that either used the *Tools* curriculum or a curriculum developed by the school district (Barnett, Yarosz, Thomas, & Hornbeck, 2008). *Tools* was found to significantly improve the quality of teaching observed in the classrooms, including positive classroom structure and quality of the literacy environment and instruction, and teachers reported fewer behavior problems (Barnett et al., 2008). Assessment a year later also showed significant effects on children's executive function skills (Diamond, Barnett, Thomas, & Munro, 2007); however, these latter assessments were made after teachers and children were allowed to change programs if desired, compromising the original randomization and introducing the potential for selection biases.

A more recent randomized trial (Wilson & Farran, 2012) compared *Tools* with "usual practice" preschools in six school districts, and found no significant effects on child executive function skills or other academic or behavioral outcomes measured. Similarly, Clements, Sarama, Unlu, and Layzer (2012) failed to replicate the positive effects of *Tools*. In the Clements et al. (2012) study, "usual practice" preschools were compared with two intervention conditions: one that included a preschool mathematics curriculum (*Building Blocks*), and the other that paired *Building Blocks* with a modified version of *Tools*. Children in the *Building Blocks* condition out-performed those in the control group on two EF tasks (*Head-Toes-Knees-Shoulders* and backward digit span), but children in the *Building Blocks* plus *Tools* condition did no better than the "usual practice" control group on these tasks. Researchers have speculated

that Tools is a complex intervention that may be difficult to deliver effectively without extensive professional development supports.

Promoting Social-Emotional Learning

A fourth approach to preventive intervention draws on research suggesting that emotion regulation, social problem-solving skills, and EF skill development are intertwined developmentally, and that promoting emotion regulation and social problem-solving skills can enhance EF. Emotion regulation skills include emotional understanding (the ability to recognize and accurately label the emotional states of oneself and others), emotional coping (the ability to modulate affective arousal), and emotion display (the ability to control behavior in the face of affective arousal). Emotion regulation skills enable children to respond adaptively to their internal arousal, modulating their reactions to upsetting or exciting situations, and controlling reactive impulses (Izard et al., 2001). Social problem-solving skills allow children to assess the problem, listen to and consider other perspectives, generate potential solutions, and negotiate a plan of action with the others involved (Zins & Elias, 2006). Good social problem-solving requires not only emotion regulation skills, but also a willingness to act with feelings of caring and concern for the others involved, and an understanding of accepted social norms and sanctions.

Emotion regulation and social problem-solving skills develop rapidly during the preschool and early elementary years, and are supported by concurrently-developing EF and language skills (Greenberg, 2006; Trentacosta & Izard, 2007). The neural areas that underlie EF have extensive interconnections with the ventral medial frontal and limbic brain structures associated with emotional reactivity and regulation, which allow EF and language skills (“top down” regulation) to modulate the emotional and autonomic arousal systems (“bottom up”

regulation) (Rueda, Posner & Rothbart, 2005). Reflecting this interconnectedness, developmental studies show associations between preschoolers' developing emotional understanding and social problem-solving skills, and their abilities to delay gratification, manage conflicts, and engage in goal-oriented and sustained learning efforts (Carlson & Wang, 2007; Denham & Burton, 2003; Trentacosta & Izard, 2007).

Teaching young children about their emotions as a strategy to build EF skills is based upon a developmental model that places affective systems prior to the frontal cognitive systems in the sequence of development (see Greenberg, 2006). That is, in infancy and early childhood, affective systems energize and motivate infants and young children to engage with others and with the environment, well before children can verbalize or reflect upon their experiences (Greenberg, 2006). As children accumulate social experiences and as their cognitive and linguistic skills advance, their capacity to reflect on and appraise their emotional experiences and their ability to understand social cause and contingency also advance. Supported largely by implicit or incidental learning (e.g., learning through observation and experience), children develop schemas that link certain social experiences with feeling states, cognitive appraisals, and habitual response patterns (Izard, Stark, Trentacosta, & Schultz, 2008). When adaptive, these schemas foster the child's capacity to navigate and act on his/her social environment in goal-directed ways that balance self-protection with active exploration and interpersonal engagement. When maladaptive, these schemas privilege reactive, self-protective vigilance or protest and impede adaptive social engagement and flexible problem solving (Izard et al., 2008). Social-emotional learning programs are designed to facilitate the development of adaptive schemas (or overwrite habitual but maladaptive schemas) by making information about social-emotional exchanges explicit and more easily available to children, clarifying some of the mystery behind

