Chapter 2

Executive Functions and Neurology in Children and Adolescents

Gokcen Akyurek

Additional information is available at the end of the chapter

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Abstract

This chapter discusses the theoretical and methodological issues of creating a developmental perspective on executive function (EF) in childhood and adolescence. Focusing on school periods, this section outlines the development of the basic components of EF—inhibition, working memory, and attention. Cognitive and neurophysiological evaluations show that despite the emergence of EF in the first few years of life, it continues to grow significantly in childhood and adolescence. The components vary slightly according to their developmental sequence. The chapter links findings to long-standing developmental issues (i.e. developmental sequences and processes) and suggests the necessary research to establish a developmental framework covering early childhood throughout adolescence.

Keywords: executive function, executive control, prefrontal cortex, children, adolescent behavior

1. Introduction

Coordination of the executive functions (EFs) with the frontal lobe is seen in all mammalian species. Executive functions are not specific to people and their need of advanced information computing, but it is an integral part of the mammalian brain development that emerges over time to facilitate a more complex problem-solving and goal-oriented behavior [1]. The basic function of the developing nervous system is revealing the efforts that are necessary for effective learning and successful adaptation. Vertical and horizontal development processes of brain development and the accompanying age and experience make control and communication more automatic and effective [2, 3]. This is a demonstration of the skills and adaptation that we have developed over time while allowing us to understand what managing means in childhood and adolescence. We acquire mastery of having and using cognitive controls with maturation. However, although the system is more effective at the beginning of maturation in parallel with increasing needs, it may provide less support afterward [4].

1.1. Basics of executive functions

The cognitive capacity of an individual increases with the executive functions being involved in many different aspects of information processing and behavior over time. The emergence of basic skills such as orientation and attention is followed by strategy determination, implementation, and then problem-solving. Executive functions change from a developmental perspective to multiple creative cognitive skills. Understanding what executive mean requires you to understand how each ability develops over time [5].

1.1.1. Attention

The attention system is a basic and supporting component of the execution system. It is a tool that guards learning for the developing individual and directs interaction with the environment, especially from birth [6, 7]. Throughout childhood, the child increasingly masters in creating schemas and representations by taking information about the environment. This supports the child's adaptation and learning of the demands and challenges of the community. For this reason, attention, regulation, and maintaining attention interact neurodevelopmentally with memory processes and constitute cognitive structures necessary for executive and behavioral control. As a result, attention during infancy and crawling period emerges as targeted behavior and serves to develop executive function skills over time [7, 8].

The infant begins to see the effects of his growing awareness with the events and experiences surrounding him over his perceived knowledge. This encourages cognitive and behavioral dialog through direct and indirect interactions with objects and people. The motor functions, senses, and cognitive functions interact to create the connection between the baby and the environment, which facilitates the infant's experience with the surroundings. This increases the infant's control over the interaction with the environment. This is initially a passive response to the environment but then it turns into an environment research process. Then, the quest for increased ties and interaction becomes an active process. As people, events, and experiences increase, babies carefully separate events and experiences that they find stimulating or uncomfortable and seek support through behavior or voice responses [9]. In the game period, the child begins to realize that they are influencing their environment and surroundings through mechanisms such as attention, reaching a target, and exploring. This awareness turns into realizing goals and desires and improves early problem-solving skills.

1.1.2. Behavioral and emotional regulation

Self-regulation develops throughout the age of infancy, walking, and primary education period. Guiding parenting initially directs this development capacity, but the baby and then the child develops his own reactions on how he behaves [7, 10]. In "real" experience, the child reacts to events through observation and imitation. By actively recalling these experiences, the child makes behavioral choices. The strategy begins to play a greater role in their behavior so that during late infancy examples of purposeful actions or even "secret" behaviors (i.e. game hiding, early denial of responsibilities) are observed [11]. These efforts are examples of executive functions that arise such as problem-solving, self-monitoring, strategy definition and implementation, and even primitive flexibility. Memory is the basis for the development of many basic executive functions; the information processed and stored in the working memory governs attention, and constant impulse control arises and evolves. As a response to the child's efforts to guide and shape experience, orientation and engagement occur.

1.2. Executive functions in childhood

Middle childhood is one of the basic periods in which executive functions are necessary to support successful learning and the development of academic skills [8]. With executive functions in the first three grades, children can identify what's important and integrate new information with the existing information. However, from the fourth-grade onward, the learners who are expected to manage integrated academic requirements more competently and strategically have considerable demands on working memory, impulse control, self-monitoring, and intent to facilitate independent problem-solving and productivity [12]. For the typically developing middle school child while learning success proceeds in a forward line which indicates a growing capacity for independence, demands are met via variable engagement of EF skills. For example, impulse control develops completely between 10 and 12 years old [13, 14]. Similar speed in organizational skills with the speed of processing, verbal fluency, multidimensional transition, and planning usually occurs during middle childhood [14].

