An Introduction to Executive Function: Current Research for Teachers

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The Alberta government states that "Quality teaching occurs when the teacher's ongoing analysis of the context, and the teacher's decisions about which pedagogical knowledge and abilities to apply result in optimum learning by students" (Alberta Education, 1997). No one would dispute the fact that the learning referred to includes academic and subject-specific skills related to numeracy, literacy, the sciences and arts. However, there is another set of higher-order cognitive skills that is essential to not only academic success, but to everyday thinking, organizing, planning and functioning. This set of skills is the executive function (EF) system, which includes: inhibitory control, working memory, and cognitive flexibility (Diamond and Ling, 2016). EF is a group of skills that aids in the optimization of learning opportunities, is more critical for school readiness than IQ or entry-level reading or math and is predictive of positive school and life outcomes (Diamond and Ling, 2016; Diamond and Lee, 2011). A delay or deficit in EF disrupts learning and may be manifested in memory difficulties, trouble following multi-step instructions or managing long-term assignments, an inability to control impulses or problem-solve and adjust to changes (Diamond and Ling, 2016; Center on the Developing Child at Harvard University, 2011). This makes it paramount that successful ways to remediate, improve and/or accelerate development in this domain are found. Teachers require an understanding of what EF is, including why it is important in school contexts, what can delay it and what can be done to support EF throughout school.

We are not born with the ability to conduct the deliberate, intentional, goal-directed behaviour that is required for daily life and success in school and the work force (Zelazo and Carlson, 2012; Center on the Developing Child at Harvard University, 2011). We are born with the potential to develop these skills, but this potential can vary depending on our experiences and genes. In order to understand and make an impact on EF, teachers must understand brain

development and how best to intervene both when deficits in EF are apparent and at each stage of development. Genes provide a map for cognitive development (Zelazo & Carlson, 2012), however experiences can cause roadblocks, detours and dead ends. The areas of the brain required for basic survival, controlling responses to threat and stress are built first and wired earlier as the brain is built from the bottom-up (Center on the Developing Child at Harvard University, 2007). As the brain develops, extensive interconnections are made between earlier developed neural areas and the prefrontal cortex (PFC) (Gibb, 2016; Cameron, 2011). The EF system, situated in the PFC, will continue to develop throughout the school years as these connections are made and impacted by an individual's experience, and management of threat, stress, and strong emotions (Gibb, 2016; Center on the Developing Child at Harvard University, 2011).

Executive function is a blanket term used to describe the important job of the brain's executive – the PFC along with the anterior cingulate, parietal cortex, hippocampus and other circuits and systems connected to the PFC (Diamond & Ling, 2016; Gibb, Piquette, Harker, Raza and Rathwell, 2015; Center on the Developing Child at Harvard University, 2011). In school EF is important for a number of reasons. Inhibitory control is crucial in terms of the ability to resist both internal and external impulses that may pull us away from learning. It includes both self-control and self-regulation (Diamond & Lee, 2011). It makes it possible for us to evaluate situations, choose reactions and change our behaviour rather than being "unthinking" creatures of habit or impulse" (Diamond & Ling, 2016, p. 34). Working memory (WM) includes holding information in mind for a short time so that we can make sense, reason and problem-solve. It is needed to follow steps, re-order information for evaluation and take part in discussions while remembering what has been verbalized previously (Diamond & Ling, 2016). Cognitive

flexibility is required to switch tasks, to adjust to changed demands or priorities. It allows us to look at the same thing from different perspectives (Diamond & Ling, 2016).

In any class, you will have some students with strong EF skills and others who struggle with EF skills. Students with strong EF skills "analyze, orientate, specify, plan, and evaluate knowledge and information, while monitoring and controlling their own learning processes to regulate their learning" but not every student is a "motivationally, metacognitively, and behaviorally active participant in their own learning" (Meusen-Beekman, Joosten-ten Brinke, and Boshuizen, 2015, p.3). These differences may exist due to individual variability, ADHD, or negative impact factors such as low socio-economic status (SES), trauma and stress or sub-optimal health (Diamond & Ling, 2016; Meusen-Beekman et al., 2015). All of these factors can result in neurological changes that impact EF. Studies on people with ADHD have shown dysfunction in the prefrontal lobes and the genes involved in dopamine regulation as well as differences in the size of brain structures such as the PFC, corpus callosum and caudate nucleus (Tripp & Wickens, 2009; Kieling, Goncalves, Tannock, & Castellanos, 2008). Faulty brain circuitry also occurs as a consequence of adverse, or low SES early environments that lack nutrients, appropriate sensory, social, or emotional stimulation, and/or contain toxins (Center on the Developing Child at Harvard University, 2011). The low SES environment can also result in chronic stress, as can other life events. The release of cortisol, most pronounced in the PFC, can disrupt the functional connectivity between the PFC and other brain regions. Even mild stress overwhelms the PFC with excess dopamine therefore trauma and stress can result in lower EF skills (Diamond & Ling, 2016). Sub-optimal health due to lack of sleep, general health concerns or insufficient physical fitness can also effect EF (Diamond & Ling, 2016). This evidence gives

credence to the fact that children will arrive at school with varying EF skills necessitating the provision of opportunities for students to build EF skills.

Diamond and Ling (2016) suggest that EF can be improved at all ages and that those with the poorest EFs consistently gain the most from any EF program. They assert that EF training can have narrow transference, should occur often but that benefits diminish once practice ends. They state that whether EF gains are made depend on whether activities/interventions are presented at the "zone of proximal development" (ZPD) and are conducted by committed individuals who believe in the activity's/intervention's efficacy. The ZPD is the difference between what a learner can do without help and what he or she can do with help (Vygotsky, 1978). They also state that without a cognitive component, aerobic exercise and resistance training have little or no EF benefit and they caution that we need to be aware that not every reason for improvement in EF is obvious. They specifically cite de Jong's (2014) study that found that trained, committed mentoring seems to be the reason for the benefits of CogMed® more than the computerized games as an example of a camouflaged reason for the program's success. With these points in mind, early intervention, secure relationships, mindfulness, aerobic exercise, and scaffolding are some of the more successful school-based opportunities we can offer.

