Executive Functions in Children with Autism: An Overview
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ABSTRACT

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by persistent difficulties in social communication and interaction and restrictive, repetitive, and stereotyped patterns of behavior, activities, and interests. Children with autism also experience sensory processing issues and it is a part of diagnostic criteria for Autism. The executive functions are fundamental cognitive skills for achieving good performance in life, as well as in the school and social environment, allowing people to face new and complex situations and the major components of executive functions are working memory, inhibition, and cognitive flexibility. Executive functions in an early age evaluating a group of ASD preschool children and confirmed the presence of a significant deficit in some aspects of executive functions in subjects with ASD. The research indicated that children with ASD are often reported problem in executive function in order to have poor working memory capacity, difficulties in switching attention between tasks, and inhibition response problems, which can seriously affect their school performance and everyday functioning. An attempt has been made to review on executive functions in children with autism.

Introduction

Executive functions are higher order functions on the top level in the cognitive hierarchy, which implies the presence of basic intellectual functions in respect to which they are superior. Executive functions thus play the role of controller and modulator of cognitive functions. It is believed that the position of executive functions, i.e. the frontal lobe, (Freeman, 2000) is responsible for the overall ability of representation of the outer world and executive functions are responsible for acquisition of all knowledge (Ranganath et al., 2003). The associative areas of the frontal lobe, strongly connected with multiple cortical and subcortical structures, subsume the highest executive functions (Stuss & Alexander, 2007). These appear to be crucial both for the overall repertoire of finalized behaviors and for the cognitive productivity, especially for tasks requiring higher attention, memory and problem solving (MacPherson et al., 2017). Moreover, these are crucial functions in the regulation of cognitive processes of “lower level” as well as in the modulation of the finalized behavior and in the processes of adaptation to the environment (Alvarez & Emory, 2006).

Executive functions

Executive functions perform complex skills known as planning, behavior modulating and monitoring, behavioral and cognitive flexibility and the functions that allow to voluntarily responding adaptively to complex or non-habitual conditions in which the automated response schemes are not appropriate or sufficient to achieve the goal. Research also revealed that when the task is familiar or simple, “automatic” action schemes may be sufficient and when the task requires choices, complex analyses, “automatic responses” are not sufficient but more “controlled” behavior requiring higher “attention” become necessary (Jurado & Rosselli, 2007). The executive functions are fundamental cognitive skills for achieving good performance in life, as well as in the school and social environment, allowing people to face new and complex situations (Lezak, 2004). At the age of 5 years the three key components of executive functions have already been partially developed, these being working memory, inhibition, and cognitive flexibility (Matthew et al., 2006). Working memory involves the monitoring, manipulation, and updating of information; while inhibition refers to the ability to deliberately and precisely inhibit the production of automatic responses when the situation requires it; while cognitive flexibility allows for switching effectively between different mental operations (Miyake et al., 2000, Sastre-Rivas, 2009). As one component of executive functions, inhibition can be understood as a set of functions related to the control of attention and suppression of reflexes or undesirable behaviors (Diamond, 2013) involving response inhibition and interference control (Friedman & Miyake, 2004). Friedman and Miyake (2004) also found that the two types of interference control differentially predicted performance on executive function tasks thought to rely on inhibition, offering further support of the distinction between resistance to proactive and distractor interference. An early empirical investigation revealed a complex pattern of both intact and impaired mnemonic abilities (Boucher & Warrington, 1976; Hermelin & O’Connor, 1967). A research attempted to make a distinction between learning and intelligence by including both a group with learning difficulty and normal IQ and a group with learning difficulty and low IQ. In results, there were no differences found between the two groups on executive function measures, but both
performed more poorly than a control group without learning problems and normal IQ (Maehler and Schuchardt, 2009). This was interpreted as evidence for the fact that executive functions are not necessarily related to intelligence, but rather to learning ability. Another research by Avila et al., (2009) also found differences between groups with high and low levels of education on a range of executive functions tests (digit span backwards, trail making, stroop, and verbal fluency). Executive function was first described as a “central executive” (Baddeley and Hitch, 1974) and later defined by Lezak (1983) as the dimension of human behavior that deals with “how” behavior is expressed. Executive functions were conceptualized as having four components: The abilities of goal formation, planning, carrying out goal-directed plans, and effective performance. As long as executive functions are intact, a person who has sustained considerable cognitive loss can still continue to be independent and productive (Lezak et al. 2004). Executive functions mediate the ability to organize our thoughts in a goal directed way and are therefore essential for success in school and work situations, as well as everyday living. The concept of morality and ethic behavior also represents an executive function (Ardila and Surloff, 2004). The articulatory loop and visual-spatial sketch pad are believed to be slave systems to the central executive. The articulatory loop is a time-based store used for the storage and rehearsal of verbal information. The visual-spatial sketch pad is assumed to have two subsystems. One of the subsystems is a passive visual component retaining material such as color and shape; the other is a spatial system responsible for retaining dynamic information about movement and spatial relations between objects (Logie, 1991; Quinn & McConnell, 1996).