Middle childhood is a time period in which attention and motivation are necessary and a child should be under observation. For successful learning, behavioral regulation must increase [15]. Children who are 6 years old start to make tasks more successfully that require impulse control, and at age 9, most children can self-monitor and correct their behavior moderately [16]. Children who manage the tasks of increased attention and regulation effectively are more resistant to situations such as blocking, dissatisfaction, insistence, and self-control. Emotional regulation should be underlined with increasing daily demands and challenges, especially in terms of disappointment, anxiety, and anger. However, the difficulties associated with attention and behavior control, which are frequently seen with attention deficit and hyperactivity disorder (ADHD) and disruptive behavior disorders (DBD), emphasize that there is a major hurdle in the development of executive functions. As difficulties arise such as inefficiency, carelessness, and poor self-control, executive dysfunction manifests itself [17].

The enhanced self-control capacity in this period is necessary to meet additional demands, especially in social areas. Young people in this age start to establish stronger ties with their peers, and the opportunities in playing and learning reinforce belonging. This social inclusion increases opportunities by providing a wider range of participation and influence across all aspects of executive control. Especially, trying to solve problems together gives children the opportunity to accept and consider the opinions of others in situations where they can develop and change their ideas and goals [18].

Cooperation and reconciliation-related activities help the child struggle on his/her own and master on these skills. A child who is weak about understanding society and solving problems in society also faces difficulties in social participation. A child who is not able to observe the wide range of perspectives, or a wide range of options offered during a group event, is usually incomplete in executive functions, and it is possible to observe that a child with faults on executive functions is affected by more than one area of socialization and academic skills [18, 19].

1.3. Executive functions in adolescents

Adolescence, in other words, upper cognitive access, is an important period in which an individual is able to make a strategic choice to increase learning capacity, evaluate options, and meet that demand. Ongoing development of the executive neural network (frontal lobe) explains the inconsistencies of high-level skills of adolescence [20]. Frontal functions, especially the dorsolateral prefrontal cortex and the orbitofrontal cortex areas, gradually begin to engage. In addition, there is a marked decrease in the gray matter of the cortex and an increase in white matter during this period [21]. While these important changes in brain structure change social awareness and expectations in this period, hormonal and physical changes improve the interaction between the individual and the environment [22]. For this reason, adolescents' capacities of awareness, decision-making, and problem-solving, which are highly affected by cognitive skills and emotional, social, and physical situations, also vary [23]. As a result, it is theorized that the development of executive functions in adolescence may be modulated in an emotional or social context. Luna and Sweeney also described adolescence as a "transition to an effective working relationship with the brain." During the adult period, executive networks become more consolidated and refined. Actions are more in sync with behaviors and interact more with others with better behavioral and emotional control [24].

Increasing independence and its capacity and managing multidimensional learning and behavioral demands develop during this period. This is a reflection of progress in the areas of attention control, flexibility and processing speed, capacity and working memory, planning, and problem-solving in conjunction with the increase in frontal cortex pruning and myelinization that occurs during adolescence [25].

While Anderson believes that cognitive flexibility and target-setting capacity mature up to the age of 12, some researchers later argue that executive functioning, memory, impulse control, and planning continue to evolve considerably in adolescence and early adulthood [26]. This theory was more widely accepted because of the proliferation of synapses at the beginning of adolescence. These developments turn into emotional decision-making and less responsive reactions to the will of the environment, and this is an appropriate response to the theory of self-control and social rules [27].

Disorder in the development of executive control during adolescence is present in psychopathology. The capacity to think before moving, to assess the appropriateness of one's answer, and to determine the most effective action that gives the desired result often varies in adolescence. However, in a typically developing young person, these skills become increasingly more effective over time [27]. Young people with impaired executive functions cannot make effective choices and cannot reach the result. In fact, while adolescents are more conscious at the beginning of pubertal maturation, they then enter into risky and sometimes reckless behavior and become more sensitive to others' views and assessments. This can make their relationships difficult with peers and adults [20].

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2. Executive functions and its neurology

2.1. Executive functions and prefrontal cortex

Executive functions are interdependent and progressively acquired; high-level cognitive skills that occur in conjunction with the expansion and integration of cerebellar, subcortical, and prefrontal nerve networks during early childhood and adolescence until early adulthood. Because the development of nervous systems that support executive functions lasts too long, they are vulnerable to changes that occur during development, which can lead to multiple executive dysfunctions [20].

