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Attention and its importance for education

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Theme/s:

Effective lifelong learning / Effective teaching / Learning how to learn

This report arises from Science of Learning Fellowships funded by the International Brain Research Organization (IBRO) in partnership with the International Bureau of Education (IBE) of the United Nations Educational, Scientific and Cultural Organization (UNESCO). The IBRO/IBE-UNESCO Science of Learning Fellowship aims to support and translate key neuroscience research on learning and the brain to educators, policy makers, and governments.

Executive Summary

Attention is not a unitary process. One popular model identifies three attentional networks (with their own functions, neural circuits, and predominant neurotransmitters): alerting, orienting, and executive attention. Those networks interact permanently between them.

Attention circuits develop and mature throughout childhood and adolescence, through the interactive influences of genes and environment.

The three networks can be trained through educational interventions.

It could be important to include in teacher training information about what attention is, what forms attention takes, how attention develops and works, and how it can be trained.

What is attention?

Attention is brain processes that let us focus on a specific stimulus or task, while filtering out distractions[1]. It is a complex set of processes that involves specialized networks to carry out functions such as achieving and maintaining vigilance, focusing on something, and controlling thoughts and feelings[2]. Attention is essential for many cognitive processes, such as learning, problem-solving, and decision-making[3], and thus, having information about attention might be useful for educators.

Attentional networks

An important insight from neuroscience is that attention is not a unitary process. There are various models dividing attention in different components that interact between them (e.g.,[4]). In one popular model, three attentional networks have been identified as neuroanatomically distinct[5,6]. Each network involves different neural circuits and structures and different neurotransmitters are predominantly used within each network (Figure 1) [7]. The performance in these three attentional networks can be measured [8]and also trained [9]. Importantly, strong performance in one network is not necessarily correlated with strong performance in another network, consistent with the distinct nature of the three networks [8]. However, the three networks interact and work together to accomplish many tasks. Let's look at these networks in more detail.

Figure 1. Neuroanatomy and predominant neurotransmitters for each attentional network.

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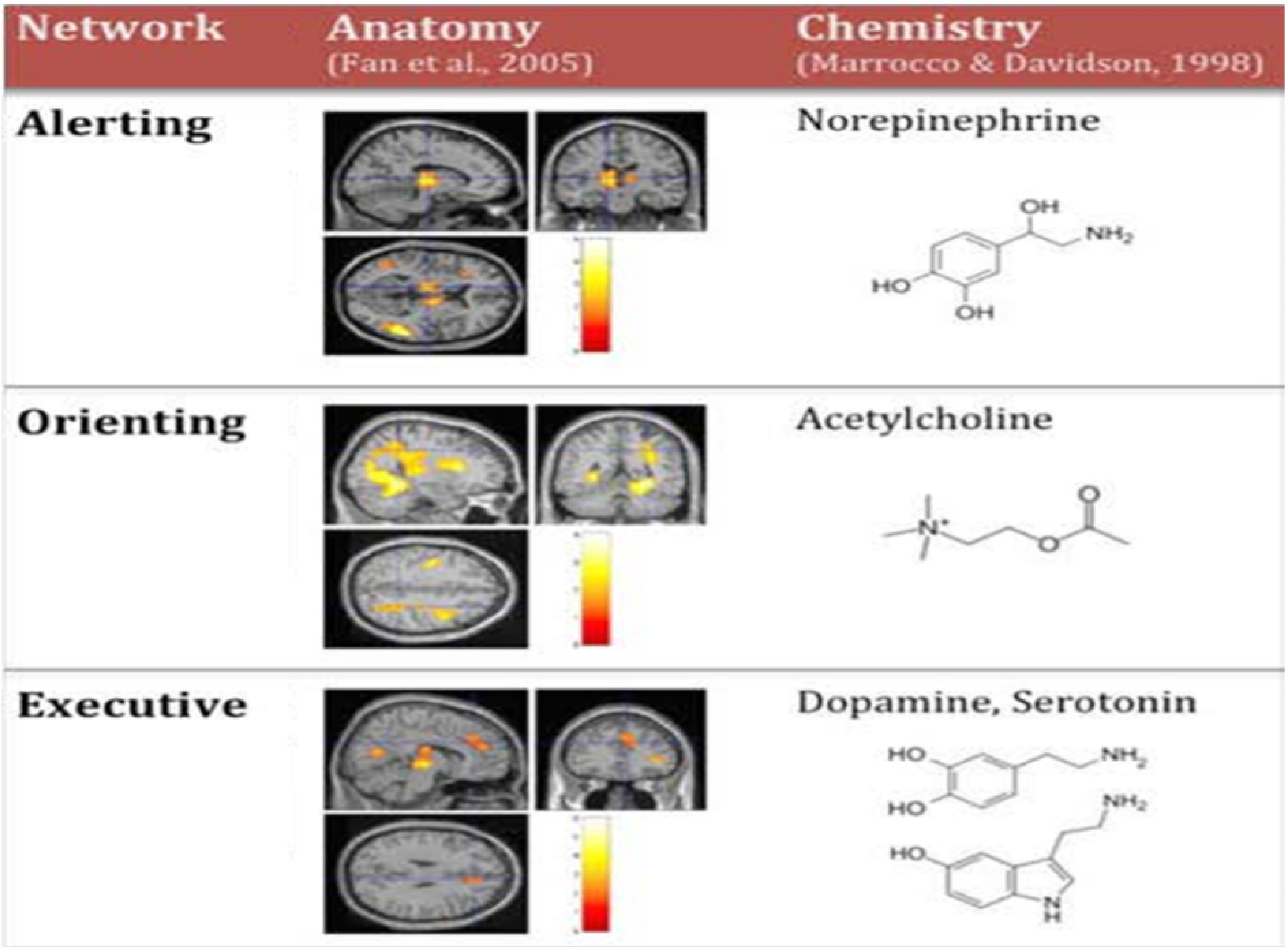

