儿童游戏如何影响执行功能相关行为
How Child's Play Impacts Executive Function–Related Behaviors

Sandra Shaheen
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摘要

执行功能是指通常与前额叶皮层(prefrontal cortex) 成熟相关的一系列组织和自我调节行为。事实上，具有前额皮质的基本神经发育的幼儿从很小的时候就发展出抑制冲动和调节行为的方法。执行功能是否会受到干预，实践或训练的影响？哪些干预措施会影响童年时期执行功能的发展，以及如何研究这些干预措施？本文总结了几个提出了积极影响执行/自我调节技能研究的计划。基于证据的研究计划与一些没有经验基础，但被教育者和家庭广泛接受的热门计划形成对比。由于自我调节对今后的学校和生活成功具有重要意义，干预措施可能会减轻注意力缺陷多动障碍、脑损伤和社会压力因素的负面影响。由于早期运动学习的重要性以及学习的社会动机方面，具有主动游戏组件的程序可能会更成功地引出改进的执行功能（在此定义为自我调节）。对于一些缺乏实证经验支持其结论的研究计划，建议谨慎推荐。精心策划的结果研究可以帮助将最有效的课程组成部分带入主流。

关键词: *executive function* , *interventions* , *play* , *self-regulation* , TEAMS, Tools of the Mind

研究人员最近强调了早熟皮质下网络与在调节发展中起着早期作用的新皮带区域(neocortical regions)的 "自下而上"关系的重要性（Castellanos，2001; Koziol＆Budding，2009）。 Shaheen（2013）认为运动行为与认知行为并不是分开的。 "了解"来自运动学习以及输入和输出的精细调整协调。认知行为与运动脚本和序列密不可分，而后两者依赖于大脑皮质下系统的"微调". Shaheen引用Denckla（1974）、Rutter，Tizard，Yule，Graham，Whitmore（1976）以及其他为运动日常行为（例如轮换，轻击和切换）的发展提供数据的研究工作，这些工作表明神经网络的渐进成熟是我们所认为的高级规划和组织或执行技能的基础。这些运动场的非典型发现对临床人群中的非运动行为敏感，包括自闭症，双相情感障碍和注意力缺陷多动障碍（ADHD; MacNeil＆Mostofsky，2012; Mahone等，2006）。 Halperin，Trampush，

Miller，Marks和Newcorn（2008）表明ADHD中的执行技能障碍可能反映出持久的皮质下缺陷会影响对觉醒的反应。 Halperin和Shultz（2006）假设前额系统的发展强加了对这些皮质下驱动系统的精神控制。 Halperin最近的工作（Halperin＆Healey，2011; Halperin等，2012）雄心勃勃地试图研究有助于调节反应的干预措施的影响。通过儿童游戏来实践运动脚本，并且可以利用这些脚本来建立有效改善幼儿和临床人群自我调节的干预措施。

Atypical findings in these motor arenas have sensitivity to nonmotor behaviors in clinical populations including those with autism, bipolar disorder, and attention-deficit hyperactivity disorder (ADHD; MacNeil & Mostofsky, 2012; Mahone et al., 2006). Halperin, Trampush, Miller, Marks, and Newcorn (2008) suggest that executive skill disorders in ADHD may reflect enduring subcortical deficit impacting response to arousal. Halperin and Shultz (2006) postulate that development of prefrontal systems imposes enhanced mental control on these subcortically driven systems. Halperin's recent work (Halperin & Healey, 2011; Halperin et al., 2012) ambitiously attempts to study the impact of interventions that aid in modulating response. Motor scripts are practiced through children's play, and these can be harnessed to build interventions that are effective in improving self-regulation in young children and clinical populations.

