MIND, BRAIN, AND EDUCATION

Developing Self-Directed Executive Functioning: Recent Findings and Future Directions

Jane E. Barker[1] **and Yuko Munakata**[1]

ABSTRACT— How do children become increasingly self-directed across development, achieving their goals without help from others? How might such developments be impacted by societal changes in how children spend their time? Children's abilities to achieve their goals are supported by developing executive functions (EFs), cognitive processes that predict important life outcomes. Efforts to improve children's EFs have benefitted their externally driven executive functioning, where goals and instructions are provided by others. Less is known about self-directed EF, when children must decide independently what to do and when. We present recent findings demonstrating that children are better at engaging self-directed EF when they have good understanding of options to choose among, and if they spend time in activities that they play a large role in directing. Within this context, we discuss the potential role of opportunities to plan, mind-wander, and play, and present the critical next steps in investigating the influence of changing environments on self-directed EF.

Across development, children become increasingly self-directed, gradually advancing in their ability to achieve goals autonomously, without help from others. In some ways, modern societies offer more support for developing self-direction than ever before: for example, it is much easier for children to find information that helps them to achieve specific goals (e.g., online tutorials for math problems, or websites describing the steps in a favorite recipe). However, while such readily available information may make it easier for children to determine *how* to achieve goals, it does not reduce the difficulty of determining (and remembering) what goals are important. Young children often need reminders about how and when they should adjust their daily routines to accomplish the things they would like to do, even for seemingly simple tasks, such as remembering to bring cookies to school for a holiday party, or stopping to grab a warm coat after a change in weather. Typically developing older children show increasing competence in planning for events in a self-directed way, without reminders from adults or peers. What supports this transition from reliance on external cues (such as reminders from others) to generation of autonomous, internal cues about what should be done, and when?

To adjust established routines so that they can accommodate new plans, children must engage executive functions (EFs), a set of cognitive processes that support thoughtful, planned behaviors, including maintenance, manipulation, and updating of information in working memory,[1] inhibition of unwanted thoughts, feelings, and actions, and flexible shifting from one task to another (Miyake et al., 2000). These abilities are supported by developments in prefrontal cortical regions and associated networks (Bunge & Wright, 2007; Houdé, Rossi, Lubin, & Joliot, 2010; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005), and develop gradually across childhood (e.g., Gathercole, Pickering, Ambridge, & Wearing, 2004; McAuley, Christ, & White, 2011; Munakata, Snyder, & Chatham, 2012; Zelazo, Carlson, & Kesek, 2008). Childhood EFs are an important predictor of academic success (e.g., Best, Miller, & Naglieri, 2011; Cameron et al., 2012; St Clair-Thompson & Gathercole, 2006). For example, preschoolers who perform well on a peg-tapping task, which requires them to inhibit an automatic action (tapping a wooden stick in the same way as an experimenter) in favor of a controlled response (tapping twice when an experimenter taps once, and tapping once when an experimenter taps twice), show better kindergarten math performance (Blair & Razza, 2007). Early EFs also predict long-term outcomes: childhood self control has

[1]Department of Psychology and Neuroscience, University of Colorado Boulder

Address correspondence to Jane E. Barker, Department of Psychology and Neuroscience, University of Colorado Boulder, Boulder, CO 80309; e-mail: jane.barker@colorado.edu

been shown to predict health, wealth, and social outcomes in adulthood (Moffitt et al., 2011).

Because childhood EFs are important for controlling behavior in the moment, and also predict long-term outcomes, explorations of whether and how EFs can be improved through training and intervention are important. Some computerized training programs have yielded improvements in children's and adults' maintenance and manipulation of information in working memory (e.g., Bergman Nutley et al., 2011; review in Diamond, 2012; Dunning, Holmes, & Gathercole, 2013; Loosli, Buschkuehl, Perrig, & Jaeggi, 2012). Preschool classroom curricula focusing on developing self-regulatory skills, such as Tools of the Mind and Montessori, have also benefitted children's ability to flexibly shift from one cognitive task to another (e.g., Diamond, Barnett, Thomas, & Munro, 2007; Lillard & Else-Quest, 2006).

