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Executive Functioning in Relation to Attention Deficit and Hyperactivity Disorder*

Abstract

The scientific literature describes findings indicating that problems in an individual's executive functioning may be a defining aspect of attention deficit and hyperactivity disorder. Many ADHD symptoms are indicative of problems in the dimensions of executive functioning. In the paper, on the base of theoretical research (1) the concept of executive functioning is analyzed, (2) the processes most frequently associated with executive functioning as inhibition, attention control, working memory, self-regulation are further discussed. Consequently, Barkley's theory (Barkley, 1997a, b) related to the explanation of the deficits in self-regulation and inhibition associated with ADHD is introduced. Based on the literature analysis there is stated in the paper that the research confirms that the performance levels of executive functions are lower in children with ADHD than in children without ADHD. Therefore, interventions at the executive functioning level can be used as complementary or alternative approaches to correcting the behavioral and cognitive problems associated with ADHD.

Keywords: executive functioning, working memory, selective attention, cognitive flexibility, self-regulation, ADHD

1. Definitions of executive functioning

The history of observing and assessing the clinical syndromes of inattention and hyperactivity stretches back over 200 years. Attention deficit and hyperactivity disorder, known as ADHD, is one of the most frequent reasons for placing a child on an intervention or remedial program aimed primarily at correct-

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ing behavior (Antshel, Hier, Barkley, 2014). The specialist literature describes findings indicating that problems in an individual's executive functioning may be a defining aspect of attention deficit and hyperactivity disorder. Many ADHD symptoms are indicative of problems in the dimensions of executive functioning. In this paper we present the concept of executive functioning and give an overview of the theories of executive functioning as they relate to ADHD.

Executive functions and executive functioning

The construct of executive functions (EF) comes from neuropsychology and stems from observations of specific neurological disorders and their behavioral manifestations. Executive functions are most frequently defined as the system of control processes that attribute priority to a particular process while inhibiting the activity of others. Executive functions are therefore mental functions controlled by cognitive functions. They determine engagement of the cognitive functions in processing stimuli and distribute the mental resources required (Barkley, 2012; Goldstein, Naglieri (eds.); Burgess, 2004; Kovalčíková a. oth., 2016; Ropovik, 2014). There are various theories that define the system of executive functioning. Research indicates that executive functioning is a set of mutually connected, yet autonomous, processes (e.g., Denckla, 1996; Fuster, 2008). The processes most frequently associated with executive functioning (EF) are inhibition, attention control, working memory, self-regulation, and planning.[1] A number of models exist that attempt to describe the form and conceptual framework of EF. Besides exhibiting some conceptual and theoretical differences these models attribute fundamental and structural importance to different executive functions: inhibition, or self-regulation (Barkley, 1997a);

[1] As part of research conducted within APVV-11-0281 "Executive functions as a structural component of the ability to learn — diagnosis and stimulation", the principal investigator, prof. PhDr. Iveta Kovalčíková, PhD., performed a linguistic and psychological analysis of the concepts of executive functioning (EF), in which theories of EF and aspects of diagnosing EF were analyzed and a basis for creating a stimulation program for pupils with low levels of EF was presented. The project outcomes were two editions of a monograph: Kovalčíková, I., Ropovik, I., Ferjenčík, J., Liptáková, Ľ., Klimovič, M., Demko, M., Bobáková, M., Slavkovská, M., Kresila, J., Prídavková, A. & Brajerčík, J. (2015, 2016). *Diagnostika a stimulácia kognitívnych a exekutívnych funkcií žiaka v mladšom školskom veku* [*Diagnosis and stimulation of cognitive and executive functions in young school-age pupils*]. Prešov: Vydavateľstvo Prešovskej univerzity v Prešove. A more detailed analysis of the concept of executive functioning can be found in: Ropovik, I. (2012). *Exekutívne funkcie ako štrukturálny činiteľ schopnosti učiť sa* [*Executive Functions as a Structural Determinant of Learning Ability*]. Thesis. Registered in the CRZP; Ropovik, I. (2014). D*o Executive Functions Predict the Ability to Learn Problem-solving Principles?* "Intelligence", 44, pp. 64–74.

system of attention control (Norman, Shallice, 1986), working memory (Baddeley, 1996, 2002a), planning (Zelazo a. oth., 1997), or the construct of cognitive flexibility (Anderson, 2002). Good executive functioning in one domain does not guarantee good executive functioning in another.