MOTOR PLAY AND INTERVENTIONS FOR EXECUTIVE CONTROL

Recently, several groups have proposed curricula and interventions that employ games with rules to shape and reinforce self-regulating systems. Diamond and Lee (2011) reviewed efficacy of interventions developed to aid in improving executive functions in young children. Programs to be reviewed here include those where play activities are explicit in the intervention. Some of these posit the role of emotion and motivation to engage mind and brain (“Floor time” DIR/FT [Developmental Individual Difference, Relationship Based Model/ Floor time]) or have evolved from the sensory and kinesthetic systems theories of Ayres (2005; (e.g., The Alert Program, Brain Gym), from rehabilitation science (Pay Attention!), and programs that have their basis in Vygotsky's (1978) theory of social reference for developing adaptive behavior (e.g., *Tools of the Mind, TEAMS, ENGAGE*). Systematic programs that engage parents in supporting appropriate behaviors target oppositional and adaptive behavior, rather than executive behaviors; the aforementioned approaches engage children motorically, with rule-based games and through use

of abstraction/pretend.

"EDUCATIONAL KINESTHESIOLOGY": WHERE IS THE EVIDENCE?

Educational kinesthesiology is a term that refers to learning through movement (Dennison & Dennison, 1985) and has basis in the work of Jean Ayres (1985; Ayres, Gingergrass, & Schools, 1979) whose theory of sensory integration was based on her understanding of neurobiology. Ayres asserted that learning takes place as a function of reward or reinforcement, that it must be purposeful and involve active engagement (Ayres, 2005, p. 38). She believed that a person must perceive the goal and process of the intervention to benefit from it, highlighting perhaps what is now termed "metacognitive" self-awareness. Drawing on motor control theories, Ayres (2005) proposed that motor learning follows inherent maturational sequences and may be dependent on incoming sensation. Ayres asserted that "the brain locates, sorts, and orders sensations, somewhat as a traffic policeman directs moving cars. When sensations flow in a well-organized or integrated manner, the brain can use sensations to form perceptions, behaviors, and learning. When the flow of sensations is disorganized, it will be like a rush-hour traffic jam" (Ayres et al., 1979, p. 5). Williams and Shellenberger (1994) authored The Alert Program based on this theoretical perspective. Their system incorporates music, metacognitive strategies, and games to guide the organization, rehabilitation, or restructuring of "sensations to perceptions." They define self-regulation as "the ability to attain, change, or maintain an appropriate level of alertness for a task or situation" (Williams & Shellenberger, 1994, p. 8), and they suggest that the ability to change how alert we feel is at the foundation of therapeutic or educational goal setting.

While this work developed at a time and in a context when terms such as "executive function" did not appear in the child development literature, the concepts of self-awareness and self-regulation may be interpreted here as closely tied with "executive function." In their book *How Does Your Engine Run*? Williams and Shellenberger (1994) introduce the analogy of the car engine, which runs on high, medium, or low speed. Children learn to self-evaluate on the basis of that analogy and learn to identify and modulate energy in this way. A number of gradations of energy can be identified, and strategies for modifying these stages are presented through worksheets, games, charts, and pictures. Teachers, parents, and therapists are trained to

teach self-regulation awareness as a preset for learning. Categories for cuing self-awareness are termed *mouth* (e.g., take a breath), *move* (e.g., stretch), *touch* (e.g., squeeze a stress ball), *look* (at a sunset), and *listen* (e.g., to preselected music). In each case, there is a cue for a (sensory) behavioral rubric. In the therapy session, the engine analogy is used to support self-awareness as a tool for self-regulation.

Unfortunately, only a few studies have used The Alert Program (http://www.alertprogram.com) to examine responsiveness of small clinically identified groups to intervention. Wells, Chasnoff, Schmidt, Telford, and Schwartz (2012) expanded the program to examine high-risk 6- to 11-year-old children who presented with "executive functioning deficits," with the goal of enhancing self-regulation. Their sample was drawn from children with fetal alcohol syndrome in foster care or who had been adopted. A total of 78 children were randomly assigned to intervention or control conditions in which comprehensive evaluation and referral to community services were made. Children in the treatment condition participated in 12 weekly 75-min neurocognitive rehabilitation group-therapy sessions, based on the Alert methods, while their parents participated in a parenting education group. Results revealed a significant treatment effect on a parent report measure of executive functioning, but no treatment effects have generalized to other settings (e.g., school) or have been maintained over time. In this series, companion sessions in self-esteem building and other skills complemented the Alert procedures.