Executive function in autism:

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by persistent difficulties in social communication and interaction and restrictive, repetitive, and stereotyped patterns of behavior, activities, and interests (American Psychiatric Association Diagnostic and Statistical Manual of Mental Disorders, 2013). It is a lifelong disorder and affects at least 0.6% of the population with males being affected three times more often than females (Baird et al., 2000; Chakrabarti & Fombonne, 2001). The prevalence rate of autism according to Centers for Disease Control and Prevention (CDC), 1 in 68 children is diagnosed with an ASD and ratio of this disorder is 4 times higher in boys (Baio et al., 2018). Children with autism also experience sensory processing issues and it is a part of diagnostic criteria for Autism. Sensory processing refers to the way the central and peripheral nervous systems manage incoming sensory information from the sensory organs, namely, visual, auditory, tactile, taste, smell, proprioception, and vestibular information. Sensory processing impairment is a neurological dysfunction affecting the adequate reception, modulation, integration, discrimination or organization of sensory stimuli, and the behavioral responses to sensory input (Tomchek, 2001). Difficulties at the level of sensory processing could contribute to impairments in higher-level integrative functions such as meaningful engagement in daily activities (Humphry, 2002), social interactions, and play (Kuhanec & Britner, 2013). In a theoretical approach by Williams & Shellenberger (1994) and Lázaro & Berruezo (2009) suggested that cognitive and executive functions (higher-order processes) would depend on sensory processing characteristics. A handful of studies focused on elderly with autism and found that autism is associated with early neurodevelopmental deficits in the same cognitive mechanisms that are also known to deteriorate with aging (James et al. 2006; Raznahan et al. 2010; Seltzer et al. 2004). In addition to these core symptoms, sleep disturbance is also commonly observed among children with ASD (Liu, Hubbard, Fabes, & Adam, 2006). Several studies have reported that the prevalence of sleep disturbance is higher in children with ASD (40% to 80%) than in children with typical development (TD; 25% to 40%) (Calhoun et al., 2014; Goldman, Richdale, Clemons, & Malow, 2012). The most frequently reported types of sleep disturbance include delayed sleep onset, difficulty in sleep maintenance, and insufficient sleep duration (Cortesi et al., 2010; Richdale & Schreck, 2009; Souders et al., 2009). A research hypothesized on theory of mind and tried an attempt to explain the impaired ability to represent mental states and the limited awareness of oneself and other people provides a compelling explanation for the failures in communication and reciprocal social interaction that characterize autism (Baron–Cohen, 1998; Happé, 1994).