emotions and relationships, and providing concrete suggestions and supports to help children develop more advanced emotion regulation and social problem-solving skills.

The *PATHS (Promoting Alternative Thinking Strategies) Curriculum* is a social-emotional learning program that focuses specifically on building the “top down” higher-order frontal cognitive control and language processes that will facilitate the modulation of lower-level limbic impulses and emotional arousal (Greenberg, 2006). *PATHS* includes: 1) an intensive focus on helping children to verbally identify and label feelings in order to manage them, including the use of emotion photographs, stories, and “feeling face” cards to help children identify and express their feelings, 2) lessons on caring and interpersonal concern, including the value of friendship and cooperation, 3) the use of explicit signals to cue and support intentional impulse control (e.g., a traffic “red light” for elementary children, and “doing Turtle” for younger children, each guiding children when distressed to “tell yourself to stop, take a deep breath to calm down, say the problem and how you feel”), and 4) explicit guidelines for social problem solving and conflict resolution (identify the problem, generate solutions, consider consequences, and choose the best plan.) In the version of the curriculum developed for young children, the *Preschool PATHS Curriculum* (Domitrovich, Greenberg, Cortes, & Kusche, 1999), teachers introduce and illustrate skill concepts with puppets, pictures, and story examples. Each lesson includes ideas for formal and informal extension activities that teaching staff can use throughout the day to generalize key concepts. Teachers are also encouraged to provide emotion coaching throughout the day, modeling feeling statements themselves when appropriate, helping children notice the feelings of peers, and prompting children to describe their own feelings. Teachers are also encouraged to watch for naturally occurring “teachable moments,” such as peer disagreements or conflicts. At these times, teachers are taught to help children stop and calm

down (using “turtle”) and then talk through the problem-solving steps of defining the problem and their feelings, listening to their friend’s feelings, and generating ideas for how to solve the problem.

Two recent studies have demonstrated positive effects of *PATHS* on EF skills. One of these studies examined intervention impact on 318 second-and third-grade children in classrooms randomized to receive the *PATHS* intervention or “usual practice” (Riggs, Greenberg, Kusché, & Pentz, 2006). Intervention teachers received a 3-day training workshop and weekly coaching in curriculum implementation. *PATHS* lessons were taught 2-3 times per week, and teachers also coached children to talk about their feelings, apply self-control, and follow the social problem-solving skill sequence in order to resolve conflicts. EF inhibitory control skills were assessed using the Stroop test, and verbal fluency was examined. Compared with children in the “usual practice” control group, children in *PATHS* classrooms showed significantly greater improvement in inhibitory control by the end of the year (Riggs et al., 2006). In addition, improvements in EF skills during the intervention year predicted lower rates of teacher-rated internalizing and externalizing behavior problems at the 1-year follow up, and mediated intervention effects on reduced behavior problems. In addition to documenting positive child outcomes, these findings provide empirical support for the conceptual theory of action that underlies the *PATHS* model.

