



CoLab EVIDENCE REPORT

Executive function and self-regulation in early childhood



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AUTHOR:

Dr Helen Monks, Telethon Kids Institute
Amy Barnes, Telethon Kids Institute

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ABOUT COLAB:

CoLab brings together families, clinicians, educators, policy makers, other practitioners and researchers to provide evidence to improve service delivery and community capacity to meet the needs of children, families and communities who are experiencing vulnerability. Our vision is that young children in Australia develop, learn and thrive so they can build a better future for themselves and their communities. CoLab has three priorities, including: providing better support to families experiencing adversity; advocating for place-based approaches to improve the ways that families, services and communities work together, and; advancing the economic understanding of early childhood, with a focus on where the best early investments can be made. CoLab was launched in 2017 through a partnership between Telethon Kids and the Minderoo Foundation, made possible by Minderoo's founding commitment to ensure every Australian child gets the best possible start in life.




Telethon Kids Institute
100 Roberts Road,
Subiaco Western Australia 6008
Telephone: (08) 9489 7777
Email: CoLab@telethonkids.org.au

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RESEARCH HIGHLIGHTS

- **Executive function** refers to a coordinating set of mental processes, including **working memory, inhibitory control** and **cognitive flexibility**.
- Together, these skills allow children to **self-regulate**, and provide the foundation for their future **social and cognitive development, school readiness and academic success**.
- Early childhood adversity and poverty are among the greatest **threats to executive function development**, and improving children's executive function holds considerable potential for **narrowing the achievement gap** between disadvantaged children and their more affluent peers. 
- Specific training programs, including **focussed preschool interventions**, can improve children's executive function early in life.
- Adults need to have well-developed executive function skills to support the development of these same **core capabilities** in their children. 
- Parents experiencing adversity can benefit from additional support and programs to improve their executive function, so they **successfully navigate** the **everyday complexities** of living in poverty, and support their child's executive function development.

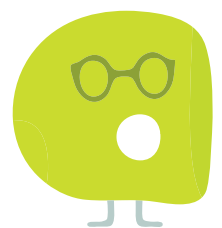
Executive function and self-regulation in early childhood



Early childhood is increasingly recognised as a critical time for the development of executive function^[1]. Executive function refers to a set of mental processes that have been likened to a personal “air traffic control system” for the brain^[2]. These processes enable children to manage multiple streams of information at the same time, filter distractions, monitor errors, make decisions, switch gears and revise plans as necessary^[2]. Essentially, these core skills help children pull together their feelings and thinking in order to manage their attention, emotions and behaviour, so that they can successfully reach their goals^[3]. Executive function skills are critical in allowing a child to successfully navigate everyday challenges in a range of environmental contexts, including coping with the demands of formal schooling^[4, 5].



This Evidence Report outlines the main components of executive function and describes how these core skills develop in early childhood. The influence of executive function on children’s school achievement, social and behavioural functioning is discussed, as well as the role of adversity, such as poverty, in hindering the development of executive function. Following this, ways to promote and restore young children’s executive function, and to help protect against the harmful effects of adversity are considered. The use of interventions in supporting executive function development in early childhood is also addressed, including programs to promote parents’ executive function, so that they can help foster these same core capabilities in their children.



Executive function processes

Executive functions are pivotal to children's ability to demonstrate essential life skills, including: communicating, making connections, considering things from another perspective, taking on challenges, thinking critically, and pursuing self-directed, engaged learning^[3]. The building blocks of executive function begin to emerge early in the life course, improving dramatically throughout early childhood, and becoming increasingly sophisticated during later childhood and adolescence^[6, 4]. These skills can be described as one, unitary process (i.e. an air traffic control system), reflecting the idea of a common underlying core ability that operates in a more general fashion, particularly as it is observed among young children in real-life situations^[2, 4]. However, some researchers distinguish between three separate aspects of executive function (e.g. working memory, inhibitory control and cognitive flexibility), and others recognise three separate components that work in an interrelated way to comprise a unitary process^[7, 8]:

