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ROLE OF EXECUTIVE ATTENTION IN LEARNING, WORKING MEMORY AND PERFORMANCE: A BRIEF OVERVIEW

Subodh Kumar[1]
Tara Singh[2]

Abstract

Executive attention is a function involved in the regulation of thoughts, emotions, responses, distractions, problem solving and switching between multiple pieces of information. It has the ability to control attention for ongoing cognitive processes such as decision-making, cognitive control, language processing, and social cognitive processes which get influenced through components of working memory. Various executive attention skills emerge with the maturation of frontal brain structures as the executive attention is mainly located in the prefrontal cortex. Understanding early stages of development of a child can help in their academic and professional outcomes, socialization and psychological well-being. But at the same time, damage to the frontal lobes, can affect the roleof executive attention in the control of thought, behaviour, and emotion. This paper aims at providing a selective review of the existing literature about the development of executive attention, functions of attentional network and its role in learning, working memory and performance.

Keywords:
Executive Attention, Learning, Working Memory, Performance, Attentional Network, Short Term Memory

Correspondence Address:
Subodh Kumar
Research Scholar,
Banaras Hindu University,
Varanasi, UP, India.
bhu.subodh@gmail.com

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[1]Research Scholar, Department of Psychology, Banaras Hindu University, Varanasi, UP, India
[2]Professor, Department of Psychology, Banaras Hindu University (BHU), Varanasi, UP, India

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Introduction

Working memory is a temporary storage system that underpins our capacity for coherent thought (Baddeley, A., 2007). It holds and manipulates information for the current processing and facilitates learning, planning, reasoning, and problem solving.

Working memory has two components, short-term memory and executive attention. Short-term memory consists of very limited information that humans are capable of keeping in mind at a time, whereas executive attention is a function that regulates the quantity and type of information that is either accepted into the short-term memory or blocked from it. In other terms, executive attention is involved in the regulation of thoughts, emotions, responses, distractions, problem solving and switching between multiple pieces of information.

Engle, et al. (1999) defined the Executive attention as the ability to control attention to ongoing cognitive processes. Many higher order cognitive processes such as decision-making, cognitive control, language processing, and social cognitive processes get influenced through maintenance, manipulation, and updating components of working memory by interacting with executive attention (Kar, B. R. and Kenderla, P.K., 2017).

Executive attention is very effective in blocking potentially distracting information from the focus of attention in order to manage information in short term memory. This is a way by which the brain is able to keep information active and in focus. Yet, the amount of information that executive attention is capable of handling at any given time is limited, and this capacity will differ from person to person. As a result, all people differ in their ability to bring attention to bear on the control of thought which is known as working memory capacity and this ability is measured most frequently through a test that needs people to commit a short list of items to memory while performing another task. Thus, reading a series of sentences and then attempting to recall the letters at the end of each sentence can be considered as one form of the test.

The capacity of working memory is measured by the number of items that an individual recall, so that if an individual recalls five letters, the working memory capacity in this case is five. In most cases, the number of letters recalled will depend upon each

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person's ability to avoid the distraction of reading the sentences. An individual's ability to perform tasks involved in reasoning can be predicted using such tests of working memory capacity. In fact, working memory capacity is strongly associated with general intelligence.