In a second study, *Preschool PATHS* was implemented in the context of the comprehensive *Head Start REDI (Research-based, developmentally informed)* program, which involved a set of enrichment activities led by classroom teachers: the *Preschool PATHS* curriculum, a dialogic reading program to enhance vocabulary and narrative understanding, “sound games” to foster phonemic awareness, and alphabet center activities to promote print

awareness. Forty-four Head Start classrooms in three Pennsylvania counties were randomly assigned to use the *REDI* program, and the others formed a “usual practice” comparison group. Teachers were provided with four days of training and weekly classroom and individual visits by *REDI* coaches (for details, see Bierman, Domitrovich et al., 2008). Observations conducted at the end of the year showed that *REDI* classrooms had more positive emotional climates than “usual practice” classrooms, with higher levels of emotion talk and greater support for child emotion regulation. *REDI* classrooms also scored more positively on classroom management (including positive limit setting and proactive/preventive management) and language use (including statements, questions, and rich, sensitive talk), and tended to have higher levels of instructional support (Domitrovich et al., 2009).

The *Head Start REDI* impact evaluation included 356 4-year-old children (86% of the eligible children in the participating classrooms). Hierarchical linear models that accounted for classroom revealed positive effects for *REDI* on a number of the specific skills targeted by the intervention (e.g., vocabulary skills, phonemic awareness, print awareness, emotion knowledge, and social problem-solving skills), as well as reduced aggression. *REDI* also showed an impact on children’s EF, with children in *REDI* classrooms out-performing children in the “usual practice” comparison classrooms on the *Dimensional Change Card Sort* ($p < .06$) which taps working memory, inhibitory control, and set shifting skills (see Bierman, Nix et al., 2008 for details). No intervention effects emerged on other EF measures (peg tapping, backwards word span, balance beam), but a significant effect emerged on examiner ratings of self-regulation, with children from *REDI* classrooms being rated as more able to “pay attention,” “sustain concentration,” and “wait during and between tasks.” Sub-group analyses revealed that *REDI* was particularly beneficial for children who started the year with low levels of behavioral

inhibitory control. Improvements in EF skills partially mediated *REDI* intervention effects on emergent literacy and social-emotional competencies. In addition, significant intervention effects were evident a year later, as kindergarten teachers (who had no knowledge of the pre-kindergarten intervention) rated children who received REDI significantly higher on classroom learning engagement than children who received “usual practice” Head Start (Bierman et al., 2014).

Other Promising Approaches

Thus far, we have focused on intervention strategies that have evidence based on randomized, controlled trials that they can promote EF skill development in young children. Two additional approaches are worth mentioning, although evidence of impact on the EF skills of young children is not yet available.

Physical movement. Particularly among older adults, research has demonstrated that aerobic physical exercise provides cognitive benefits (Hillman, Erickson, & Kramer, 2008). Adolescents also appear to benefit, as research suggests that regular, aerobic physical activity may enhance verbal and math skills (see Sibey & Etnier, 2003 for a review). Much of this research is non-experimental in nature, making causal interpretations difficult. For example, correlations between physical activity and academic performance may reflect the impact of activity on cognitive functioning, but these links might also represent the impact of third variables upon both outcomes, such as family support or organizational skills, that support youth engagement in school and sports activities (see also Etnier & Chang, 2009). A number of studies show improved cognitive performance on EF tasks immediately following aerobic exercise, when compared with performance prior to that exercise. However, many fewer studies have examined the longer-term EF benefits of exercise intervention programs for children utilizing

randomized-controlled trials (see Best, 2011, for a comprehensive review). We provide a brief discussion of findings from these randomized intervention studies, which have shown promise for older children and adolescents, but have not yet been evaluated with young children.