For younger children, a commercially available program called Brain Gym (http://www.braingym.com) is widely used and provides a series of simple body movements purported to "integrate all areas of the brain to enhance learning." Twenty-six activities are detailed in training manuals and address midline coordination (e.g., a cross-crawl activity), "lengthening," and focusing energy. Proponents claim these activities foster eye teaming, spatial and listening skills, hand–eye coordination, and other skills considered presets for learning. Dozens of books and articles are published on the braingym.com Web site, and describe case improvements in behaviors associated with autism, learning and non-brain-specific medical conditions, and aging and sports performance. The package is used in British and Australian schools, sometimes with little adherence to the program's principles upon which it claims basis (Hyatt, 2007) and with no empirical data for the theory or outcome claims (Goswami, 2006; Hyatt, 2007; Spaulding, Mostert, & Beam, 2010; Stephenson, 2009).

WHY ARE THESE PROGRAMS IN DEMAND?

Goswami (2006) reviewed neuroscientific evidence with implications for learning and asserted that educators are eager for information about how brain function contributes to education. However, she contrasted the work of neuroscience with some commercially available programs that provide misinformation through what she terms the brain-based learning "industry."

The American Academy of Pediatrics provides a policy statement on the use of sensory integration therapies (Zimmer & Desch, 2012) and cautions that interventions using sensory-based therapies "may be acceptable as one component of a comprehensive treatment plan, but that parents should be informed that research regarding the effectiveness of sensory integration therapy is limited and inconclusive" (p. 1186). May-Benson and Koomar (2010) reviewed evidence on the efficacy of movement and sensory interventions from 27 published reports and suggested that small sample size, variable schedules of intervention, lack of fidelity to planned intervention, and poor specificity of outcome goals contribute to problems adapting these programs more generally. While some children or some behaviors may improve with repeated practice on a set of developmentally appropriate tasks, the contribution of motivational, social or dyadic, and general maturation variables cannot be separated from results without specific and well-designed studies. Even if response to specific diagnoses such as ADHD is addressed or specific symptoms such as poor executive function are targeted, taxonomy, etiology, and theoretical perspective need to be more clear.

METHODS ADAPTED FROM REHABILITATION SCIENCE

Pay attention! is a program used for attention training in children and was adapted from Sohlberg and Mateer (2001), who posit that attention, memory, and executive functions are subserved by overlapping brain systems. Based on the principles of rehabilitation of attention in postacute injury, the attention program was adapted for use with children by Thomson et al. (2001). Kerns, Eso, and Thomson (1999) provided training to 14 children aged 7 to 11 years old twice per week for 8 weeks. Performance on nontrained attention tasks after the program indicated better performance from participants in training when compared to controls who participated in non-attention-training computer games. However, teachers reported no difference in the groups posttreatment, and parents reported improvements regardless of group. Similar results were

reported by Tamm et al. (2010; Tamm, Epstein, Peugh, Nakonezny, & Hughes, 2012), who studied children (ages 8–14 years old) with ADHD with this system and found little objective evidence of transfer of skills or longer-term effects. The efficacy of this program for children with brain injury, for whom the methodology was originally intended has been studied with survivors of pediatric cancer (Butler & Copeland, 2002). The methodology, which differentiates tasks of *focused, sustained, selective, alternating, and divided attention* has potential for use in other cases of acquired brain injury (e.g., concussion) and merits further study for specific neurodevelopmental disorders. However, social/motivational and motor-learning components are not incorporated in this methodology. Inclusion of these factors may result in stronger and more generalizable results.

ADDRESSING REGULATORY DISORDERS IN AUTISM AND DEVELOPMENTAL DELAY

"Floor time" DIR/FT was developed by Greenspan and Wieder (1997, 1998), who conceptualized disorders of development to include regulatory and social/communication difficulties. Although the authors did not speak specifically of "executive control" processes, the methodology speaks to many principles now incorporated into interventions for executive functioning. For example, DIR/FT goals include *helping the child become more alert, take more initiative, become more flexible, tolerate frustration, sequence longer actions and plan and execute them, and mediate the process of finding solutions*.