The prefrontal cortex has an important role in the development of executive functions. The prefrontal cortex is located in the anterior part of the premotor cortex and constitutes approximately one-third of the cortex (**Figure 1**). The neural connections between the prefrontal cortex, motor and sensory cortices, and the brain's subcortical structures are carefully regulated and are responsible for controlling, influencing, and regulating behavioral goals and behaviors. As the individuals mature, large neural networks that are responsible for learning and behavior become increasingly integrated and coordinated with prefrontal cortex-related networks. As a result, the regulation of high skill levels that lead to many behaviors is related to the neurodevelopmental processes of the mature brain. This contributes to the enhancement of coordination of communication and behavioral regulation related to executive functions [21].

At the beginning of life, subcortically managed neural processing is the primary ability to interact and understand sensory input, to interact more extensively with the environment, and to reinforce and remember these experiences over time. These experiences reinforce the link between more integrated sources of knowledge that are better understood by the ongoing myelination of the more integrated and mature brain (**Figure 2**). As the connections between the subcortical structures and the prefrontal cortex increase, attention and memory control increases. In infants and children who begun to walk, growth episodes are associated with increases in attention control and working memory capacity. Subsequent brain growth episodes occur at 6–8, 10–12, and 14–16 years of age. Coordination between the prefrontal cortex and regulatory and executive networks improves the communication further [22].

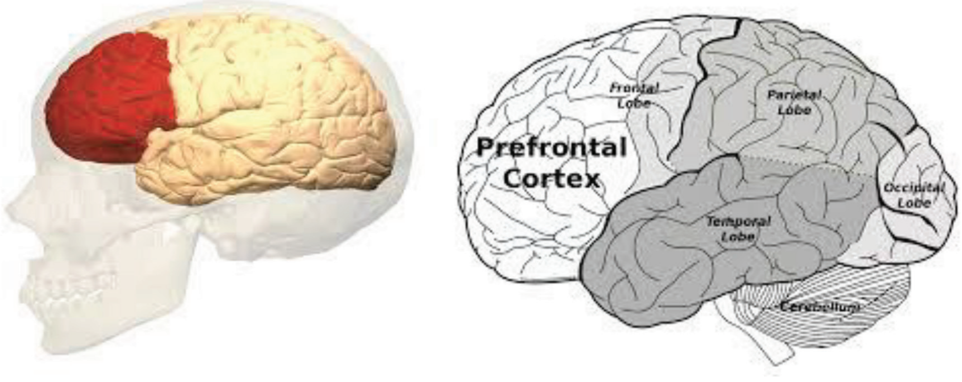

Figure 1. Prefrontal cortex.

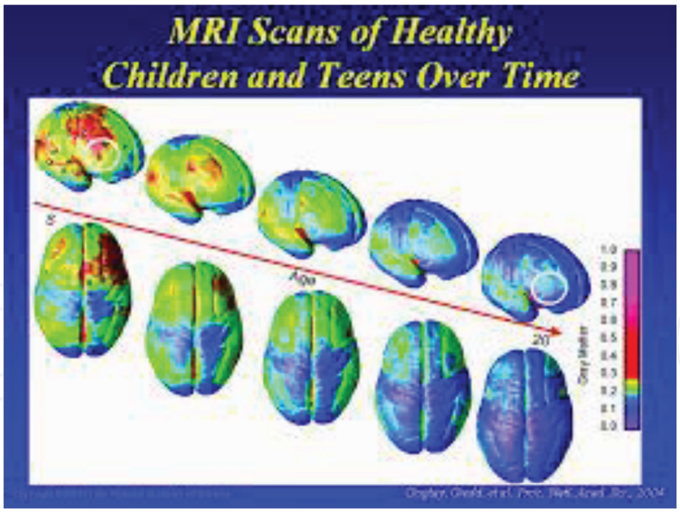

Figure 2. Development of the dorsolateral prefrontal cortex.

In the first years of life, the prefrontal cortex grows with its expanding nets which leads to the development of facilitation and memory increase. As the child progresses toward middle childhood, connections related to prefrontal cortex and communication develop. The development of the prefrontal cortex accelerates the development of information processing and cognitive flexibility between the ages of 7 and 9 years. These developments in the frontal system and related networks encourage the analysis and integration of complex information and the communication needed for effective decision-making. The prefrontal cortex is especially involved in impulse control and the following strategy development and self-monitoring [23].