In one of the first experimental evaluations of the impact of aerobic exercise on children's cognitive functioning, Tuckman and Hinkle (1986) randomly assigned older elementary children (grades 4-6) to a 12-week aerobic running class or to a "usual practice" physical education class. Although EF skills were not evaluated directly, Tuckman and Hinkle (1986) reported significant intervention effects on a test that assessed flexible and divergent thinking, suggesting the potential of this intervention approach to improve EF. In a more recent study, Kamijo and colleagues (2011) randomly assigned 43 children (ages 7-9) to an afterschool physical activity program ($n = 22$) or a waitlist control group ($n = 21$). The after-school program included 40 minutes of vigorous physical activity (e.g., visiting fitness stations and engaging in individual or small group activities and games), followed by a healthy snack and rest period, and then 30 minutes of organizational games centered around a skill theme (e.g., dribbling). Effects on working memory were assessed separately for tasks at three levels of difficulty (remembering sets of single letters, three letters, or five letters.) Significant benefits associated with the intervention emerged for working memory at the medium level of difficulty (three letters), but were less distinct at the lowest level of difficulty (one letter) and non-significant at the highest level of difficulty (five letters).

In another study, Davis and colleagues (2011) randomly assigned overweight elementary students (aged 7-11) to a no-intervention control group ($n = 60$), or to one of two after-school programs, involving either a high dose of exercise ($n = 56$, 40 minute sessions of running games, jump rope, soccer, etc.) or a low dose of exercise ($n = 55$, 20 minute sessions). After the three

month intervention, children's performance was compared on the Cognitive Assessment System (CAS) which measures integrative cognitive skills that utilize EF. Treatment benefits emerged on the Planning scale of the CAS, with the exercise groups performing significantly better than the control group, and children in the high dose condition performing significantly better than children in the low dose condition. However, no significant treatment effects emerged on the Attention, Simultaneous, or Successive scales of the CAS, which also utilize EF skills. No differences emerged between the exercise and no treatment groups on the math or reading achievement tests, although children in the high dose group out-performed those in the low dose group on the math achievement measure (controlling for pretreatment scores.) Although these findings are mixed, they provide some evidence for benefits of exercise to EF functioning in elementary-aged children.

There are several hypotheses regarding the mechanisms by which aerobic physical activity promotes EF functioning. One focuses on the physiological changes induced by aerobic exercise, including increases in capillary blood supply to the cortex and alterations in neurotransmitter levels (particularly dopamine) (Davis et al., 2011). This hypothesis is based upon animal research that documents nonspecific neural activation associated with exercise that promotes robust and enduring neurogenesis in the learning and memory centers of the brain (see Best, 2011). A second hypothesis is that exercises that require complex and controlled movements activate and utilize EF, particularly when they must be done in a way that dynamically adjusts to changing conditions (Diamond & Lee, 2011). This hypothesis suggests that EF will be strengthened by exercises that incorporate complex movements, but not by simpler activities which are more automatic, such as walking (Best, 2011). Finally, a third hypothesis is that the complex dynamics of rule-governed games might place demands on EF

skills, thus strengthening them. For example, motivated by a goal of winning the game, children may need to constantly adjust their movements to coordinate their actions with their team-mates, anticipate their opponents' moves, and make on-going adjustments to their strategy and movements in response to other players' actions (Best, 2011).

Although the impact of physical activity on EF development has not yet been studied in young children, two studies suggest that it may be a promising approach. Lobo and Winsler (2006) randomly assigned 40 Head Start children to an 8-week experimental dance program or an attention control group. Although EF skills were not assessed in this study, the investigators found positive effects of the dance program on teacher and parent ratings of child social competence, and reduced levels of internalizing and externalizing problems. It would be of value to know whether this kind of dance and movement intervention might also impact EF skills in young children.

In a second study, Tominey and McClelland (2011) randomly assigned 65 preschool children to active playgroups or an untreated control group. Playgroups included 5-8 children and met twice weekly for 30-minute sessions for 8 weeks. They engaged in a curriculum of games selected to emphasize EF skills: inhibitory control (e.g., the Freeze Game) and attention set-shifting (e.g., Red Light, Green Light). EF skills were assessed using a behavioral regulation task (Head-Toes-Knees-Shoulder [HTKS]) in which children are instructed to touch body parts that are the opposite of those being requested by the examiner (e.g., when the instructor calls "head" the child is to touch "toes"). Treatment had no overall effect on HTKS; however, additional analyses suggested positive treatment gains for children who had low scores at the pre-treatment assessment. Treatment also enhanced letter-word identification skills, suggesting an impact on cognitive functioning.