Manifestations of executive functioning deficit in an education context

The concept of executive functions is of great importance in both education and diagnosis. Pupils find the learning process exerts continual strain on their capacity for adaptive change. Shallice (in Walsh, 1978) summarizes three types of situation that activate or require the engagement of executive functions: (1) new or unfamiliar circumstances for which there is no existing routine behavior or cognitive pattern, (2) where the task is too complex, (3) where the task requires the integration of several information sources (in Ropovik, 2012).

The process of targeted learning in schools fulfills all these conditions. If a child's level of executive functioning is low, then in any of these three situations that child's cognitive functioning will probably become disorganized, uncontrolled, and therefore ineffective. Individuals with insufficiently developed executive functioning can have problems in several areas. Specifically they may not be capable of focusing and maintaining attention; inhibiting impulsivity and various interfering (exogenous and endogenous) elements; holding information in the memory while simultaneously processing it (poor working memory); planning (e.g., when performing tasks); being organized and disciplined in thinking; generating and implementing new task-solving strategies; or learning from mistakes (perseverance behaviors) (Stuss, 1992; Temple, 1997). Pupils with dysexecutive syndrome (a serious deficit in executive functioning) are often diagnosed as having a learning disorder (McCloskey, Lennon, 2010), particularly ADD or ADHD. Ropovik (2012) has stated that if teachers deliberately target deficits in executive functioning (by providing a clear structure to lesson content, analyzing complex problems in stages, mediating appropriate self-regulation techniques, etc.), pupils will probably be capable of learning much more effectively. If, however, pupils lacking sufficiently developed executive functions are left on their own to solve problems that require organized thinking, a planned approach, the generation of strategies, or solving of unclearly structured problems, then this deficit is likely to manifest itself in the types of productive disorders mentioned above — therefore they will be incapable of performing as required.

Deficits in the various EF domains have different behavioral and cognitive manifestations. These will be briefly described in each of the subsections below on the processes of executive functioning.

3. Models and processes of executive functioning

Conceptualizing executive functions and executive functioning can be found in cognitive psychology (e.g., Anderson, 2002; Baddeley, 1986; Borkowski, Burke, 1996; Burgess, 2004; Eslinger, 1996; Fletcher a. oth., 1996; Norman, Shallice, 1986), cognitive neuropsychology (e.g., Anderson a. oth., 2008; Denckla, 1996; Fuster, 2008; Goldman-Rakic, 1984; Stuss, Benson, 1986), pathopsychology (e.g., Anderson a. oth., 2008; Denckla, 2005, 2007; Pennington, 1997), and psychological and education guides (e.g., Meltzer (ed.), 2007; McCloskey, Perkins, van Divner, 2008; Dawson, Guare, 2010; Dehn, 2008; Gathercole, Alloway, 2008). The literature analysis revealed that while there is no opposing explanation of this concept, there is no universally accepted and empirically verified theoretical model of executive functioning either (Ropovik, 2012).

In the following section we will focus on these processes of executive functioning: (1) attention control, and inhibition, which is an integral component of attention control, (2) working memory as the primary construct of (3) cognitive flexibility.

Selective (control of) attention and inhibition

According to Posner and Rothbart (2007) attention is a mechanism that regulates brain activity; it is the primary means of self-regulation. Ropovik (2012) pointed out that it is important to note the difference between the concepts of "attention" and "attention control." While attention is a high-order construct that involves the involuntary focusing of awareness characteristically associated with external stimuli (e.g., an unexpected trigger), attention control is understood to mean the ability to consciously focus on a given stimulus (effortful control), and subsequently regulate distracting external and internal influences to achieve a particular goal (Carver, 2004). This is basically the opposite of acting impulsively (Barkley, 1997a). Attention control is the primary construct of executive functioning and is probably of crucial importance in education. The attention mechanism is key because it selects the stimuli it processes, while "deflecting" stimuli irrelevant to solving the problem at that particular moment (Broadbent, 1958).

Some scholars (Barkley, 2000; Pennington, Ozonoff, 1996) consider the capacity for inhibition to be the primary mechanism for attention control, and executive functioning in general. Behavioral inhibition is a behavioral pattern that involves the suppression of automatic reactions or socially inappropriate behaviors (Ropovik, 2012; Kovalčíková a. oth., 2015). Inhibition is a mental process in which the reaction, thought, or automatic process is suppressed. It

is the opposite of activation, intensification; it refers to the mental state during which the blocking act occurs (Ropovik, 2012; Kovalčíková a. oth., 2015). Barkley (1997a) considered inhibition to be a special system, hierarchically superior to the other systems of executive functioning, and the highest of all the systems in the cognition hierarchy. Without inhibition neither self-regulation nor attention are possible, both of which are essential to the processes of working memory and cognitive flexibility (Kovalčíková a. oth., 2015).