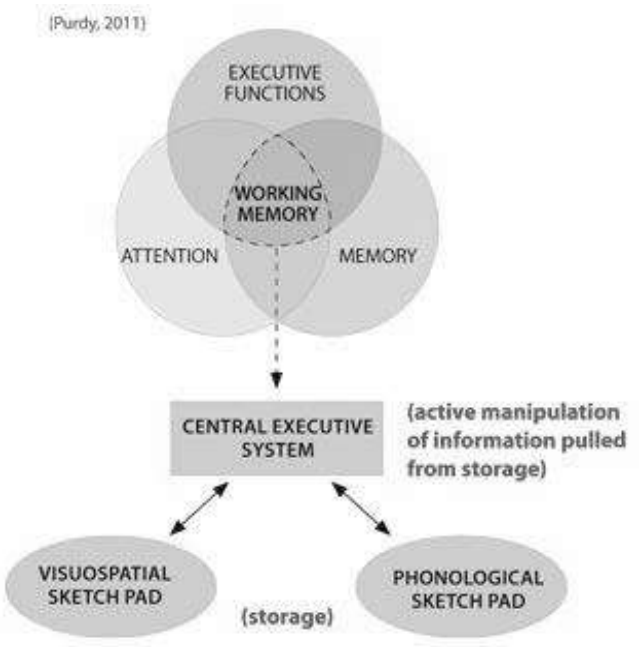

Figure 1: Conceptualization of the relationships among attention, memory, executive functions andworking memory (Purdy, 2011).

Development of Executive Attention

Executive attention experiences major development at about the end of the first year of life and continues during preschool years into adolescence and is associated with a neural network involving the anterior cingulate cortex and prefrontal structures. However, despite the major development throughout childhood, executive attention shows a major period of development from about the end of the first year of life up to about 7 years of age (Rueda, et al., 2004a, 2005a).

Development of executive attention is likely related to brain areas's structural changes that are part of the executive attention network and their connectivity patterns with other brain structures, specially, the appearance of greater fronto-parietal functional connectivity over development (Power, et al., 2010). From a neurofunctional point of view,

both the Executive Functions and the attentional processes are associated with frontal lobe regions in connection with other cortical areas and subcortical structures of the brain (Bench, et al., 1993; Fuster, 1997; Smith, & Jonides, 1999). However, the executive attention is mainly located in the prefrontal cortex. Understanding early stages of development can help in promotion of Executive Attention development outcomes like academic and professional outcomes, socialization, psychological well-being, etc.

Maturation of frontal brain structures help the emergence of Executive Attention skills. Some evidence has also shown that frontal brain structures related to Executive Attention are already functional in the first months of life and first signs of Executive Attention can be seen by the second half of the first year of life.

Attentional Network and its Functions

Miyake, et al. (2000) established that inhibitory control, working memory and cognitive flexibility are three closely related cognitive abilities for executive functioning.

According to Posner's model, different networks of brain regions are involved in carrying out the three functions of attention (Posner, MI., Petersen, SE., 1990; Petersen, SE., Posner, MI., 2012):

(1) Reaching and/or maintaining the alerting state,
(2) Orienting attention and choosing the source of stimulation, and
(3) regulating thoughts, emotions and action

The third function is carried out by the executive attention network (Figure 2) which involves the anterior cingulate cortex and prefrontal regions of the brain (Posner and Petersen, 1990; Posner, et al., 2007). Working memory and executive attention enhance the processing of relevant information for goal-directed behavior (Kar, BR. and Kenderla, PK., 2017).

Functions associated with the executive attention network overlap with the more general domain of Executive Functions to some extent, which encompass a set of interrelated processes involved in planning and executing goaldirected actions, including

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working memory,mental-set switching or attentional flexibility, inhibitory control, and conflict monitoring (Blair and Ursache, 2011; Welch, 2001; Welsh and Pennington, 1988).

These cognitive abilities are required when it is necessary to hold information in mind, manage and integrate information and resolve conflict between sources of stimulation or response options.