With so little research examining the impact of physical movement on EF development among young children, it is not possible to determine the potential of this intervention approach. However, the preliminary findings suggest that further investigation of this intervention strategy may be worthwhile.

Parenting interventions. Parenting interventions for infants and young children also warrant further study as a possible strategy for enhancing EF development. Certainly, there is evidence that the skills that support self-regulation begin to develop in infancy, and parents play a critically important role as socialization agents, directly affecting children's development of self-regulation (Fox & Calkins, 2003). There is evidence that working memory is affected by the quality of the home literacy environment, as well as by daycare/preschool attendance (Noble et al., 2005). Parents may influence language development (which is highly affected by family socioeconomic status), which in turn fosters EF skill development. In addition, sensitive-responsive adult-child interactions that provide scaffolding (sensitive support to facilitate successful goal-oriented activities) and help children label and understand their emotions and motivations may play a key role in fostering their developing capacities for self-regulation (Bernier et al., 2012; Hughes & Ensor, 2009); many home visiting programs that target child school readiness focus on promoting sensitive-responsive parenting, enriched language use and parent-child conversations, scaffolded play, and interactive reading (see Welsh, Bierman, & Mathis, 2014, for a review). However, the effects of these programs on child EF have not yet been explored.

There are several reasons to expect that these kinds of early parenting interventions might foster child EF skill development. These interventions may promote secure attachments, increasing feelings of security and reducing neuroendocrine and autonomic stress reactivity that

impedes EF development (Bernier et al., 2012; Cicchetti, 2002). They may enrich support for child language development, which is intertwined developmentally with EF skill development (Noble et al., 2007). Finally, parenting interventions may improve external support for behavioral regulation, providing the limits and redirection that help children control their emotional reactivity and aggressive behavior, thereby creating a foundation for the internalization of self-regulation (Kopp, 1982).

Integrative Summary

As the studies reviewed in this chapter illustrate, a wide variety of intervention approaches show promise in terms of their ability to promote the EF skills of young children. To date, these different intervention approaches have emerged within different discipline and research traditions. “Cross-talk” among the investigative teams is limited. Looking forward, intervention development would benefit from more cross-disciplinary discussion, which might support integrative models and comparative designs. To help bridge the disciplinary divide, future research would benefit from 1) greater attention to the logic models underlying the various approaches, and measurement models designed to examine mechanisms of change, 2) more consistency and rigor in the intervention trial methodology, meeting standards of evidence that are acceptable across the disciplinary fields and particularly meeting standards that are acceptable to the educational sciences, where eventual implementation is desired, and 3) an expanded focus on preschool and early elementary school outcomes, to better test the hypothesized links between the acceleration of EF skill development fostered by preventive intervention and later school success.

Articulating logic models and measuring mechanisms of change. The capacity to make comparisons across intervention approaches and to identify strategies that might increase the

impact of various approaches would be greatly enhanced by future studies that clearly articulate and measure the processes and change mechanisms that are thought to account for the intervention effects. Doing so will help to build our knowledge of the unique and/or common mechanisms that are associated with improved EF in different approaches, thus informing basic research on EF development while also providing a basis to further refine and strengthen intervention components (Diamond & Lee, 2011). In addition, the approaches have different theoretical and empirical roots, and may each be enriched by a consideration of the alternative models.

For example, several of the intervention approaches reviewed here were developed and evaluated first with adults and older adolescents before being adapted downward in age for use with young children. Working memory and attention control training programs, as well as programs focused on increasing aerobic physical exercise to promote EF, derived from successful intervention effects on older populations, may be enriched by considering research on the developmental processes associated with EF in early childhood. Particularly in the age range that is a focus of this chapter (ages 3-7), EF skills are emerging rapidly and their maturation is affected heavily by socialization experiences and intertwined skill development (language, emotion regulation), creating a context for intervention that is very different from adulthood or later childhood.