Given the central role of the prefrontal cortex in the successful development of executive functions, lesions of this critical region have been associated with memory weakness, impulsivity, attention problems, and disorganization. It is known that the damage of the left dominant prefrontal cortex causes particularly the impairment of the divided attention. Contrary to the lateral prefrontal cortex, regions associated with the ventral and medial prefrontal cortex show strong neural connections toward the limbic system and amygdala and are therefore responsible for the integration of mainly emotional and nonemotional information. Given the nature of this relationship, damage to the medial prefrontal cortex means impaired activity initiation, and individuals with lesions in this region are typically irrelevant, flat, and unmotivated [24–26].

It is difficult to determine the contribution of a particular cortical area over the executive functions. Although studies to this date have indicated that the main area control is related to the prefrontal cortex and the component structures, it is seen that the indefinite variability persists. Although some investigations suggest that some aspects of executive functions may be related to certain subregions of the prefrontal cortex, much of this work has been completed with adult and nonhuman specimens [28]. For this reason, the age in which brainstem connections of executive functions are established and whether these distinctions are appropriate for children or not are yet unknown. Preliminary studies, however, show that children have larger and less specific work in brain regions during executive functions. For

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example, when children and adults were assessed for "Go/No-Go" tasks, while both groups showed functional magnetic resonance imaging (fMRI) activation in the anterior cingulate cortex, orbitofrontal cortex, and lower and middle frontal glands (**Figure 3**), children showed more activation on the anterior cingulate cortex and prefrontal cortex than adults [29]. These findings suggest that children work in wider areas of the prefrontal cortex during inhibitor tasks compared to adults. In a similar study, the increase in cortical activation on the left inferior frontal gyrus and orbitofrontal cortex due to the age is further emphasized; also it was shown that the activation of the left upper and middle frontal gyrus and anterior cingulate cortex decreased with age.

Another study that tackles the relationship between conflict resolution and cortical activation in children and adults, using event-related potentials, supports that executive functions become more productive as the brain signals become more mature [30].

Functions of the prefrontal cortex: *Inhibitory control* is described as the basis of the executive functions. Anterior prefrontal cortex is defined as the responsible area for impulse control in walking children and adolescence [31]. Impulse control processes are lateralized in the right hemisphere and are connected to the parietal lobes via ventral prefrontal cortex. At the same time, orbitofrontal cortex, anterior cingulate cortex, parietal and temporal cortex, and gyrus rectus are responsible for the impulse control [32]. A group of children with normal development, the ages between 4 years, 4 months, and 6 years, 8 months is the highest age for the cortex activation level with the working memory task [33]. This suggests that important morphological and structural changes affecting impulse control occur in the prefrontal cortex and the connected brain regions during childhood and adolescence.

Working memory depends on the prefrontal cortex activation, and tasks related to working memory development are age-related (especially during childhood) [32]. In the prefrontal cortex, in particular, the left middle frontal gyrus and the lower frontal gyrus are associated with working memory. The mid-frontal gyrus also plays a role in the control of automatic behaviors and competing answers and in responding to conflicting emotional intelligence. The right middle frontal gyrus is associated with judgmental response and the organization of the activity used to reach a goal [34].

The shifting, interaction with the prefrontal cortex, and its activation is a common finding with the adult period. The prefrontal cortex produces a strategy against the surrounding

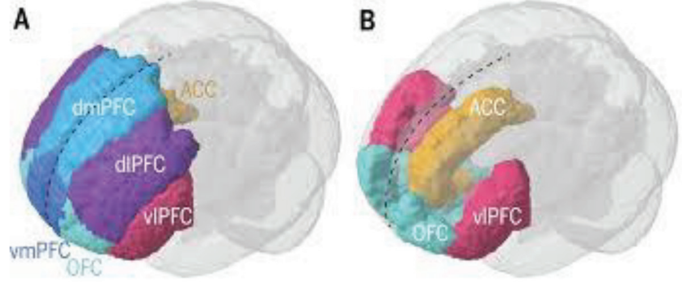

Figure 3. Dorsolateral prefrontal cortex, orbitofrontal cortex and anterior cingulate cortex.

information. This situation changes with regional activation differences, intelligence, and age. An event-related fMRI study investigated the performance of young adults and adults in the task of shifting attention using intelligence quotient (IQ) as a covariant and found that the average IQ individuals showed a higher activation of both prefrontal cortex and anterior cingulate cortex during the activation of response [35]. During the feedback, participants in the high IQ group showed a more complex relationship, including parietal, caudate, fusiform, and occipital regions. The authors reported that the feedback of high IQ people may be more strategic and they may experience less response overlap in the choice of responses for the task.