Despite these successes, attempts to improve EFs also have limitations. First, training focused on improving specific EFs (such as maintenance and manipulation of information in working memory) typically results in limited transfer to other domains, such as fluid intelligence or multitasking (e.g., Dunning et al., 2013; Klingberg et al., 2005; Redick et al., 2013; Thorell, Lindqvist, Bergman Nutley, Bohlin, & Klingberg, 2009; cf. Loosli et al., 2012). Second, the long-term gains from training and intervention studies are largely unknown; no studies have reported whether the effects of early training or interventions on EFs persist beyond 1 year (Diamond & Lee, 2011; Melby-Lervåg & Hulme, 2013). Third, efforts to improve children's EFs via training and intervention experiences have been limited to improvements in their externally driven executive functioning, where goals and instructions are provided by other agents, such as adults. Tests of externally driven EF measure how well children can execute EFs when an experimenter instructs children about what they should do (e.g., remember a series of images presented on a screen) and when they should do it (e.g., recall the images in reverse order).

By contrast, relatively little is known about what supports the development of children's self-directed EF, where they must determine on their own how to set and achieve goals. The limited set of studies that have investigated self-directed EF have found that it emerges more slowly than externally driven EF (Chevalier, Wiebe, Huber, & Espy, 2011; Jacques & Zelazo, 2001; Smidts, Jacobs, & Anderson, 2004; Snyder & Munakata, 2010; Welsh, Pennington, & Groisser, 1991), and is more cognitively taxing across the lifespan (e.g., Bryck & Mayr, 2005; Forstmann, Brass, Koch, & von Cramon, 2005; Lie, Specht, Marshall, & Fink, 2006). However, self-directed EF is more difficult to study in children, as it is challenging to devise well-controlled tasks wherein children determine on their own how they should strategically approach a task, and when they should switch from one goal-directed action to another. Perhaps because of these complexities, few studies have investigated whether childhood self-directed EF is sensitive to training and intervention.

One measure that has proven useful in measuring self-directed EF in children is the semantic verbal fluency task (Bousfield & Sedgewick, 1944; Troyer, Moscovitch, & Winocur, 1997). In this task, participants are given 1 min to generate as many items as possible falling within a category (e.g., animals, foods). Performance on this task benefits from strategic clustering (producing groups of words falling into the same semantic subcategory, such as zoo animals) and shifting from one subcategory to another when production of additional exemplars becomes difficult (e.g., switching from zoo animals to farm animals). Although participants are provided with the overall task goal, they must decide on their own when to switch from one subcategory to another, and endogenously select what new subcategory to switch to. Verbal fluency performance predicts real-world self-directed behaviors, including functional impairments in individuals with frontal lesions (Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998) and with some clinical disorders (Joyce, Collinson, & Crichton, 1996; Rich, Troyer, Bylsma, & Brandt, 1999), behavioral outcomes and social competence in elementary school children (Nigg, Quamma, Greenberg, & Kusche, 1999), and academic and social problems in college students (Wingo, Kalkut, Tuminello, Asconape, & Han, 2013).

Using this task, correlates and causal factors in children's self-directed EF have been identified. Emergent self-directed EF can be supported in young children when they are given information that can help them select appropriate actions to achieve goals. Understanding what options are available is important because selecting *what* to do to achieve goals is a key part of self-directed executive functioning (Munakata et al., 2012). For example, a young child may encounter a room cluttered with many activity options (e.g., building blocks, markers and paper, books), and struggle to select the option that would allow him or her to accomplish a desired goal (e.g., making a holiday ornament). However, adults can make selection of the appropriate activity easier by briefly orienting the child to each activity. In the verbal fluency task, children who demonstrate better understanding of the options (in this case, of the subcategories, as assessed in a separate sorting measure) show better performance on the verbal fluency measure. Moreover, young children switch more often and produce more words when they are made aware of task options (e.g., different categories of animals) via pretask reminders given by the experimenter (e.g., "vegetables are foods") (Snyder & Munakata, 2010). Children given such reminders switch between subcategories more often (and produce more words) than children given specific exemplars (e.g., "broccoli is a food"), controlling for individual differences in vocabulary. This benefit generalizes to subcategories beyond those provided by the adult. Experimenter provision of these categorical reminders may aid children by reducing the high selection demand induced by multiple response possibilities during the task (e.g., choices between multiple competing subcategories, and items within those subcategories; Snyder & Munakata, 2010, 2013).