Conversely, other intervention approaches reviewed in this chapter were developed for a different purpose and have other central goals, but show some evidence of impact on EF. For example, the *Incredible Years Teacher Training Program* has the primary goal of improving teacher-student interaction quality and classroom management in order to reduce child behavior problems and improve child social competence. Early childhood parenting programs that focus

on improving sensitive-responsive parenting and enriching parent-child language have the primary goal of fostering child cognitive development and/or behavioral adjustment. By integrating models of EF more explicitly in these intervention designs and assessments, the impact on child EF might be strengthened. Better understanding the nature of their impact on EF might in turn inform improved intervention designs.

Finally, a third type of intervention reviewed here is one that targets the promotion of skills that are intertwined developmentally with EF. For example, academic tutoring programs (such as those used by Rabiner et al., 2010) focus on teaching academic content in specific domains. *PATHS* focuses on promoting emotion regulation, social problem-solving skills, and social competence, with a strong emphasis on promoting the language skills that support effective self-regulation and social functioning. Socio-dramatic role playing focuses on building narrative comprehension, perspective taking, and social interaction skills (Saltz et al., 1977). In each of these cases, domain-general EF skills may be strengthened because they are exercised in the context of domain-specific skill-building activities, resulting in dual gains in the content area of focus as well as EF skills. For example, Rabiner and colleagues (2010) found that computerized academic tutoring fostered attention skills as well as direct EF training, but had the added advantage that it fostered academic learning as well (which the direct EF training did not). Comprehensive programs such as *Tools of the Mind*, which embed academic learning within a restructured classroom designed to enhance support for self-regulation, may represent a good way to strengthen EF during learning activities – but more specific and well-controlled research is needed to determine how best to structure academic or social-emotional learning activities in ways that maximize benefits for children’s EF development.

As more comparative research is undertaken, the findings may well show that there is more than one way to effectively improve EF. It is also possible that the interventions that work best share some common features. As Diamond and Lee (2011) note, many types of activities, perhaps even some not yet studied, can improve EFs if they possess certain features common to existing, effective interventions. These include opportunities for repeated practice on motivating tasks that require effortful EF, continual and gradually increasing levels of challenge, limited sit-and-listen time, and elicitation of joy, self-efficacy, and social bonding in children.

Measuring a broad range of self-regulation and school adjustment outcomes. The recent and intensive interest in EF among early childhood researchers and practitioners stems from a hypothesis that interventions that promote EF will have unique benefits for children by improving behavior, social-emotional functioning, and achievement. This hypothesis is based on developmental research that demonstrates predictive relationships between early EF and learning behaviors, functioning, and achievement (see Blair & Diamond, 2008). However, more experimental research is needed to test the causal linkages, and determine whether (and to what extent) the promotion of EF with early intervention will have generalized behavioral or academic benefits for children. In order to better understand intervention impact, randomized trials need to include a broad range of outcome measures that allow for an assessment of generalized effects on non-targeted dimensions of self-regulation, as well as school-based academic and behavioral adjustment.

Behavioral adjustment, academic learning, and self-regulation are multiply-determined, with EF skills being just one contributing factor. Among preschool children for example, behavioral impulse control (as assessed by delay of gratification tasks or teacher ratings), emotion regulation skills, and language skills each affect school behavior and learning in ways

that are distinct from the contribution of EF skills (Hughes & Graham, 2002). Whereas socialization (reflected by family SES) has a significant impact on the development of EF and language skills, it is not associated with impulsivity (reward processing; capacity to delay gratification), reflecting different developmental determinants that interact to contribute to effective classroom engagement and learning behaviors (Noble et al., 2007). Similarly, although oppositional-aggressive behaviors have been linked with deficits in EF functioning in “hard to manage” preschool children (Hughes & Ensor, 2009), associations between EF deficits and behavioral problems are not always present (Bierman et al., 2009). Substantial research indicates that oppositional-aggressive behaviors are often instrumental, shaped and maintained by interpersonal contingencies and coercive family interactions (Webster-Stratton et al., 2001), and hence not necessarily an indication of EF or self-regulation deficits.