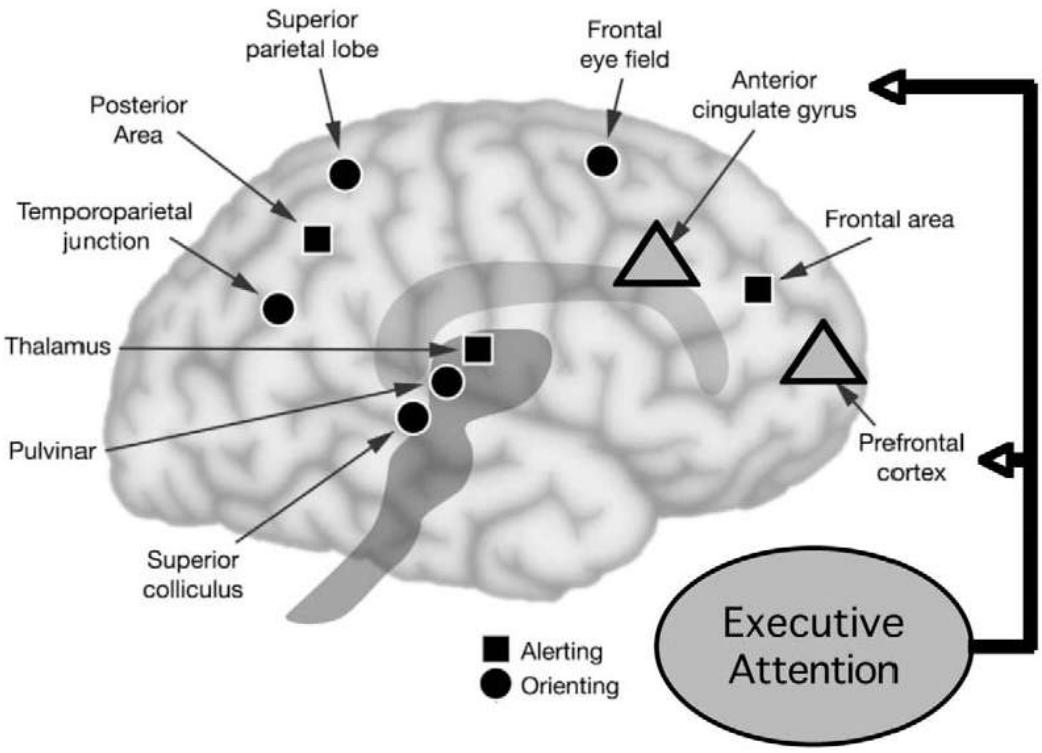

Figure 2: Anatomy of three attentional networks: Alerting (Square), Orienting (Circle) and Executive Attention (Triangle) (Posner and Rothbart, 2007).

Encyclopaedia Britannica (2020) reported that Executive attention is involved with the frontal lobes which is associated with a condition called dysexecutive. Thus, damage to the frontal lobes, can affect the role of executive attention in the control of thought, behaviour, and emotion. Dysexecutive syndrome is often accompanied by diminished social inhibitions due to significant reduction in the individual's abilities to set goals, make plans, and initiate actions. Thereby it leads to behaviour that is considered rude or inappropriate. Excessive use of alcohol and other drugs can also lead to similar behavioral problems.

Executive Attention and Learning

Executive functions and their components which are involved in planning strategies and in cognitive monitoring have vital roles in academic success. A broad agreement exists about learning disorders that result in emotional problems, like the acute effect of a psychosocial stressor (Vogel & Schwabe, 2016) or the neurocognitive aftermath of early and chronic stress situations (Nemeroff, 2004) emerges due to the modulation of neuronal circuits in the prefrontal cortex paired with subcortical structures like the basal ganglia and the hippocampus (Daw & Shohamy, 2008).

Paying attention to these emotional aspects is crucial to promote learning. The modulation of neuronal circuits in the prefrontal cortex paired with subcortical structures like the basal ganglia and the hippocampus is responsible for the interaction between motivation and cognition (Daw & Shohamy, 2008).

Learning could be delineated by reinforcement through this map of cortical activation, which is sensitive to the motivational influences related to incentives. Berridge (2004) has defined the value of the incentive in terms of stimulus properties, and specifies the behavioral choices made in a particular domain of action.

Teruel (2013) stated that "all lasting learning processes and memory consolidations are emotionally colored" i.e. during learning, emotional processing allows for maintained, selective attention to take part in the circuit of working memory and in the access to new modules of executive functioning that guarantee the efficacy and durability of learning. This also suggests modern teachers to develop understanding and ability to distinguish emotions in learning by enabling playful and innovative neuro-psycho-pedagogical activities that promote the passion for efficient use of information for the individual and collective benefit, allowing each individual to stand out for their individual talents and contributions to society.