- **Working memory** refers to children's ability to hold and manipulate information in their minds for short periods of time^[2, 4, 9]. This enables children to remember and follow instructions multiple-step instructions without reminders (e.g. put on your pyjamas and go clean your teeth, and pick out a book for your bedtime story). Working memory also enables children to remember information from one paragraph to the next when they are reading. When interacting with others, working memory allows children to remember the rules of a game, when it is their turn in the game, as well as remembering who is taking on certain parts in a role-playing skit.
- **Inhibitory control** (also known as response inhibition) allows children to manage their thoughts and actions, prioritise, and direct, focus and sustain their attention^[2, 4, 10]. This skill is valuable for children when they are in the school setting, so they can ignore distractions (e.g. something happening outside the classroom window) and stay on task with their schoolwork, and wait until they are called upon when speaking in a classroom discussion. It is inhibitory control that enables children to control their immediate reaction (e.g. reacting aggressively by yelling or pushing another child who inadvertently bumped into them in a busy hallway), in light of a more considered response. This skill also underlies children's developing ability to refrain from saying what immediately comes to mind (e.g. a judgement about how someone looks or acts differently from others), and instead say something nice, or say nothing at all.
- **Cognitive flexibility** (also known as attention or set shifting) means that children can adjust their goals, switch between tasks, change their priorities, learn from mistakes, and revise their beliefs and actions when they learn of new information^[2, 4]. This capacity emerges later than working memory and inhibitory control^[11]. As an example of cognitive flexibility, a child may learn that how they would interact with their brothers and sisters at home is different to how they would interact with teachers at school. When they experience conflict with a peer, children use cognitive flexibility to use different strategies to resolve a disagreement, until they find one that works. When learning grammar, punctuation and spelling, children use cognitive flexibility to remember exceptions to common rules. For instance, knowing that 'read' is sometimes pronounced 'red', depending on the context. When learning mathematics, children learn that a zero means one thing when it is on its own, yet has another meaning when there is a number five in front of it^[5].



Executive function and self-regulation

In the first few years of life, parents and caregivers play an important role in monitoring and guiding their young children's social behaviour. However, by the time they enter formal schooling, most children have developed an internal, independent capacity to regulate their own behaviour, thus enabling them to navigate the many challenges they face in a range of everyday settings^[12]. Through their executive function processes, children can learn to effectively self-regulate, which is crucial for optimal adult functioning^[6, 4]. Self-regulation skills allow a child to maintain an optimal level of alertness, and smoothly transition between the higher levels of arousal needed for meeting a challenge, versus the lower levels of arousal needed for rest and recovery^[13]. Notably, the ability to return to a baseline level of being calmly focused and alert can depend on the number of stressors (biological, environmental and social) a child is dealing with at any given time^[13]. Self-regulation also allows children to recognise situations in which an automatic or habitual response is not appropriate, and prioritise their thoughts, emotions and behaviour accordingly^[4]. They can hold personal goals in mind, while at the same time suppressing impulsive responses, filtering out distracting or irrelevant information, and altering their behaviour when a goal, or the means to accomplish a goal, changes^[4]. As an example, a young child may be enjoying playing with their peers and see a toy car that another child is playing with, and decide they want to play with it themselves. Instead of just grabbing the toy car from the other child, they learn to overcome their immediate and instinctive reaction, through their knowledge of what social behaviour is appropriate in this situation. Rather than just acting in service of their more immediate goal (i.e. playing with the toy car), they adjust their behaviour to prioritise another goal (i.e. continuing to enjoy playing alongside the other child). They may distract themselves from their distressing thoughts or feelings about not having the toy car, such as by playing with another toy until the other child is finished.

School achievement, social and behavioural functioning

Executive function skills weave together children's social, emotional and intellectual capacities, allowing them to reflect, analyse, plan and evaluate^[3]. In the first few years of life, young children demonstrate reflexive and automatic responses in response to different cues in the environment (e.g. throwing a tantrum in the aisle of supermarket when denied a treat that they want). Yet, by the time they enter formal schooling, they have developed the remarkable capacity to modulate their behaviour and emotions in accordance with identified goals, social norms and expectations^[4]. For example, they can learn to sit quietly, listen to the classroom teacher give out instructions, focus on designated tasks for set periods of time, while resisting distractions and suppressing the urge to get up from their desk or talk with their classmates until they are instructed to do so. Essentially, executive function skills are a set of internal resources that children can draw on as they respond to the demands of formal classroom learning^[4]. Young children's capacity to effectively self-regulate their thoughts and behaviour is also central to their social and behavioural functioning more generally. For instance, research indicates that measures of working memory, inhibitory control and cognitive flexibility predict children's later literacy and numeracy skills, school achievement, interpersonal behaviour, communication skills, and emotion regulation^[12, 14]. These higher-order mental abilities enable children to successfully manage confusing and unpredictable situations and incoming information^[5]. For instance, in the school context, children make use of cognitive impulse control to become proficient at spelling and pronunciation (e.g. knowing rules and their exceptions)^[5]. Similarly, children learn how to overcome their immediate and instinctive reactions through emotional impulse control, such as their ability to refrain from acting aggressively when frustrated by difficulties with their peers or when completing challenging academic tasks^[5]. In essence, through supporting the process (i.e. the how) of learning, executive function is the basis upon which children can effectively master the content (i.e. the what) of reading, writing and mathematics^[2].