Regulatory disorders are identified in infants and young children with significant constitutional and maturational deficits as these pertain to sensory over-reactivity or under-reactivity, muscle tone, and motor-planning difficulties. Greenspan and Wieder (1998) related these to irritability, distractibility, and poor frustration tolerance, among other concerns. Greenspan, who conceived the Zero to Three early intervention project and was a pioneer in relating principles of neuroplasticity to education and early intervention, was a physician and psychoanalyst. He valued the caregiver's style and family dynamics as contributors to regulation in the young child. He and his colleagues developed a series of interventions for regulatory difficulties that involves structured play and is termed DIR/FT. In this acronym, "D" refers to the *developmental* theories of Vygotsky, Piaget, and others who influenced this work. "I" refers to the *individual differences* in sensory processing of Ayres et al. (1979),

whose work was receiving widespread attention at this time. "R" refers to *relationship-based*, which appears critical to supporting motivation and goal directedness of an intervention. A training program that aided in behavioral and emotional adaptation (regulation) evolved from motor to more abstract interactions. DIR/FT (http://www.icdl.com/DIR) is widely used worldwide to engage children who are handicapped by autism and related disorders. However, efficacy studies for DIR/FT are few (Pajareya & Nopmaneejumruslers, 2011), and the individualized, child-centered nature of the timing and content of interventions makes comparisons across groups quite difficult. Proponents point to the lack of uniform effectiveness of Applied Behavioral Analysis (ABA) treatments alone in the treatment of autism (e.g., Spreckley & Boyd, 2009) and emphasize the relational and individualized nature of the program.

PROJECTS DERIVED FROM RUSSIAN VIEWS OF BIOBEHAVIORAL DEVELOPMENT

Vygotsky's (1978) sociocultural theory is central to the conceptualization of how play interfaces with executive control. Vygotsky proposed that adults and peers facilitate learning of more complex mental tasks. More able partners guide what children cannot yet do on their own, but their participation helps to "scaffold" the learner to gradual mastery. Further, Luria (1973) suggested that behavior is hierarchically derived and socially mediated and involves a process of increasingly goal-directed and internalized behaviors. Bodrova and colleagues (Bodrova & Leong, 2007; Bodrova, Leong, & Akhutina, 2011) have developed a well-studied curriculum called *Tools of the Mind*with reference to sociocultural and hierarchical principles. They use "executive function" and the term "self-regulation" interchangeably and define self-regulation as the capacity to control impulses to stop doing something, if needed (even if one wants to continue doing it), and also to start doing something, if needed (even if one does not want to do it). They assert that self-regulated children can delay gratification and suppress their impulses long enough to think ahead to the possible consequences of their actions, or to consider alternative actions that would be more appropriate. Self-regulation can apply to cognitive behaviors, such as remembering or paying attention, or to social-emotional regulation. Bodrova and Leong (2007) suggested that these two facets of self-regulation are related: Children who cannot control their emotions at age 4 are less able to follow teacher directions at age 6 and will not become reflective learners in middle

and high school.

Tools of the Mind is implemented widely, from Head Start programs to large city school districts, in 18 U.S. states and Canada. The curriculum uses simple props (e.g., holding up a photo of the ear to signal for listening and adapting "Simon Says" or hopscotch activities). The designers of this program suggest that in pretend play, one *inhibits* acting out of character: Thus, social scripts and pretend play are important in developing and reinforcing executive skills as well. In the *Tools of the Mind* curriculum, play planning is an instructional strategy used to promote self-regulation. Children devise their play plan to describe the role and actions intended in pretend play. Facilitation and flexibility ensure that children can modify their plans as they play, and resolve disputed change in activity.

Leong and Bodrova (2012) described simple games and exercises to help develop skills in 4- and 5-year-olds. "Dance and Freeze," "Opposites Games," and Simon Says" are among activities with demands on waiting, switching, listening/attending, and sustained activity, termed elsewhere as executive control behaviors. Diamond and Lee (2011) reported that the *Tools of the Mind* project has been compared to programs focusing on more direct instruction. They reported that children involved in the curriculum with greater emphasis on play than on direct instruction demonstrated so much better self regulation that groups assigned to other conditions withdrew from the design to implement *Tools of the Mind* in all classrooms.