Executive function is traditionally used as an umbrella term for functions such as planning, working memory, impulse control, inhibition and shifting set as well as the initiation and monitoring of action (Stuss & Knight, 2002). Executive functions are typically impaired in patients with acquired damage to the frontal lobes as well as in a range of neurodevelopmental disorders that are likely to involve congenital deficits in the frontal lobes. Such clinical disorders include attention deficit hyperactivity disorder (ADHD), obsessive compulsive disorder, Tourette syndrome, phenylketonuria, schizophrenia and autism spectrum disorder and also observed executive dysfunction with acquired damage to non-frontal brain areas. Executive function is an umbrella term for functions such as planning, working memory, impulse control, inhibition and mental flexibility, as well as for the initiation and monitoring of action. The primacy of executive dysfunction in autism is a topic of much debate, as are recent attempts to examine subtypes of executive function within autism and other neurodevelopmental disorders that are considered to implicate frontal lobe function (Elizabeth, 2004). A study suggested that individuals with ASD employ effortful, executive processes in order to process relational information in memory (Lara et al., 2013). A research also revealed that children with Fetal Alcohol Spectrum Disorders (FASD) are faced with a range of physical, cognitive, behavioral, and/or learning deficits, as well as poor executive functioning and social skills (Carmen et al., 2009). Norman et al., (2015) investigated the course of and association among changes in autism symptoms, depression symptoms and executive functions (EF) in children with high-functioning autism (HFA). The study revealed according to both children and parents, symptoms of depression were elevated relative to TDC over the 2-year period. The children’s self-reports revealed no significant change in symptoms over time, but the parents reported a significant decrease in symptoms of depression. Alsaeed et al., (2020) examined the executive functioning abilities and development profiles of children with autism spectrum disorder (ASD). The results found that children with ASD experience significant EF difficulties in everyday and laboratory settings, 75% of children with ASD surpassed the clinical cut-off points for the global executive composite. A study investigated executive functions in an
early age evaluating a group of ASD preschool children and confirmed the presence of a significant deficit in some aspects of executive functions in subjects with ASD (Marco et al., 2019). Maysa et al., (2012) revealed executive function (EF) deficits in children with ASD and suggested that these EF impairments are associated with language deficits intrinsic to ASD, specifically the inability to utilize inner speech to regulate non-routine behaviors. Four specific domains of EF (Working Memory, Organization, Shift, and Inhibition) were assessed and demonstrated a mediating effect of language on the executive function component of EF when assessed directly or indirectly. Elizabeth et al., (2003) compared the performance of preschoolers with autism to a control group matched on age, and verbal and nonverbal ability and found that children with autism initiated fewer joint attention and social interaction behaviors than counter parts and concluded a serious challenge to the executive dysfunction hypothesis of autism. Gemma et al., (2019) analyzed whether sensory processing dysfunctions can predict the cognitive and executive dysfunctions evaluated in a group of children with level 2 autism spectrum disorder (ASD) in the school context. In the ASD group, the sensory processing difficulties predicted executive and cognitive dysfunctions in the specific domains of inhibitory control, auditory sustained attention, and short-term verbal memory, after controlling the possible effect of ASD severity. The field of communication impairments and EFs promises to continue as an important area of research concerning the challenging problems of autism and a research found that a significant link between prosodic skills and divided attention, working memory/sequencing, set switching, and inhibition (Marisa et al., 2018). Research also found the significant impairments in the inhibition of prepotent responses (Stroop, Junior Hayling Test) and planning (Tower of London) were reported for children with ASD, with preserved performance for mental flexibility (Wisconsin Card Sorting Task) and generativity (Verbal Fluency). Atypical age-related patterns of performance were reported on tasks tapping response inhibition and self-monitoring for children with ASD compared to controls. When matched with typically developing control group for IQ and language levels participants with ASD exhibited a specific pattern of executive impairments, with poor performance on measures tapping planning, the inhibition of prepotent responses and self-monitoring (Sally et al., 2009). A study concluded that there are limited relationships between representational mental state understanding (knowledge and false belief) and executive control skills (working memory, combined working memory and inhibitory control, and planning) and symptom severity in autism. It also suggested that language plays significant role in the social and cognitive developmental outcomes of children with autism (Robert & Helen, 2004).