Brain development and executive function

Children's emerging executive function has its basis in early brain development, particularly the growth of the prefrontal cortex, and key neural mechanisms^[2]. Rapid increases in the growth and connectivity of the brain in the first few years of life support young children's accelerated learning and the acquisition of core skills^[4]. The greater plasticity of the brain during this formative stage of development also means that children are particularly sensitive to the quality of the environments they experience; this determines which neural connections are strengthened or pruned, according to whether they are used or neglected^[15]. In this way, the rapidly developing brain both contributes to, and is shaped by, the emergence and refinement of executive function. Substantial changes in a child's brain take place between preschool age and formal school entry, particularly an extensive reorganisation of neural pathways. This is thought to underlie children's remarkable capacity to transition from a dysregulated toddler in the first few years of life, to being able to function competently and far more independently as they navigate the complex social and academic demands of the school setting^[4].

Individual differences in executive function

Children can demonstrate altered developmental trajectories and individual patterns of executive function development that deviate from general trends^[2, 4]. As such, they can differ widely in terms of their ability to follow rules and directions, maintain focus and shift their attention, control impulses, and adjust to the demands of changing contexts^[2]. A range of factors influence these individual differences in children's executive function, such as genetic makeup, temperament and developmental delays^[2]. Factors within the family environment can also influence the development of executive function among young children^[4]. In addition, children's ability to use executive function processes may be limited at any particular time dependent on features of the context in which they are in. Specifically, when children are confronted with negative emotion or stress, their attention and focus will be diverted towards adaptively assessing and responding to threat^[4]. This means they will be distracted from broader contextual goals and their executive function processes will be blunted.



Even a child with well-developed executive function capabilities will have difficulty enlisting these skills when they are experiencing the toxic stress of a chaotic home environment, for instance^[2]. However, in a safe and predictable environment (e.g. at their preschool), the more positive emotional context means that they are better able to deploy their executive function processes and demonstrate core competencies such as planning, controlling impulses, focusing attention, and following instructions^[2, 4]. This reinforces the need to provide the supportive environments in which children can successfully practice their executive function skills. When a child begins school with poor executive function, this can launch them on a negative developmental trajectory and create a negative feedback loop. For instance, children with poor inhibitory control can have difficulty paying attention, staying seated, avoiding distractions and completing their schoolwork^[11]. Subsequently, their teachers start to expect poor performance from that child, and the child experiences self-doubt and has low expectations of their own success too, and doesn't enjoy being in school. However, improving executive function skills early in a child's life can get them started on a trajectory of success. This creates a positive feedback loop whereby their own and others' perceptions and expectations can help reinforce the further development and refinement of executive function skills^[11].



The family environment and the impact of adversity

The relationships experienced by young children as they develop has a powerful influence on their executive function^[2, 4]. Specifically, the emergence and refinement of these core skills requires the presence of responsive relationships with caregivers and access to safe, protective environments^[4, 16]. Parents experiencing adversity such as poverty, however, may be challenged to provide the warm and nurturing interactions that are central to children's healthy development, and the enriching environments and experiences that enable children to develop their executive function skills^[6, 4]. For instance, low-income families are more likely to experience multiple daily stressors, such as poor quality housing, overcrowding, household instability, lack of safety, negative life events and mental health issues, while also reporting fewer family and friends whom they can rely on for support^[4]. Furthermore, children from low-income households are also less likely to have access to learning materials and resources (e.g. books and toys), hence limiting their ability to practice executive function skills^[4]. Growing up in stressful, chaotic and unpredictable environments in early childhood can also impair the development of the prefrontal cortex; the part of the brain that is critical to executive function^[9]. Correspondingly, children experiencing the "toxic stress" of poverty demonstrate poorer working memory, inhibitory control and cognitive flexibility^[2, 4]. As such, young children growing up in adversity can generally find it more difficult to concentrate and maintain attention, follow directions, achieve goals, manage their time, make decisions, apply learned information and rebound from disappointments^[5, 17]. They are also more likely to have difficulty managing behaviour and emotions, engaging in healthy behaviours, delaying gratification, and working with others^[17]. When the development of executive function skills is undermined by adversity, it can contribute to the lower levels of school-readiness demonstrated among children from low-income families^[14, 17, 18]. Indeed, it is unsurprising that being constantly overwhelmed by uncontrollable impulses and struggling with negative emotions can have a direct effect on children's ability to respond to the challenges of formal schooling^[5]. In this way, executive function delays early in life can create learning disparities between children that widen over time and have far-reaching effects, leading to adverse social and economic outcomes well into adulthood^[14, 19].