The prefrontal cortex is also associated with multitasking ability. The prefrontal cortex plays a role in the ability to hold knowledge as well. This feature is unique, prefrontal cortex neurons do not interrupt firing against a new stimulus [36]. This response pattern is useful in terms of showing maturity when individuals are forced to interfere independently with an increasingly complex and changing environment. Blakemore and Choudhury suggest that adult's multitasking skills are better than children or adolescents. Adolescents (aged 11–14) and children (aged 6–10) completed a number of tasks related to prospective memory with an adult group (mean age 25); results showed that adults use more effective strategies than adolescents or children. Thus, the prefrontal cortex also allows us to recall our daily life and the necessary information to achieve its mission despite disturbing stimuli [37].

2.2. Executive functions and limbic system

Regarding executive functions, the limbic system and prefrontal cortex, especially the anterior cingulate cortex are related to emotional regulation and processing, impulse control, and directing attention (**Figure 4**). An error monitoring task study on early adolescence, late adolescence, and adult performance revealed that the error rates were 11% in young adolescents, 7% in late adolescence, and in adulthood, it was even lower [38]. Potential related to the events during the mission localized on the anterior cingulate cortex or on its surroundings, which suggests that the difference in age-related task performance may be due to the maturation of the anterior cingulate cortex. Adults with good performance in an impulse control task were found to have larger anterior cingulate cortexes on magnetic resonance imaging (MRI) [39].

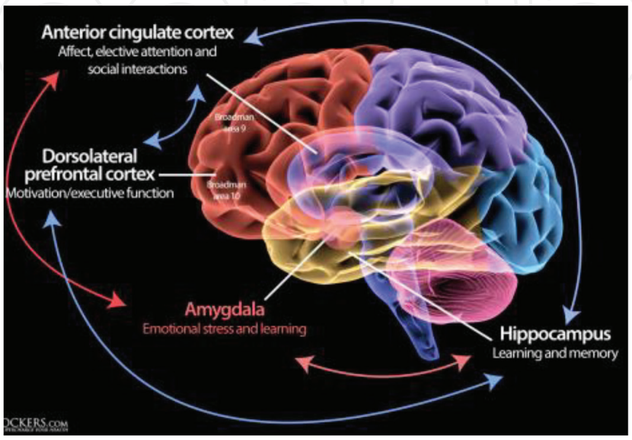

Figure 4. ACC with limbic system.

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In addition, the relationship between anterior cingulate cortex and attention maintenance control is supported. According to Rueda and colleagues, the anterior cingulate cortex is a kind of “control rod” that allows the attention system to be arbitrary [40]. A group to define the relationship between anterior cingulate cortex and lateral prefrontal cortex during direct attention tasks showed that the anterior cingulate cortex takes place during tasks requiring continuous attention control and performance monitoring [41]. Another study examined the reciprocal relationship between emotional control and effort; hence, the anterior cingulate cortex has a proximity to emotional processing regions. Accordingly, the anterior cingulate cortex is associated with the cognitive evaluation of distressing photographs, thereby reducing the negative effect [42].

2.3. Parietal and temporal cortexes

Temporal and parietal cortexes are also important components of the executive net at the same time. Both temporal cortex and parietal cortex are associated with inhibitory control, set shifting, initiation, goal-directed behavior, and working memory (**Figure 5**). The upper parietal cortex plays a primary role in task change, regardless of whether the task involves verbal, visual, or spatial knowledge or not. Other areas of the parietal cortex are primarily responsible for initiating and completing targeted activities. It appears that the parietal cortex regions are also involved in updating the working memory. Especially, the upper left parietal region is linked to the current tasks of ongoing activity [43].

2.4. Executive functions and cerebellum

The cerebellum is a major but often a less well-understood component of the executive functions system. Cerebellum reaches its size at about 11 years for girls and 15 years for boys and is as important as regions that control executive function in early childhood [44]. Cerebellum gains maturity during motor control, emotional processing, and adolescence period and plays a central role in high cognitive functions. The cortico-ponto-cerebellar network works intensively in the timing and ordering of requests such as verbal working memory and executive aspects of visual and verbal analysis (**Figure 6**) [45]. In addition, it is also known