By measuring multiple dimensions of a child’s self-regulation skills (e.g., EF, impulsivity, frustration tolerance), as well as the child’s learning behavior and achievement in the classroom, intervention research may improve our understanding the specific effects of improved EF on children’s school readiness, as well as identifying aspects of child self-regulation that require alternative or additional intervention approaches.

Improving research designs. Discipline-based differences in research methodology and design are evident in this area of research. For example, the direct EF training studies reviewed here analyzed only the sub-set of children who completed a minimum of training sessions (to assure that those who are analyzed actually received the intervention), whereas school-based researchers typically run intent-to-treat analyses (to avoid selection biases associated with intervention drop-out). Many of the smaller studies reviewed here conducted randomization at the level of the school, but analyzed at the level of the individual, without modeling the

dependencies associated with the unit of randomization (school) or the unit of implementation (group). Certainly, smaller, less well-controlled pilot studies are appropriate to test the feasibility of a new intervention approach. However, in order to make inferences about the degree to which an intervention approach may improve outcomes for children in “real-life” education or community settings, more rigorous designs are required with intent-to-treat approaches, representative sampling, and analytic designs that account for the levels of randomization and implementation (Raudenbush & Bryk, 2002).

In addition, more careful study is needed to understand variations in intervention responding, and the factors that might moderate the impact of an intervention approach. For example, exploratory analyses described in this review suggest that greater benefits in some interventions were observed among children with larger initial EF skill deficits (see Bierman, Nix et al., 2008; Tominey & McClelland, 2011). Other forms of moderation may also emerge. More research is needed to explore potential interactions between type of program and characteristics of child participants, the broader school, and the neighborhood or family context. Research that can simultaneously examine programs based on different logic models in a variety of settings may help address “What works for whom, and under what conditions?”

Finally, almost nothing is known about dose effects, and the amount of training or intervention experience that is needed to produce improvement in EF skills or associated self-regulated behaviors. In addition, little is known about the maintenance of gains over time and the possible need for “booster” intervention sessions to sustain effects. These are important topics for future research.

Conclusions

In recent years, developmental neuroscience research has generated new optimism regarding our capacity to intervene in ways that will reduce the early disparities associated with socioeconomic disadvantage and improve children's school success. In particular, EF research has expanded our understanding of early neural development and stimulated innovative approaches to prevention and early intervention. At the same time, caution is warranted in terms of the current evidence base supporting EF intervention in early childhood. A majority of the well-controlled studies of young children indicate promising but mixed effects on EF measures, and none have yet documented generalized and sustained effects on school behavior and achievement after school entry. In some cases, "traditional" intervention approaches targeting other primary goals (e.g., classroom management skills, academic tutoring) have out-performed innovative approaches directed specifically at promoting EF skills, in terms of their impact on children's school adjustment and learning. This may well be because "stand-alone" interventions that practice specific EF skills in a consistent and predictable manner do not prepare children well for the day-to-day classroom and peer interactions that are often unpredictable and emotionally laden. For this reason, interventions which can harness opportunities for children to practice self-regulation skills during naturalistic moments of challenge, guided by familiar adults, may have the greatest potential for generalized gains. The potential value of short-term interventions that target EFs deserves ongoing exploration, but it may be that promoting substantial and sustained gains in children's school readiness requires a broader focus, longer intervention time frames, and partnering with and supporting parents and teachers. In this context, attention to the neuro-cognitive developmental processes in intervention design and direct measurement of EF and related self-regulatory skills may contribute significantly to our understanding of

developmental processes, as well as to more powerful prevention and early intervention programs.

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