**Executive functions in autism and other disabilities**

Booth et al., (2006) comapred ASD, ADHD, or typical development (TD) on a battery of EF tasks tapping three core domains are response selection/inhibition, flexibility, and planning/working memory. The ADHD group showed greater inhibitory problems on a Go-no-Go task, while the ASD group was significantly worse on response selection/monitoring in a cognitive estimates task and age-related improvements were clearer in ASD and TD than in ADHD. It also found that EF scores were related to specific aspects of communicative and social adaptation and negatively correlated with hyperactivity in ASD and TD and the overall findings suggested less severe and persistent EF deficits in ASD (including Asperger Syndrome) than in ADHD. Rasch & Santos, (2014) investigated on executive function and working memory in children and adolescents with ASD compared to children and adolescents with typical development matched by age, formal education, and nonverbal IQ and concluded that impairment of executive function especially in planning, flexibility, inhibition, and also visuo-spatial working memory. It also found that there is no significant difference in cognitive and affective aspects of moral reasoning between individuals with ASD and typically developing children (Anett et al., 2014). Some studies concluded that reliable differences between children with and without speech and language impairment were found on inhibition and cognitive flexibility tasks (Laura & Lisa, 2016). It is also found that children with specific language impairment (SLI) show a deficit in verbal working memory tasks that involve simultaneous processing of information (Klara, 2006). Young people with GD had relatively more disturbed behavior related to executive functions and social impairment associated with autistic traits when compared with their control counterparts (Gozde et al., 2018). Compared to children with TD, children with ASD presented significantly more ADHD symptoms and poorer learning behaviors. In addition to that the central coherence involves the processes of perceptual coding and attention mechanisms, highly deficient in children with ADHD. Adding up to this theory it is also found that children with autism are overly focused on details to the expense of a global perspective, and this negatively affects their ability to integrate environmental stimuli into a coherent whole. Individuals with ADHD exhibited significant deficits in perceptual skills and problem solving, failing also in mental states understanding tasks. While the children with autism spectrum disorder showed impairments in making pragmatic inferences. (Happé, Booth, Charlton, Hughes, 2006). Mirjana & Dragana, (2008) studies on the quality of development of executive functions through logical thinking, keeping the conceptual direction and applying the problem solving strategies and found that school age children with intellectual disabilities show marked problems with tasks in which they are required to develop strategies for problem solving and adjust these to new requirements. A study conducted by Hilde & Marlies, 2012 considering as autism is a life-long disorder and aging also has a strong impact on cognitive functioning in autism and found that elderly with HFA show impairments in sustained attention, working memory, and fluency, while other cognitive domains are intact. It also concluded that different developmental patterns emerged for fluency and visual memory in elderly with HFA and controls. An investigation by Turner (1997) to examine the relationship of repetitive behaviors and executive functions and theory of mind in older children with autism. In results, lower level repetitive behaviors, such as stereotyped motor behaviors, were associated with “recurrent” perseveration (i.e., simple response repetition) on the Intradimensional–Extra-dimensional set-shifting task, whereas higher level repetitive behaviors, such as circumscribed interests, were associated with “stuck-in-set” perseveration (i.e., inability to change set) on the set-shifting task. In contrast, Turner (1997) found no association between false belief understanding and repetitive behaviors in individuals with autism. Research also revealed that there is no compelling evidence that the social–cognitive abilities tapped by false belief tasks can explain differences in
symptom severity in individuals with autism, giving some credence to arguments that success on false belief tests does not generalize to competencies in actual social–communicative functioning (Bowler, 1992; Frith, Morton, & Leslie, 1991; Happé, 1994; Klin, Schultz, & Cohen, 2000). An additional issue of interest was the relationship of general cognitive ability and particularly language ability to the variables under consideration. First, it is well-documented that theory of mind abilities in individuals with autism is strongly correlated with language ability (Happé, 1995; Tager-Flusberg & Sullivan, 1995; Yirmiya, Erel, Shaked, & Solomonica-Levi, 1998). Second, it has been hypothesized that formal and pragmatic language deficits contribute to executive deficits in autism (Hughes, 1996; Liss et al., 2001; Russell, 1997; Russell, Jarrold, & Hood, 1999). Third, language level and general intellectual ability are important prognostic factors with regard to symptom severity in autism (Bailey et al., 1996; Lord & Paul, 1997). Thus, an important consideration was whether associations between theory of mind ability, executive functions, and symptom severity in autism could be established independently of their shared relationships with language skills and broader cognitive abilities. Research shows that poor sleep can exacerbate various symptoms of autism, resulting in increased stereotypic behavior (Mazurek & Sohl, 2016), more severe communication impairment (Taylor, Schreck, & Mulick, 2012), and intensified emotional control problems (Gregory & Sadeh, 2012). In a recent case-control study, Maski and colleagues (2016) indicated poor sleep could aggravate the impaired memory consolidation in children with ASD. Research indicated that children with ASD are often reported problem in executive function in order to have poor working memory capacity (Barendse et al., 2013; Russell, Jarrold, & Henry, 1996), difficulties in switching attention between tasks (Reed, Watts, & Truzoli, 2013; Wallace et al., 2016), and inhibition response problems (Hopkins, Yuill, & Branigan, 2017), which can seriously affect their school performance and everyday functioning (Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002). A study on fMRI established functional underconnectivity in the cortical systems and disturbances in integrative information processing as the basis for the clinical deficits that define autism (Kana et al., 2006; Just et al. 2007). Autistic performance might be tied to dysfunctional integration of the frontal lobes with the rest of the brain, abnormal developments in neuronal sophistication and/or abnormal myelination (Luna et al., 2002; Chugani, 1998). Research also found that transient delayed postnatal maturation of the frontal lobes in autism (Zilbovicus et al., 1995; Ohnishi et al., 2000) and reduced functional connectivity of frontal cortex with other cortical and subcortical regions (Luna et al., 2002) support this view. The failure of the frontal lobes to follow a normal maturation pattern is likely to have long-term consequences for all development. This abnormality might be reflected differentially over time as the impact of abnormal development which shows the link between frontal lobe abnormality and executive dysfunction. In contrast, another study suggested that planning deficits might have related to level of general intellectual functioning and maturation and it also reported that impaired planning ability on a kinematic reach-to-grasp task was related to level of IQ rather than to autism (Mari et al., 2003). The term “executive dysfunctions” refers to impairments in a range of loosely related cognitive processes that play a primary role in coordinating higher-order cognitive abilities and emotions, as well as in regulating behavioral responses to non-routine environmental demands (Mok et al., 2007). Executive dysfunctions (EDFs) are among the most prevalent neurodevelopmental features associated with autism spectrum disorder. Indeed, it has been estimated that 41% to 78% of individuals with ASD exhibit executive dysfunctions (Lynch et al., 2017). Such deficits could hinder several areas of development, including children’s neurocognitive, behavioral and psychosocial development (Leung et al., 2016; Pellicano, 2007; Pugliese et al., 2016). Executive dysfunctions are most commonly associated with abnormalities affecting the frontal lobe, particularly the prefrontal cortex (PFC), in both typically developing individuals and those with ASD (Brady et al., 2017; Hil, 2004). However, it is now generally understood that the executive functions are not solely linked to the frontal brain structures but are instead associated with a widely distributed neural network and based on the integration of cortical and subcortical systems throughout the brain (Suchy, 2009). Children with intellectual disabilities (ID) often demonstrate impairments in executive functioning (Danielsson, Henry, Ronnberg, & Nilsson, 2010; Memisevic & Sinanovic, 2014). Executive functions (EF) are crucial for children’s lifetime performance (Center on the Developing Child Harvard University, 2011). They are often connected with school readiness and school achievement (Morrison et al., 2010), physical health (Miller, Barnes, & Beaver, 2011), successful work (Bailey, 2007), social functioning (Diamond, 2012) and the quality of life (Brown & Landgraf, 2010).