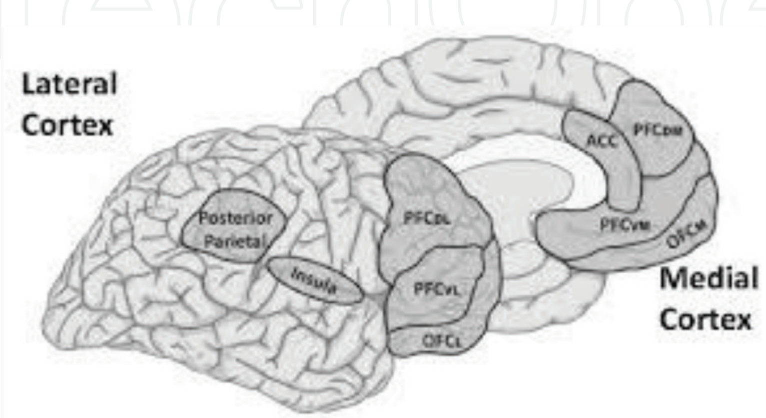

Figure 5. Prefrontal cortex and parietal cortex.

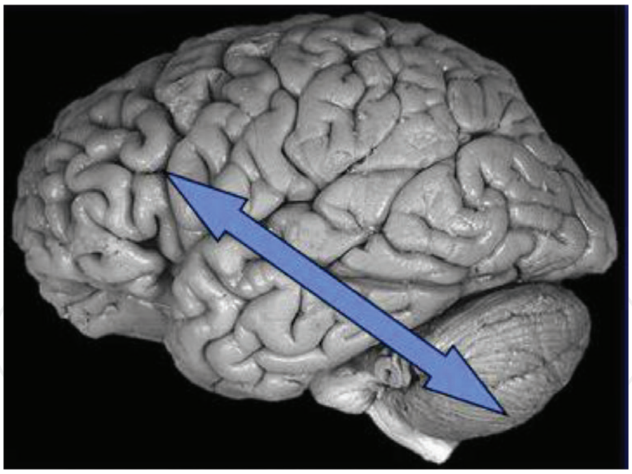

Figure 6. Prefrontal cortex and cerebellum.

that cerebellum has a modulating effect on emotional, cognitive, and regulatory capacities. However, cerebellar lesions do not appear to explain the impairment executive functions alone. It is thought that when executive dysfunctions are accompanied by cerebellar dysfunction, executive functions are impacted [46].

3. Dyslexia and executive functions

Evidence supports that executive functions are accompanied by learning difficulties (commonly known as learning disorder [LD]). In general, the first indicator of learning difficulty is the low rate of academic achievement in reading, mathematics, or writing [47–50].

Students with learning disabilities who have difficulty in planning, initiating activity, organizing thoughts and materials, self-monitoring and progression, impulse control, or attention shifting cannot learn as effectively as those who master these executive function skills [49]. While executive dysfunctions and learning disabilities often coexist, the relationship between executive dysfunctions and learning disability is still not fully established. A fundamental question is whether the specific characteristics of a particular academic field challenge are executive function difficulties or not. Even if there are no academic weaknesses, it is a bigger question to consider the difficulties of executive functioning as a learning disadvantage.

Phonological difficulties are seen as the greatest cause of reading difficulty, but the difficulty of executive functioning presents an additional difficulty in reading. A recent study has shown that children with dyslexia produce fewer words and complete fewer categorical tasks than typical readers in the semantic fluency task. In addition, in learning disorders, the meta-analyses of executive functions show that children with learning disabilities typically cannot achieve their peers' performance in executive function tests [51]. For example, a meta-analysis involving 48 studies, typically comparing the difficulties of executive functions on developing children with learning disability, attributed moderate (0.56) effect dimension on executive functions [52]. Wechsler intelligence scale for children- fourth edition (WISC-IV) Coding has

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distinguished and identified the participants with learning disability the most accurately from their typically developing peers. Similarly, the meta-analysis of 13 researchers comparing children with learning disorder and children with typical development has shown that the overall impact dimension which was measured by planning, organizing, strategy development, attention to detail, and recall tests for executive functions is moderate. Although verbal and visual working memory seems to be effective, verbal working memory has been shown to be more effective than visual working memory [53–56]. It is seen that the difference between the subjects with reading difficulty and typical readers increases with age. Overall, findings suggest a strong association between learning disability and executive functions [49, 57, 58].