Focusing only on intellectual and cognitive aspects of learning by neglecting the emotional variables can be a mistake since the integration between both aspects is crucial for a holistic comprehension of this always complex phenomenon.

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Executive Attention and Performance

Children with low attentional abilities have lower performance in tasks assessing the Executive Functions and make more errors in the most complex aspects of the task with respect to children with higher abilities (Arán-Filippetti, V., & L. Krumm, G., 2013).

Individual differences play an important role in efficiency of executive attention in school competence and socialization (Checa, et al., 2008; Eisenberg, et al., 2010, 2011; Rueda, et al., 2010). Besides school preparation, executive functions constitute a marker of quality of life in domains like professional progress in adult life, getting and maintaining a job, developing healthy living habits and forming adequate interpersonal relationships (Diamond & Ling, 2016).

Children having greater executive attention efficiency have higher levels of competence at school, understanding competence as a combination of school achievement and good and stable socio-emotional adjustment in the classroom (Bull and Scerif, 2001; Blair and Razza, 2007; Checa, et al., 2008; Rueda, et al., 2010).The anterior cingulate cortex which is considered as the main node of the executive attention network is part of the cinguloopercular network and is responsible for maintaining the mental set (task instructions or goals) associated with the current course of action, and closely linked to the dorsolateral prefrontal network, implicated in switching between mental sets (Dosenbach, NU., et al., 2007). Also, the neurotransmitter (dopamine) has a key role in modulating the activation of the executive attention network. Low levels of dopamine in prefrontal areas of the brain have been related to difficulties in inhibitory control, attention flexibility and conflict resolution (Posner, MI., et al., 2012).

Genotype and training both influence performance on specific attentional tasks (Rueda, et al., 2005). Cognitive training as an alternative to school learning can help improve and even speed up the executive function.

Implementation of certain computerized tasks to train working memory have also shown some efficacy (Harrison, et al., 2013). Bergman Nutley, et al. (2011) suggested that people improve the abilities that they practice, and this is transferred to other contexts where similar abilities are needed.

Motivation can also play a role for the core of executive function. The use of incentives in pedagogical scenarios could increase and improve cognitive processes, such as working memory and decision making, among others.Sohlberg, MM. & Mateer, CA. (1989) has stated that attention process therapy can improve the performance of adults with brain injury. One recent study also found improvement in visual attention in normal adults after training with video games (Green, CS. & Bavelier, D., 2003). Attention process therapy has also been adapted for use with children who have attentional deficits and has been shown to be beneficial for school age and preschool children (Kerns, KA., et al., 1999; Dowsett, SM. & Livesey, DJ., 2000).

Conclusion

The executive attention regulates various cognitive processes like thoughts, emotions, responses, problem solving, and various information which may either be accepted into short-term memory or blocked from it. Executive attention is associated with the frontal lobe region of the brain and its development is likely related to changes of brain areas's structures. The damage to the frontal lobes can affect the role of executive attention in the control of thoughts, behaviour and emotion. It also plays an important role in learning and performance which may further be influenced through both, the genetic as well as psychological factors. Working memory and executive attention enhance the processing of relevant information for goal-directed behaviour and the amount of information that executive attention is capable of handling at a given time differs from person to person. Some studies have indicated that children having greater executive attention efficiency have higher levels of competence and children with low attentional abilities have lower performance in tasks. Various cognitive training and computerised tasks may be helpful in training working memory that further can improve executive attention. Also, some psychological factors like motivation, use of incentives in pedagogical scenarios can play a role for the core of executive function which constitute a marker of quality of life in various domains like professional progress in adult life, getting and maintaining a job, developing healthy living habits and forming adequate interpersonal relationships.

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