Working memory

The working memory is a component of executive functioning. It is the active memory system which is responsible for temporary storage of information while they are simultaneously processed (Bayliss a. oth., 2005). It is a workspace in which we manipulate activated mental representations (Stoltzfus, Hasher, Zacks, 1996). Nonetheless, the working memory is not the true memory, as it does not store information indefinitely, just that which is relevant to completing the task (T. P. Alloway, R. G. Alloway, 2010). It is the area in which knowledge is formed and semantically coded. Almost everything pupils learn (or remember) goes through this system. The working memory can be defined as the individual's ability to hold information "online" (Pennington, Ozonoff, 1996), and store it so it does not become deformed while the mental operations analyze and restructure the information; that is, actively work with it (Kovalčíková a. oth., 2015).

Cognitive flexibility

Various models of executive functions, which differ in structure and number of executive functioning components, can be found in the literature (Anderson, 2002; Baddeley, 2002; Barkley, 1997a, b; Zelazo a. oth., 1997). In total there are more than 30 different components (M. Yeager, D. Yeager, 2013), and cognitive flexibility is among those most frequently mentioned (apart from working memory, inhibition, and planning). In recent years cognitive flexibility has attracted a substantial amount of research interest. As was the case with definitions of executive functions there is no agreement on a single definition or method of measuring cognitive flexibility as one of the components of executive functioning (Dennis, Wal, 2010). In the international literature, concepts such as shifting, set-shifting, task-switching, and attention-switching can be found in addition to cognitive flexibility (Tharp, Pickering, 2011). Given the variety of definitions and lack of a uniform approach in much of the research

on perceptions and assessments of cognitive flexibility, Ionescu (2012) identified the two most frequent, but opposing, views of this construct. In the first cognitive flexibility is seen as a special ability and is associated with a synonymous understanding of cognitive flexibility and shifting. In this strand of cognitive flexibility research the focus is on the ability to quickly move away from one rule (for the task, cognitive focus) to focus on another; that is, the ability to flexibly switch between responses depending on the situational conditions (Dennis, Wal, 2010; Goldstein, Naglieri, 2013). In the second approach cognitive flexibility is seen as a characteristic of various cognitive processes. In this approach constructs such as flexible categorization, flexible language use, and flexible responses are investigated (in Kovalčíková a. oth., 2015).

4. Executive functioning and ADHD

The etiology of ADHD is complex and multidimensional. Knowledge from neuropsychology has led experts to accept that executive functioning (EF) in individuals is mediated, at least within the partial executive functioning processes of the frontal and prefrontal cortices. This is also implied in the neuropsychology of ADHD (Castellanos a. oth., 2006; Nigg, Casey, 2005; Sagvolden a.oth., 2005). As Bush, Valera and Seidman (2005) have stated the biggest difference between the cerebral structures of individuals with ADHD and individuals without ADHD can be seen in the prefrontal section of the cerebral cortex, but especially in the dorsolateral section responsible for vigilance, attention, transfer and selective attention, working memory, cognitive planning ability, and cognitive flexibility. Seidman, Valera, and Makris (2005) identified significantly lower levels of blood flow and reduced activation in the prefrontal and frontal cerebral cortex in children with ADHD. These areas of the cerebral cortex determine various executive functions considered exhibit typical core cognitive deficits identified in child populations with ADHD (Konrad a. oth., 2006).

ADHD models assume that deficits in functions located in the frontal lobes are manifest in various behavioral and cognitive symptoms (Castellanos, Tannock, 2002). In 1997 Barkley unveiled his theory of executive function in relation to ADHD. Barkley stated that problems in areas of executive functioning, chiefly in the areas of self-regulation, were central to ADHD and caused a clear set of behavioral symptoms, represented as DSM-5 in the diagnostic criteria. This theory holds that behavioral inhibition, self-control, and executive functioning are mutually overlapping and interacting human abilities. Executive functions enable self-control, and the self-regulation of behavior (Gioia, Isquith, Guy, 2001). Brown (2008) stated that ADD/ADHD is in essence a cog-

nitive deficit, a developmental disorder in executive functioning controlling the brain system. In the next section we will analyze specific deficits in executive functioning in individuals with ADHD.