Some studies have investigated the difficulties of executive functioning in subtypes of reading disorders. In particular, researchers compared the difficulty of reading a word with the difficulty of understanding reading. For example, in one study, adolescents were categorized as difficulty in reading a word, difficulty in isolated understanding, or typical reading achievement. Working memory and planning (when controlling attention, coding, fluency, and vocabulary) make a meaningful contribution to understanding what is being read but not word recognition. Findings of difficulty in planning have continued in adolescents who had difficulty understanding the reading even after controlling the accompanying ADHD and phonological processing ability. Although reading disorders are often accompanied by ADHD, these studies show that executive functioning difficulties may also occur in individuals without ADHD but reading-comprehension difficulties, and that the difficulties of strategic planning are closely related to the difficulties of understanding [58–60].

4. Evaluation of executive functions

During the individual assessment, a child's approach to a mission can reveal the strengths and weaknesses of executive functions. While some tests are designed to evaluate executive functions, each component of the evaluation process may provide different information about executive functions and disorders.

4.1. Key issues in evaluating executive functions

1. Almost every test contains executive functions. The executive function is related to many things, and it is impossible to draw conclusions from an evaluation alone. For example, even completing the most standard scales requires some planning, strategy, or impulse control. The opposite is also true; most of the tests described as primary "executive functioning evaluation tool" include other cognitive processes. This is called "task impurity" [61]. As a result, other tests (including intellectual work and academic achievement) and behavioral observations also provide information about executive functions. It is important to be aware of these elements and their role in evaluation and definition.

2. Standardization can remove features of executive functions. The structure of an ironically standardized test may reduce the requirements of some of the aspects of executive functions [62, 63]. Most of the standardized tests contain clear instructions and scoring. This

reduces the chances of the person who applies the test to observe executive dysfunctions that are more likely to appear in uncertain situations. Some uncommonly used tests due to difficulties in standardization include open-ended scenarios. A person can gather enough cognitive resources to perform executive functions tasks for a short period of time [64].

3. It is difficult to isolate the skills of a single executive function. Each aspect of the executive functions is intertwined, which makes it difficult to assess a single executive skill. For example, self-monitoring is part of impulse control or vice versa. These skills are different from each other, but it is difficult to distinguish them because they usually occur at the same time and affect each other. A low score on a test aiming to measure the performance of an executive function may reflect the difficulty in a different execution process.

4. The executive functions may vary depending on the environment. Unfortunately, when evaluating executive functions, a child can perform differently in different environments. This can be clearly seen even when comparing home and school, different classes or everyday challenges. In such cases, it is important to examine the people, circumstances, and all sources of information that would lead to confusion regarding the child's functions.

   For a child with executive dysfunction, some environments may have their own advantages (such as getting immediate, specific, explicit feedback from the teacher and learning in a highly structured classroom). The support and coherence of some people according to the nature of the child can intuitively increase this advantage. During interactive games, the success of the activity can be improved by providing clear, consistent, and clear results or awards for the child's actions. In such cases, it is important to include environmental factors in the developed treatment plan for the person and the activity success. It is important to gather information not only about the most challenging environment of the child's executive function but also in the environments that the child is successful at the same time. These exceptions may provide the data needed to describe the executive functioning difficulties and possible remediation strategies. It is important to assess the performance of the child in different environments (home/school and daily/laboratory).

5. Some factors can worsen (or heal) executive functions. These include self-care factors such as fatigue [65, 66], hunger [65], pain [67], stress [68], mood (positive or negative) [69], or lack of exercise [70]. Excessive stimulation with multiple sensory inputs (e.g. auditory, visual, and tactile) and multiple cognitive demands are also significant exacerbations [71, 72]. The sudden change of the surrounding and people around, a new teacher, new classroom, or new school may cause the difficulties in temporary executive functions occurrence. However, a child who is already struggling with compensation for executive function difficulties typically has less cognitive reserves [73]. The child is more vulnerable to the occurrence of any of these factors, and as soon as the effect of these factors accumulates, they become choked. For this reason, it is important to keep them under control. Teachers or their families can be informed of this by creating a checklist for various skills, such as self-care in children.

6. It is difficult to define appropriate peer comparison. It is important to identify the appropriate peer group when evaluating the executive functions. This allows you to make a

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direct comparison. Given the "typical" expectations and differences, it provides an important contrast point. However, it is not easy to determine the best comparison group, as the appropriate comparison group can be chosen by age, gender, intellectual ability, school grade, or other factors.

7. A statistically significant inconsistency between average executive functions and a high IQ is not necessarily a clinical deficit [74, 75]. Compared to IQ scores, there are a number of factors that can lead to lower executive function scores. A person's low motor performance can cause average executive functions.

8. Disability is an important aspect of executive dysfunction. As in any circumstance, assessing the existence and degree of disability is also a necessary condition for examining executive functions. In cases where the child interferes with daily life, it will be difficult to provide parental, teacher, or student care. It is important to remember that even when there is an inconsistency between skill and executive function scores, there may be also a difficulty in obtaining or expecting developmentally expected benefits.