EXECUTIVE FUNCTION INTERVENTIONS FOR SYMPTOMATIC CHILDREN

After two decades of longitudinal research, the work of Halperin and colleagues suggests that structured social play improves outcomes for children diagnosed early with ADHD (Halperin & Healey, 2011; Halperin et al., 2012; O'Neill, Rajendran, & Halperin, 2012; Sonuga-Barke & Halperin, 2010). Halperin and his collaborators suggest that improving executive skills associated with ADHD helps children compensate and adapt. Halperin's approach is called TEAMS, for *Training Executive, Attention, and Motor Skill*. Their work also derives from Vygotsky's (1978) theoretical position on the sociocultural basis for motivation.

In a small "proof-of-concept" study performed without a control group, Halperin and his colleagues (2012) recruited twenty-nine 4- to 5-year-old children with ADHD who were not taking medication.

Parents and children met weekly for 5 or more weeks for 90-min sessions and were taught and then practiced games from this curriculum. The families learned to play variations of several exercises that Halperin (2012) said tend to develop key cognitive skills and motor control. Examples of the curriculum include "Puppet Says," a variation on "Simon Says," in which parents and children take turns with puppets who "give" commands such as, "Jump up and down" or "Puppet says, jump up and down." By attending to the difference in commands, inhibition (when using the preface, "puppet says") is reinforced. Working-memory activities involve simple props (e.g., a coin under paper cups) with successively more complex requirements for remembering where the "treasure" (target item) is moved. Motor control activities may involve balancing a ball on a spoon while walking. The families promised to spend 30 min daily, 6 days per week, on the games at home. In an initial study, children also participated in aerobic activities, such as jumping jacks and twirling a hula-hoop, as relaxation techniques. Three months after the treatment sessions ended, parents and teachers reported significant reductions in inattention, hyperactivity, and impulsivity. Teacher reports suggested fewer impairments in the ADHD-identified children who had participated.

One New Zealand-based collaborator has further adapted the activities to be appropriate for the culture and language of this country and terms her similar program Enhancing Neurobehavioural Gains with Games and Exercise (ENGAGE; Healey & Halperin, 2012; D. Healey, personal communication, June 3, 2012). O'Neill, Healey, and Halperin point to promising initial results with this socially referenced, play-based parent–child intervention for children with ADHD.

IMPLICATIONS FOR PEDIATRIC NEUROPSYCHOLOGY

Self-regulation is being shown to have higher predictive validity for educational success (McClelland, 2012), inferential reasoning (Richland & Burchinal, 2013), and general adaptation and school success in homeless children (Masten et al., 2012), than any other cognitive or academic factor. A number of programs are marketed as improving self-regulation, attention, or other behaviors that contribute to notions of executive function. Some of these are not supported by efficacy data, and their theoretical underpinnings may be nonspecific and inferential. Neuropsychologists and other caregivers are called on increasingly to generate suggestions for treatment planning, which are independent or adjunctive to

pharmacological intervention in disorders of executive function. Games that engage the motor system are observed to have greater potential in modifying executive function (at least in young children) compared with parent training or behavioral approaches alone. Games (with inherent social cues and motivational components such as competition) are more effective than aerobic exercise alone (Diamond & Lee, 2011). Two approaches based on Vygotsky's (1978) theoretical writings are exemplified by the work of Halperin and colleagues (Halperin & Healey, 2011; Halperin et al., 2012) and by Bodrova and Leong (2007) and Bodrova, Germeroth, & Leong (2013). These are theoretically based, empirically driven programs with promise for adapting "games with rules" and pretend play to enhance aspects of self-regulation. Although these may not be the only programs that merit replication, all programs that purport to address executive function should be put to empirical test. Programs that incorporate motor play and acknowledge the important role of social referencing for promoting self-regulation appear to be those with the potential for long-term and more generalized effects. Clinicians and educators should be aware of the programs available for promoting self-regulation and should have improved understanding of how effective programs can be and should be assessed.