Self-regulation of individuals with ADHD

Goal-directed behavior requires the ability to consider and think about a specific point in the future. The assumption is that a person can contrast "now" with "later" and assess the extent to which the future state is more desirable than the current state. The capacity to consider future events requires mental resources for (1) handling the concept of time and sequencing events over time, (2) actively keeping these sequences in mind, (3) using the information to sequence their own performance over time (Shimamura, Janowsky, Squire, 1990). In order to perform the chain of actions required to span the current situation and the later one, the individual's actions have to be hierarchically organized. This involves breaking the chain down into smaller elements, or parts, depending on the anticipated goal, which is itself based on a goal with a higher level of determinacy (Badre, 2008). In Barkley's theory linking executive functioning and ADHD, executive functioning is represented by the level of self-directed behavior or the activities we perform as part of self-directed behaviors. The individual's self-directed behavior is therefore directed at changing something in their own future (Barkley, 1997a. b). Within this context, the operationalization of EF is based on the idea that the entire system — the process of executive functioning — is basically a system of self-directed actions. This principle is the main criterion for distinguishing between executive and non-executive mental abilities. An executive act is any kind of activity that achieves the level at which individuals are capable of stopping the action, regulating their own time, organizing themselves and dealing with the related circumstances and problems over time, activating themselves to overcome obstacles, perform actions, and achieve the goal. This requires persistence and self-motivation to achieve the goal. It is a process accompanied by emotional activation of various types and levels; individuals are required to self-regulate their emotions. All these actions are conscious, require a certain amount of effort and will, and are initiated by the individuals themselves. Neuroimaging research findings show that it is possible to measure these aspects of covert behavior (Ryding, Bradvik, Ingvar, 1996).

The ability to self-regulate requires the ability to inhibit reactions or responses. Behavioral inhibition is a core problem in individuals diagnosed with ADHD (Nigg, 2001). Barkley's theory (Barkley, 1997a. b) points out in an original way that deficits in self-regulation and inhibition associated with ADHD

may result in a cumulative increase in second-order problems in the remaining parts of executive functioning. Behavioral dysinhibition (1) causes problems in the nonverbal operating memory and subsequently causes forgetfulness (forgetting to do things that have to be done at a crucial moment); (2) disrupts the ability to organize and perform actions relating to the organization of time (e.g., time management); (3) reduces the ability to foresee and anticipate; (4) leads to a reduced ability to adjust anticipated actions in relation to future events (Antshel, Hier, Barkley, 2014).

Consequently, the capacity to organize behavior along overlapping timelines is typically minimized in individuals with ADHD. This is because the ability to order complex chains of future-targeted actions is impaired. However, in later revisions to his theory, Barkley accepts that as self-awareness, self-control or inhibition, and self-sensory-motor actions (such as non-verbal operating memory) can develop in parallel and co-exist as a whole, then they are all primary deficits insofar as ADHD is concerned. This could be the basis for explaining the symptoms of ADHD, accepting that it has a two-dimensional structure — attention/hyperactivity. Research shows that it is not just inhibition but also nonverbal operating memory, time management, and forethought that are deficient in ADHD (Frazier, Demaree, Youngstrom, 2004; Rapport a. oth., 2008). The more marked the temporal aspects separating behavioral contingency, event–reaction–outcome, or the greater the length of time between event–reaction–outcome, the harder tasks and situations become for individuals with ADHD. In this context Barkley (Antshel, Hier, Barkley, 2014) stated that non-verbal working memory could be a primary deficit where ADHD is concerned, alongside a deficit in inhibition and self-awareness, in contrast to the previous suggestion that nonverbal working memory and deficits thereof were a secondary effect of an inhibition deficit. According to Barkley's most recent statements another problem, manifest in cases of ADHD, is that alongside limits to operating memory there is a deficit in self-speech, or, put differently, in the privatization of speech, which can exhibit signs of late development. This deficit results in (1) more marked levels of uninhibited and excessive talking in public, (2) a lack of verbal reflection and inhibition before acting or speaking, and (3) an absence of rules for regulating self-speech. Deficits in regulating self-speech lead to a reduction in the individual's behavior regulation and control and to problems accepting rules and instructions defined externally; that is, by others (Antshel, Hier, Barkley, 2014). Research by Berk and Potts (1991), and Winsler a. oth. (2000) confirms this hypothesis. According to research by Frazier, Demaree, Youngstrom (2004) the results of tests assessing quality of verbal operating memory, such as backward digit span, mental arithmetic, and paced auditory serial addition, indicate that individuals with ADHD perform less well on these.

In the specialist literature all these deficits in nonverbal and verbal operating memory, inhibition, and control of self-speech are associated with the processes of executive functioning and cause or lead to an additional problem — weak emotional/motivational self-regulation.