Early Intervention

Research suggests that periods of relative plasticity, or sensitive periods exist. These are usually tied to times of rapid neural growth, for example the preschool years, when "particular regions of the brain and their corresponding functions are especially susceptible to environmental influences" (Zelazo & Carlson, 2012, p. 357). Interventions at this time that help increase EF may initiate a cascade of beneficial events for children, resulting in school success (Gibb et al.,

2015; Zelazo & Carlson, 2012). The biggest benefits arise when interventions are structured to explicitly foster emerging executive function skills; train and support teachers in effective classroom management strategies and train teachers to model and coach children in pro-social behaviour, social problem-solving skills, expressive and receptive emotional understanding, and the ability to control impulsive behaviour to reach goals (Center on the Developing Child at Harvard University, 2011).

Relationships

Sensitive, responsive caregiving relationships (both within and outside the home) need to be formed. These relationships guide children from complete dependence on adult support to gradual assumption of the "executive" role for themselves. This requires an adult that is able to fully commit time to the child in order to practise skills such as decision-making and emotional regulation (Center on the Developing Child at Harvard University, 2011; Zelazo & Carlson, 2012). As discussed earlier, low SES, trauma, and stress can impair the development of EF skills as a result of the disruptive effects on the developing architecture of the brain (Harker, 2016; Center on the Developing Child at Harvard University, 2011). Children who have a secure attachment with someone who is sensitive and responsive will more likely develop EF skills than those who aren't (Gibb, 2016).

Mindfulness

Mindfulness is the art of "paying attention in a particular way: on purpose, in the present moment, and non-judgmentally" (Kabat-Zinn, 1994). This ability can help students with initially poor EFs improve in shifting and monitoring (Diamond & Lee, 2011). Emotions usually compete with other cognitive processes for attention. Practicing mindfulness helps with emotional regulation, allowing the PFC to inhibit and shift attention from the emotions to the higher order

cognitive processes needed in any situation (Sanger and Dorjee, 2015). Teachers should access and assess many diverse mindfulness activities to find ones that they can commit to after assuring themselves of the program's or strategy's efficacy.

Aerobic Exercise

Aerobic exercise with a cognitive component robustly improves PFC and executive functions through multiple pathways (Diamond & Ling, 2016; Best, 2010). The physiological changes (e.g., increased blood flow) that occur in aerobic activity occur in sequence with an immediate neurochemical response that may enhance cognitive performance (Best, 2010). Although Diamond and Ling (2016) tell us that more research has been done on aerobic exercise alone compared to aerobic exercise plus a cognitive component, they state that stronger, more encouraging results emphasize that aerobic exercise (with exercises becoming more demanding over time) plus a cognitive component improves EF, including cognitive flexibility and creativity. Studies have shown that team sports might benefit EFs more than aerobic exercise alone because of the sustained attention, WM, and goal directed behaviour in team sports (Schmidt, Jäger, Egger, Roebers and Conzelmann, 2015; Diamond & Lee, 2011). Aerobic games also require skilled and complex movement, which directly relies on the prefrontal neural circuitry supporting EF (Best, 2010). It will be interesting for teachers to monitor research to determine just how much aerobic exercise is needed and how much of a cognitive component is most beneficial.

Scaffolding

Scaffolding refers to a variety of instructional techniques used to move students progressively toward stronger understanding and, ultimately, greater independence in the learning process. It is similar to the goal of early intervention in that teachers provide and

incrementally remove successive levels of support that help students reach higher levels of comprehension and skill acquisition that they would not be able to achieve without assistance. The end goal of scaffolding is self-regulation (SRL) of the learning process. Scaffolding procedures are chosen as a consequence of formative assessment. Through formative assessment, we determine whether gaps exist and what instructional activities will most likely result in student improvement in authentic learning environments, and we support students in reflecting, planning, and monitoring their progress (Meusen-Beekman et al., 2015). Generally, models of scaffolding and SRL are separated into cyclical phases of forethought and planning, performance monitoring, and reflections on performance (Zumbrunn, Tadlock, and Roberts, 2011).

EF skills help children develop self-regulation and the ability to successfully engage in a wide variety of skills that will have both academic and lifelong benefits. We, as teachers, can build EF, especially for those students with the poorest EF skills, through the use of a combination of the purposeful interventions discussed in this paper. These interventions have demonstrated at least short-term effectiveness, and may possibly have impacts on other aspects of learning as well ((Diamond & Ling, 2016; Center on the Developing Child at Harvard University, 2011). Leadership and teamwork, decision making and making positive choices, working towards a goal, critical thinking and organization and planning skills are just a few examples of EF skills that will have positive lifelong benefits when developed (Center on the Developing Child, 2012). It is my belief that in order to meet Alberta Education's (1997) teaching quality standard to optimize learning we need to address EF. It is crucial that teachers recognize what EF behaviours they should expect and which ones may not yet be present at each stage of development. They need to be aware that sometimes a delay in EF development is due to individual variability and sometimes adversity throughout life will impact the EF as well.

Teachers must support the emergence of children's EF skills until they can practice and perform them on their own. Quality teaching will only occur when teachers' decisions about which pedagogical knowledge and abilities to apply include consideration of EF, thoughtful consideration of interventions that support EF development and result in optimized learning through bettering academic and life outcomes for all children.

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