In addition to a good understanding of task options, certain kinds of life experiences may help to improve children's self-directed EF. For example, the way in which 6- to 7-year-old children spend their leisure time predicts their self-directed EF (Barker et al., 2014). Estimates of child time use coded from parent-reported annual, typical, and past-week child activities were classified as *structured* (including homework, adult-led lessons and practices, religious activities, and chores) or *less-structured* (including free play, social events such as parties and family gatherings, and enrichment activities such as museum or zoo visits). Controlling for differences in income and vocabulary, children who spent more time in less-structured activities displayed better self-directed EF, as indexed via a verbal fluency task. By contrast, children who spent more time in structured activities, such as lessons and formal practice sessions, exhibited marginally poorer self-directed EF. The relationship between less-structured time and self-directed EF persisted with increasingly strict measures of less-structured time, first excluding media and screen time, which may have provided more structure than other activities in this category, and secondly excluding enrichment activities, which may have yielded benefits specific to verbal fluency performance. Additionally, not all less-structured activities were equally predictive of self-directed EF: enrichment activities (such as visits to museums, libraries, or zoos, and other educational events), social events (such as parties, camping, or group outings), and play with others predicted better self-directed EF. By contrast, media multitasking predicted marginally worse self-directed EF. Time use did not predict performance on two externally driven EF measures: a Flanker interference task and the AX-Continuous Performance (AX-CPT) task, a measure of cognitive control.

To understand links between children's time use and developing self-directed EF, future work will need to address several limitations of these preliminary findings, which were based on a small, affluent, suburban sample in a restricted age range, using a narrow set of time use and EF measures (Barker et al., 2014). For example, less-structured time may be most likely to benefit children in safe, stimulating, and resource-rich environments, where activity options are plentiful. Moreover, determinations of what activities fall into less-structured and structured time categories are difficult to make, and fail to capture important differences in the degree of child autonomy within different kinds of activities. More precise estimates of child time in structured and less-structured activities could be generated by supplementing retrospective parent-reports on child time use with direct observation, or with experience sampling, which would allow parents to provide information about child behaviors in real-time (e.g., via their mobile devices). In addition, measures of self-directed control that more closely approximate real-world situations could inform the question of how time use relates to children's broader functioning. Although verbal fluency measures predict some aspects of real-world self-directed functioning, adoption of new measures would help to establish ecological validity. Such measures could also address issues of generalizability, by establishing that links between self-directed EF and time use are not driven by other characteristics tapped by verbal fluency, such as the organization of children's developing semantic networks.

Additionally, causal links between time use and developing EF have not been thoroughly investigated (Figure 1). One interpretation of this relationship is that children's self-directed EF is influenced by how they spend their time. Alternatively, children with better-developed self-directed EF may engage in (or be encouraged to engage in) less-structured activities more often; similarly, children with poorer self-directed control may be more likely to engage in structured activities. Longitudinal studies could yield preliminary insights into causal relationships. For example, if child time spent in less-structured activities predicts subsequent changes in self-directed EF, less-structured time may causally influence developing self-directed EF. By contrast, if early self-directed EF predicts changes in the amount of time children spend in less-structured activities, EF may play a causal role in children's time use. However, longitudinal studies cannot be used to determine whether the observed relationship between less-structured time and self-directed control is driven by an unmeasured, mutually predictive third variable, such as genetic influence. For example, parent executive functioning might simultaneously predict child self-directed EF and parenting behaviors that influence child time use (such as a tendency to allow children to pursue activities independently). Such linkages may be explored via twin modeling approaches, wherein the independent roles of genetic, shared environmental, and nonshared environmental factors can be investigated via comparison of heritability estimates across dizygotic and monozygotic twins.

If such future investigations support the interpretation that less-structured time benefits developing self-directed EF, another unexplored question relates to the origin of such benefits: what kinds of less-structured experiences are most beneficial to self-directed EF, and why? One interpretation is that less-structured experiences allow children to practice planning what they will do, and when. This explanation

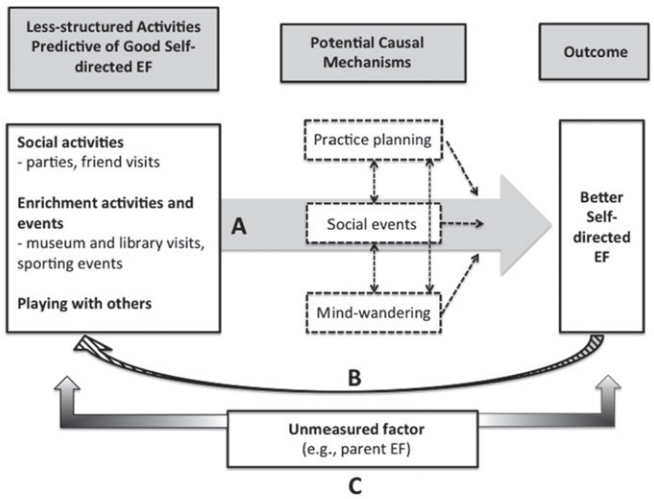

Fig. 1. Possible explanations for observed links between time in less-structured activities and self-directed EF. Pathway **A**: Children's time in less-structured activities may promote better self-directed EF, via opportunities to plan, engage in social play, or mind-wander. These activities are not mutually exclusive, and may be engaged simultaneously (as indicated by connecting arrows). Pathway **B**: Alternatively, children with better self-directed EF may engage in (or be encouraged to engage in) less-structured activities more often than children with poorer self-directed control. Pathway **C**: The observed relationship may be driven by an unmeasured, mutually predictive third variable, such as parent EF.