Parents' core capabilities

The executive function skills that have their foundations in early childhood are also essential for optimal functioning and life success in adulthood. Specifically, these core capabilities enable adults to effectively manage parenting, provide responsive care for their child, manage a household, maintain secure employment, and contribute productively to the community^[20]. To fulfil these roles and responsibilities, adults continuously draw on their executive function abilities to pay attention, plan ahead, avoid distractions, remember important information, adapt to changing contexts, and respond to situations appropriately. However, when adults are exposed to ongoing stressful and threatening situations (such as poverty, violence, addiction, and mental illness), this can overload and overwhelm the pre-frontal cortex, impacting on their ability to use key executive function processes, and instead triggering reactive and impulsive behaviour^[20]. Subsequently, parents can be overwhelmed by everyday challenges, and are unable to use the very skills they need to address their adverse experiences. Parents' executive function (including their capacity for attention, memory and planning) may also be undermined by their own experiences of childhood adversity^[20]. This makes individuals living in poverty doubly vulnerable, as these diminished executive function skills are also the very skills they need to thrive amidst challenging circumstances. Indeed, it is these core capabilities that enable adults to address life challenges and achieve greater social and economic stability^[17, 20]. Fortunately, adults can build their core capabilities to cope with adversity, to meet their own life goals and manage parenting effectively^[20, 21]. By supporting parents to develop these core skills that enable them to successfully manage life, work and parenting, parents can create the stable and responsive environments that are critical for the healthy development of children in their care^[20].

Interventions for improving children's executive function

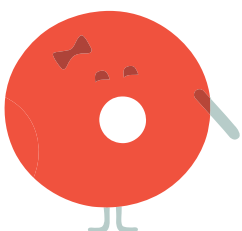
Executive function skills like all skills, develop from opportunities to practise these, especially in early childhood^[2]. While some children demonstrate delayed executive function, particularly those growing up in adversity, opportunities that create enriching environments and experiences will help to enable them to successfully build these core skills^[5]. For instance, a range of interactions and activities (see Table 1 for examples) can foster the development of these core executive function processes in early childhood, and can be made more challenging (i.e. "scaffolded") according to children's developing capabilities^[2, 10, 12]. Over time, the gradual reduction of adult assistance helps children learn to practise these skills more independently^[2].



Table 1: Early childhood age-appropriate activities to enhance executive function skills

Age	Activities	Skills practised
6-18 months	Lap games (peek-a-boo; pat-a-cake); Hiding games (find the toy, hide and seek); Imitation or copying games (gestures, toys); Simple role playing (involving child in daily tasks); Fingerplays (eensy-weensy-spider); Conversation (naming objects, talking about events).	Working memory, attention, self-control, tension regulation, language, imaginative play.
18-36 months	Active games (song games with gestures, physical activities, imitation games, 'freeze' games); Conversation and storytelling (narrating play, reflecting on experiences, talking about feelings); Matching/sorting games (sort objects by characteristics, simple puzzles); Imaginary play (pretending to clean or cook; child-directed games; provision of props).	Focus and sustain attention, action inhibition, working memory, trying new strategies, imaginary play.
3-5 years	Imaginary play (provision of inspiration and props; group play); Story telling (creating stories through words, images and acting; group collaboration); movement songs and games (physical games; 'freeze' games; yoga); quiet games and activities (matching and sorting, puzzles, cooking).	More independent use of EF-related skills: Working memory, attention, inhibition, cooperative play, social problem solving, language, cognitive flexibility.