Conclusion

The executive functions within autism are considered to be frontal lobe dysfunction and has problem in processing relational information in memory and changes in autism symptoms, depression symptoms and executive functions (EF) in children with high-functioning autism (HFA). It is concluded that children with ASD experience significant EF difficulties in everyday and laboratory settings, 75% of children with ASD surpassed the clinical cut-off points for the global executive composite. In elderly HFA it is found that the impairments in sustained attention, working memory, and fluency, while other cognitive domains are intact. In addition to that there are limited relationships between representational mental state understanding (knowledge and false belief) and executive control skills (working memory, combined working memory and inhibitory control, and planning) and symptom severity in autism. The poor sleeping pattern would exacerbate various symptoms of autism, resulting in increased stereotypic behavior more severe communication impairment and intensified emotional control problems. In the ASD group, the sensory processing difficulties predicted executive and cognitive dysfunctions in the specific domains of inhibitory control, auditory sustained attention, and short-term verbal memory, after controlling the possible effect of ASD severity and there is a significant link between prosodic skills and divided attention, working memory/sequencing, set switching, and inhibition. ASD exhibited a specific pattern of executive impairments, with poor performance on measures tapping planning, the inhibition of prepotent responses and self-monitoring and when it compared with other disorders no significant difference in cognitive and affective aspects of moral reasoning between individuals with ASD and typically developing children. Individuals with ADHD exhibited significant deficits in perceptual skills and problem solving,
failing also in mental states understanding tasks. While the children with autism spectrum disorder showed impairments in making pragmatic inferences. It is also concluded that Fetal Alcohol Spectrum Disorders (FASD) are faced with a range of physical, cognitive, behavioral, and/or learning deficits, as well as poor executive functioning and social skills. In a comparison the overall findings suggested less severe and persistent EF deficits in ASD (including Asperger Syndrome) than in ADHD. Children with Autism required therapeutic intervention program to improve their condition and for a better quality of life. The multidisciplinary approach has brought out significant improvement in children with autism and the improvements are in the areas of relating to people, listening and visual response, and there are reduction in body use, object use, and activity level (Sridevi & Rangaswamy 2013). It is also important that an intensive early intervention is critical in maximizing outcomes for children with behavior problems and evidence suggests that the earlier the intervention, the better the outcome. Research also found that an early intervention can improve adaptive and personal-social behaviors of children with autism (Sridevi & Saroj Aarya, 2014). Children with autism also required sensory integration therapy that improves the synchronized functions of various sensory inputs in children with autism to help them in socialization and Activity of Daily Living. (Dabushis et al., 2018)

References