Executive function causes challenges in a range of areas including academic [76–79], emotional [16], behavioral [16], social [16, 79, 80], and adaptive functions [81]. When we think about many aspects of functioning, such as social interactions, family relationships, family responsibilities, and community involvement, and employment for adolescents and young adults, the success of the individual is greatly influenced by adaptation via limiting the actual independence of executive dysfunction [81].

It is also important to assess the effect of executive dysfunction on the functional and emotional well-being of the person. For example, a teenage girl in class may have difficulty in integrating and expressing emotional and social life-related feelings and thoughts. In addition, the struggle with the school can increase her anxiety by reducing its prosperity and self-confidence. These issues can further aggravate her executive functioning difficulty.

4.2. Rating scales

In its simplest form, the assessment scale is a list of items that are evaluated to identify the presence, frequency, and/or severity of a behavior, emotion, or thought. A number of evaluation scales have been developed over the past decade to help to define executive functions. In general, such assessment scales are thought to be more predictive of executive dysfunctions than laboratory tests [82]. This difference can be attributed to the contextual factors (clinic/home, school, community). This difficulty in assessing highlights the fact that it is important to understand the story of the assessed child.

When evaluating children, it is important to have age-based normative data. Smaller age groups allow the child's symptoms to be assessed more accurately in terms of appropriate development or consistent with a psychopathology. Many studies have shown a change in executive function performance during childhood and adolescence. Most of the statistical analyses for the assessment scales also show significant gender effects, against men in executive function ratings [83, 84].

Behavioral Rating Inventory of Executive Function, which is available for parents and teachers to complete developed to evaluate executive functions—for preschoolers (2–5 years old, BRIEF-P) and for school age children (aged 6–18 years). There is a self-report form for completion by youth 11– 18 years old (BRIEF-SR), as well as a group of forms for adults 18–90 years old (BRIEF-A). BRIEF was developed by a group of pediatric neuropsychologists who are collecting data on real-life executive function in the home and school environment. For this reason, expectations of daily adaptive needs and academic achievement provide reasonable information to parents and teachers. Normative data for BRIEF is somewhat restrictive because it is collected from a limited geographical area, and therefore may not represent the general population. EFBAI scores provide summaries of various aspects of executive functions (e.g. impulse, working memory, self-monitoring, etc.), and a clinician tells where and why a student struggles. It has been found that executive functions of BRIEF have a greater correlation with the descriptions of parents and teachers than the performance on laboratory tests and therefore considered to be a good standard tool for executive functions of the person.

Clearly, although executive functions are a tool for assessment. The Brown Attention Deficit Disorder Scales for Children and Adolescents (Brown ADD Scales) are based on the theory that attention deficit represents a developmental disorder of executive functioning. These assessment scales include organizing, prioritizing/activating, focusing/sustaining/recording attention, and executive functioning.

Conners 3 is another attention deficit and hyperactivity disorder (ADHD)-based assessment scale that includes executive functional aspects of the assessed areas. "Executive Functionality" includes the scale, initiation, time management, planning, prioritization, and organization concepts. Other scales in Conners 3 can also reflect executive functions such as attention/focus and self-control. The information obtained with Conners 3, such as the Brown ADD scale and BRIEF, can help identify the areas that require more focus and evaluation which leads to intervention initiatives [85].

Assessment scales such as the Behavior Assessment System for Children, Second Edition (BACS-2), the Conners Comprehensive Behavior Rating Scales (Conners CBRS), and the Achenbach System of Empirically Based Assessment (ASEBA) do not explicitly refer to executive functions, but they can provide information about executive functions. Comprehensive assessment scales such as these can help gathering relevant information in a broader context of issues beyond executive functions.

5. Conclusions

Unlike previous exams focusing on pre-school EF, this focus on EF focuses on a much larger age range. This view allows the study of the developmental form of EF, the gains in EF development, to be examined in the light of developments in behavioral and neural levels. Based on the developmental problems, the following research bases can be established: (1) to compare developmental progress of each EF component with a sample of a wide range of age and (2) to evaluate the developmental sequence of the EF component. Thus, cognitive neuroscience can provide a developmental theoretical focus on EFs for children with/without dyslexia.

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Conflict of interest

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Author details

Gokcen Akyurek

Address all correspondence to: gkcnakyrk@gmail.com

Department of Occupational Therapy, Faculty of Health Science, Hacettepe University, Ankara, Turkey

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