Specific training programs are available for children who face difficulties with executive functioning, including focussed preschool interventions [2]. For instance, the Tools of the Mind preschool program has been found to be effective in improving children's executive function and self-regulation [22, 23]. In this program, children's learning, attention and memory is supported by appropriate scaffolding of activities, and they develop skills to regulate their own social and cognitive behaviours through dramatic play and purposeful interactions with classmates. The preschool PATHS (Promoting Alternative Thinking Strategies) social-emotional learning curriculum incorporated in Head Start REDI program has also been found to be effectively in improving children's executive function [22, 18]. Alternatively, some intervention programs emphasise physical development, such as aerobic exercise, to improve functioning of the prefrontal cortex [24]. Similarly, the Alert Program for Self-regulation® emphasises the use of sensory strategies to enable children to effectively regulate their levels of "alertness" and improve executive functioning [25]. Other approaches that can aid children's executive function development include the use of computerized training or noncomputerized games, as well as programs that combine physical exercise with character development (e.g. martial arts) and mindfulness (e.g. yoga) [24].



Some intervention programs specifically aim to enhance parents' capacity to foster executive function skill development in their children^[6]. One approach engages parents as 'change agents' who can support their child's executive function skills by capitalising on everyday moments an opportunity for learning. To do this, the Vroom initiative, which is currently being evaluated, provides more than 1,000 tips for families and caregivers to incorporate 'brain-building' activities into their daily lives, disseminated via the web, a free app (Daily Vroom) and community partnerships^[26]. Children's executive function is fundamental to their school success, and poor executive function can have a cascading effect for children growing up in poverty. Hence, improving children's executive function has potential to help narrow the achievement gap between disadvantaged children and their more affluent peers^[5, 18, 23].

Interventions for improving parents' executive function

Parents' ability to successfully foster their child's executive function skills is contingent on having well-developed executive function skills themselves^[20]. At an individual level, parents can be supported to build or restore their own self-regulation and executive function skills through dedicated practice. This can include learning how to identify emotional triggers and reassess stressful situations, slow down automatic and impulsive reactions, and consider alternative responses. Through individual skill-building techniques, parents can start to feel a sense of control over their lives, and be empowered to make decisions, plan for the future and engage in the pursuit of personally motivating goals^[20, 27]. Several promising interventions that aim to improve these core capabilities among adults are currently being evaluated, including the use of coaching with an intergenerational lens. Essentially, through strengthening parents' abilities to navigate the complexities of poverty, and assisting them to transform their own lives, such approaches aim to improve the developmental outcomes of children growing up in adversity, and disrupt the intergenerational cycle of poverty^[21].

Fully integrated, two-generation programs are recommended to provide both children and their caregivers with the opportunity to develop executive function skills^[21, 26, 28]. For instance, the Ready4Routines program involves adult caregivers and their children working together to establish consistent routines^[29]. Parents learn mindfulness, reflection and planning skills through a coaching/practice component, and use activity cards at home with their children to build and practise family routines. This intervention is currently undergoing evaluation to determine its effectiveness^[29]. However, it is expected that, enhancing the predictability and stability in children's daily lives, will allow them the opportunity to practise and strengthen their emerging executive function skills in a safe and supportive environment. Additionally, creating and maintaining regular family routines is likely to decrease parental stress, which then enables parents to engage and strengthen their own executive function skills more effectively^[29].



Individual skill-building programs to improve adults' core capabilities also need to be supported by a concerted effort to reduce environmental stressors in the lives of families in poverty. This includes, for instance: making service systems easier to navigate; providing support for basic needs, and; paying attention to the style of interaction between caseworkers and the families they serve ^[20]. Parents' executive function can already be severely comprised by the challenge of raising a child in poverty; hence, they require extra support such as mentoring, engaging and simple information, structured organisational tools, and opportunities to practise and receive constructive feedback ^[17]. Moreover, community, state and national policies and services have a critical role in proactively protecting young children from the toxic stress (including poverty, violence and maltreatment) that hinders their optimal development and restricts their chances to learn the foundational skills for life success ^[16].

Conclusion

To successfully navigate the routine tasks of daily life, individuals need to stay focused, remember and follow instructions, make decisions, shift priorities and control impulses. Mastering these executive function processes is a key developmental task of early childhood, and enables children to successfully cope with the demands of formal schooling. However, these core skills can be negatively impacted by growing up in adversity, such as poverty. However, there is much opportunity to help both children and adults improve their executive function through specialised practice and training, due to the malleability of these skills. Improving executive function among children is a promising means to help protect against the impact of adversity on children's academic, social and economic outcomes. Additionally, by promoting adults' executive function, it means they can foster the same core skills in their children, as well as assisting parents themselves to cope more effectively with everyday challenges and thrive amidst challenging circumstances.

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