is consistent with the theoretical perspective of Vygotsky (1967), who theorized that advanced forms of pretend play allow children to practice generating, maintaining, and carrying out plans and objectives. For example, during pretend play activities, children develop and maintain goals that are inconsistent with cues from the external environment, often while enlisting symbolic props (e.g., pretending to act as a baker while standing in a living room, using a pencil to stir imaginary batter). Some preschool curricula, such as Tools of the Mind, draw from this theoretical perspective by training teachers to scaffold complex play behaviors in the classroom, and have been shown to improve self-regulation and some EFs (e.g., Blair & Raver, 2014; Diamond et al., 2007). By contrast, during structured activities, goals and instructions are often provided externally, by adults, giving children less opportunity to practice selecting what actions are most likely to yield beneficial outcomes. For example, during a typical adult-run soccer practice, a coach determines what team members need to improve on (such as shooting goals), selects an activity that will help children to practice that skill (a shooting drill), and decides when children are ready to switch from an easier to a more complex drill. In self-directed activities, children, rather than adults, choose goals, select appropriate activities to achieve those goals, and determine when they should switch from one activity to another.

An alternative explanation for posited benefits of less-structured time to self-directed EF is that such experiences afford children time to mind-wander. Mind-wandering is sometimes characterized as a sign of poor attentional control, and can predict decreases in ongoing task performance (e.g., McVay & Kane, 2010). By contrast, other work has focused on the cognitive benefits associated with positive, constructive forms of mind-wandering (e.g., Immordino-Yang, Christodoulou, & Singh, 2012; McMillan, Kaufman, & Singer, 2013). Such mind-wandering often involves reflections on past and future events or states, and helps individuals to connect events across time (Smallwood & Andrews-Hanna, 2013; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011; Suddendorf, Addis, & Corballis, 2009; Tulving, 1987). In empirical studies, mind-wandering has been linked to better planning ability and reduced impulsivity in economic decision-making tasks (Frith & Frith, 2007; Smallwood, Ruby, & Singer, 2013), as well as enhanced creativity (Baird et al., 2012). In addition to benefits to future planning and creativity, mind-wandering may promote *attentional cycling*, or the ability to rotate through different information streams, which helps individuals to make progress toward multiple, distinct goals; and *dishabituation* of ongoing tasks, by generating short breaks that refresh mental capacity and facilitate the enhanced learning associated with distributed, rather than massed practice (Schooler et al., 2011). Each of these benefits could contribute to improved learning and EF. Benefits may be more pronounced in self-directed EF (relative to externally driven EF), because individuals must dishabituate from an ongoing task at the appropriate moment (without help from external cues), and then rotate to an alternative task.

A third explanation of the benefits of less-structured time for self-directed EF is that specific forms of social play drive improvements in neural function that yield general benefits to planning and organization, and skills that may benefit more complex planning, such as language ability. In rodents, juvenile play and social experiences leads to anatomical changes in cortical areas that contribute to executive functioning, including the medial prefrontal cortex and orbitofrontal cortex (Bell, Pellis, & Kolb, 2010). Juvenile play experiences are critical precursors to normal social function in adult animals; when rodents are deprived of play as juveniles, they are more aggressive toward other rats and show heightened fear in novel environments in adulthood (Pellis & Pellis, 2009; Pellis, Pellis, & Bell, 2010). Rodent play also increases expression of brain-derived neurotrophic factor (BDNF), which promotes learning and memory (Gordon, Burke, Akil, Watson, & Panksepp, 2003). In preschool settings, children who are given opportunities to play show improved school readiness and conduct (Coolahan, Fantuzzo, Mendez, & McDermott, 2000). Additionally, increasing the amount of time that children spend playing through intervention has been shown to improve vocabulary and literacy skills (Christakis, Zimmerman, & Garrison, 2007; Levy, Schaefer, & Phelps, 1986; Lovinger, 1974). Thus, play appears to yield broad benefits to learning mechanisms, and more specific benefits to language growth and maturation. However, given this general set of play-based benefits, it is unclear why the benefits of less-structured activities might be limited to self-directed EF, rather than a broader set of self-driven and externally driven EFs.