Individuals with ADHD therefore exhibit

(1) a higher level of impulsiveness in their emotional responses to events,

(2) a lower level of objectivity when selecting the appropriate reaction to an event,

(3) a lower level of prosocial empathy (social perspective-taking, where the individual is able to inhibit a response or reaction such that they are capable of reflecting the views and needs of others),

(4) greater difficulties self-regulating during initial emotional reactions,

(5) greater difficulties in situations requiring self-control in deflecting attention; in other words, in controlling their attention when confronted with provocative stimuli to minimize the effect these have on the behavior of the individual (Antshel, Hier, Barkley, 2014).

ADHD can also negatively affect individuals' abilities to activate or motivate themselves to adopt goal-oriented behaviors. Individuals with ADHD rely more on the environmental context in certain situations or tasks; these environmental variables have more of a motivational influence than those associated with, for instance, the individual's will (Barkley, 1997a, b). Barkley's EF model also predicts that ADHD is associated with a lower level of reorganizational behavior, a consequence of inadequate analysis and synthesis when consolidating verbal and nonverbal reactions to the stimulus or situation. The ability to mentally visualize and subsequently generate different potential reactions such that the individual is able to select the optimal option may be greatly diminished. This reorganization deficit can be seen in everyday verbal fluency when the individual is faced with a situation or task that requires them to quickly, appropriately, and correctly select language (word class) and formulate a response consistent with the task requirements. This phenomenon can be observed in tasks where visual information has to be held in the memory, elaborated and subjected to mental manipulation so various alternative solutions to the problem can be generated. Weak self-regulation and self-organization have an effect on the individual's problem-solving abilities. Although there is limited evidence on verbal and nonverbal (e.g., figurative) fluency, planning, and problem-solving in relation to ADHD, the knowledge that does exist is consistent with Barkley's theory (Clark, Prior, Kinsella, 2000; Klorman a. oth., 1999).

To summarize the above, we can say that individuals with ADHD are influenced more by external events than by their own mental representations of time or the future. The influence of other people on their self-control is greater

than other influences. They favor immediate satisfaction or gratification. Temporally the "here and now" has a greater influence than the probability of circumstances. From this angle ADHD is not an attention disorder, or at least not in relation to factors in the external environment, but is more an impairment of focus, will or intention, an attention deficit regarding the future and ascertaining what the person needs in order to prepare for that future. ADHD is also a time-perception disorder or time-management disorder, manifest in the inability to regulate self-behavior as regards time compared with other individuals at the same developmental stage. Barkley refers to this phenomenon — where individuals react to or prepare for immediate or more pressing situations rather than more distant ones — as temporal short-sightedness.

Conclusion

Based on this literature analysis we can state that the research confirms that the performance levels of executive functions are lower in children with ADHD than in children without ADHD. This means it is important to find interventionist approaches that can benefit both cognitive and executive functioning in children with ADHD (Piepmeier a. oth., 2015). Interventions at the executive functioning level may consist of complementary or alternative approaches to correcting the behavioral and cognitive manifestations associated with ADHD. The literature describes experimental research on EF in individuals with ADHD. For example, Mahone and Silverman (2008) discussed the prospects of correcting ADHD symptoms by training EF. They found support for this in MRI results from the last 20 years that have helped shed light on the neurological basis of EF in children with ADHD and children without ADHD. Of particular importance where children with ADHD are concerned is the finding that EF level is dependent on interaction between the individual and the environment. It is possible to boost performance in individuals with ADHD through appropriate and effective organization of the home and school environments, and by optimizing the number of stimuli and requirements. Tamm and Nakoneczny (2015) built on previous research indicating that quality of EF is lower in individuals with ADHD and used it as the basis for designing interventions targeting EF in early childhood seeking to eliminate the symptoms of ADHD at later developmental stages.

Deficits in executive functioning in children with ADHD can be improved through pharmacological treatment. However, there is no caution about using this method. Qianm, Chen a. oth. (2017) have stated that medication-based treatments for children with ADHD are ineffective in mitigating the symptoms of the disorder. As pharmacological treatments have many side effects the cur-

rent preference is to use non-pharmacological methods to treat attention deficit and hyperactivity disorder. Intervention programs are a non-pharmacological alternative used to correct ADHD. They are targeted at various areas of the individual's cognitive and executive functioning. Interventions at the executive functioning level can be used as complementary or alternative approaches to correcting the behavioral and cognitive problems associated with ADHD.

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