Determining what aspects of child less-structured time—child-led goal-seeking experiences, social play, or opportunities to mind-wander—drive posited benefits to self-directed EF may prove exceedingly difficult, given that these competing explanations are difficult to tease apart even when highly detailed information about children's activities is available. First, planning, play, and mind-wandering activities are not mutually exclusive, and may be engaged simultaneously. For example, children often engage in planning during pretend play activities; such planning is considered an integral component of complex, mature play, so much so that developing play planning is sometimes the focus of preschool intervention efforts (e.g., Tools of the Mind; Bodrova & Leong, 2007). To develop a typical imaginary scenario, children must decide what scene or environment they would like to create, decide on what roles they will play within that scenario, and determine what rules they should follow to maintain the desired pretense. Likewise, planning can be a component of mind-wandering, which may facilitate planning directly, through consideration of future events, or indirectly, by allowing children to consider connections between past events that can be useful for future planning activities.

Further complicating attempts to identify how less-structured time might benefit self-directed EF, each of the activities predictive of good self-directed EF in child time use analyses, including social and enrichment activities, and play with others, could support opportunities for planning, mind-wandering, and play, while each of those activities predicting worse self-directed EF could hinder the same such opportunities. For example, during museum and zoo visits, children often have opportunities to plan which exhibits they would like to see, and how they would like to progress through them. Because such visits typically involve a mix of adult interaction and independent child exploration, children are also likely to have time to mind-wander. Additionally, during many such visits children have opportunities to engage with other children in social play (e.g., within child-focused museum exhibits, or zoo play areas). By contrast, adult-led lessons and practices, religious activities, homework, and chores afford few such opportunities. Adults often plan lessons and practices with little child input, and children are typically expected to attend to adult instructions and reminders throughout the activity, precluding opportunities for mind-wandering. For many lessons, social play is impossible (in the case of one-on-one lessons) or structured and organized by adults (e.g., in many sports practices). Although the real-world co-occurrence of activities potentially benefitting self-directed EF presents challenges, time spent in each activity could be partially distinguished via direct observation or experience sampling, which would provide finer-grained estimates of children's time use than retrospective parent report measures. Causal relationships could also be investigated via discrete interventions selectively targeting each proposed mechanism. Ultimately, even if the independent contributions of planning, social play, and mind-wandering opportunities cannot be distinguished, establishing causal links between time use and developing self-directed EF would be informative for theory and intervention.

A final, intriguing question concerns whether historical changes in child time use and opportunities for self-directed behaviors might have contributed to shifting developmental trajectories for self-directed EF across time. Despite increases in readily accessible information about how to achieve goals across time, children may have fewer opportunities to practice self-direction today than in previous eras. In addition to changes in technological access, growing societal emphasis on early skill acquisition and heightened parental vigilance have contributed to reductions in the time children spend in unsupervised activities, including independent travel and play (Clements, 2004; Hancock, Lawrence, & Zubrick, 2014). Activities such as outdoor play have increasingly been supplanted by media activities, such as video game play, computing, and television watching (Bavelier, Green, & Dye, 2010; Hofferth, 2010; Johnson, 2010; Vandewater, Rideout, Wartella, Huang, & Shim, 2007), which are often more passive, and potentially offer fewer opportunities for child decision-making, than other forms of leisure. Children also spend more time in structured, adult-led activities (Bianchi, Robinson, & Milkie, 2006; Hofferth & Sandberg, 2001; Larson, 2001). In the absence of detailed longitudinal studies of child time use and developing EF, such questions might best be investigated through well-controlled cross-sectional comparisons of developing self-directed EF in modern and developing societies. Better understanding of the sensitivity of self-directed EF to specific childhood experiences may ultimately inform, extend, and improve extant EF-focused interventions, benefitting individuals' decision-making and goal outcomes across the lifespan.

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NOTES

1 Working memory is sometimes characterized as a unitary, central processing resource underlying efficient coordination of multiple cognitive systems (e.g., Salthouse, 1990). However, in neuropsychological investigations of control processes, working memory is often characterized as one of several EFs contributing to cognitive control (e.g., Blair, Zelazo, & Greenberg, 2005; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Munakata et al., 2011; Pennington & Ozonoff, 1996).

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