Note: this figure represents results obtained through methodologies to measure brain activation (functional magnetic resonance) and neurochemistry (pharmacological manipulation). It shows the differential neuroanatomy and neurochemistry of the three networks

As the name suggests, *alerting attention* involves the brain's ability to maintain a state of alertness and preparedness to respond to incoming stimuli. It is often associated with the release of the neurotransmitter norepinephrine[10], which can increase heart rate and blood pressure, and, for example, can help a person to focus and respond rapidly to important stimuli.

Orienting attention involves the brain's ability to shift its focus to a new stimulus or target. This type of attention is associated with the brain's ability to move the eyes and orient the head and body towards the stimulus to process it[11]. The dominant neurotransmitter for this attentional network is acetylcholine, which has been linked with memory and concentration, among other functions[10].

Executive attention[[1]] involves the brain's ability to control and regulate cognitive processes, such as working memory, problem-solving, and decision-making (Garon et al., 2008). The predominant neurotransmitters in this network are dopamine and serotonin; they have been linked with regulation of emotion and cognition[10]. Executive attention is essential for complex cognitive tasks that require cognitive control, thus executive attention seems the most relevant for most learning expected to occur in school[12].

To exemplify how do these networks are seen inside the classroom, let's imagine a primary school class which is starting after a break. Children came from the break, sit down while speaking between them, but started to shut up progressively, waiting for the teacher to start to talk. Children are using *alerting attention* to wait prepared for the teacher start a lesson. Let's imagine that now, a geometry lesson starts. However, to be awake is not enough to understand the lesson: it is also necessary to direct their attention to the teacher through the *orienting attention* network. Children focused in a butterfly outside the classroom, or feeling hungry and thinking in the next meal, might not be able to learn from the lesson. But let's imagine now that the geometry lesson is about rectangle surface calculation. Children already might have learned how to calculate the square surface. But this is the first time of rectangle surface calculation. So now, *executive attention* is needed for voluntary concentration on how to solve the problem is needed, as well as the avoidance of distractions, such as the previously known formulae for square surface.

Remarkably, all networks interact between them, as well as with another cognitive processes such as executive functions (https://solportal.ibe-unesco.org/articles/executive-function/). Thus, although those networks can be identified and each one has its own function, it does not mean they act separately. Instead, the three networks work in permanent interaction and most task (in school, home, and general life) would require being in alert, orienting to the correct stimulus and also avoiding distractions to reach the goal. Thus, the point of distinguishing between networks is not to think they are mutually excluding, but instead, distinguishing among these networks might help educators to recognize different forms of attention interacting during school activities and tasks.

Development of attentional networks

Developmental trajectories

The brain regions and processes involved in attention develop and mature throughout childhood and adolescence[1]. Performance on attentional networks tasks increase across infancy and childhood, and further, executive attention network performance continue increasing during adolescence. Executive attention is the attentional network with a prolonged development. In laboratory studies, the ability to maintain attentional focus during the execution of a repetitive task (for example, to press a button on a computer when a stimulus appears) improves markedly in the preschool years[13], and continues to develop progressively until around 13 years of age, when performance is similar to that of adults[14].

However, being developed is not a synonym for immutability. Once those networks are developed, school and other life experiences will continue shaping attentional networks, producing individual variability in attentional performance.

Factors influencing attentional networks development

As with all cognitive processes, the development of attentional networks is partly specified by genes and is also related to experiences through the actions of caregivers and the culture[15]. Genes and experiences interact in complex ways to produce attentional networks' development. In that interaction, the experience of practicing and using these networks (for example through learning in school) has a main role in helping attentional networks to develop over time.

Environmental factors that can influence the development of attention include the quality of a child's early experiences, such as the amount of stimulation and support they receive, as well as their exposure to stress and adversity[16,17]. One of the most studied environmental factors affecting attention is socioeconomic status. For example, in a study[18] conducted with children between 3 and 8 years of age, brain functioning during an executive attention task was compared by socioeconomic status (measured through a proxy: maternal education). Specifically, researchers measured brain functioning (using a method called event-related potential) during the execution of a task: children had to listen simultaneously to two stories, but only focus on one of them. The children were divided into two groups by their mothers' education levels (higher or lower) and their performance at the task, as well as brain activity during the execution of the task were compared by group. Results showed that both groups differed at their brain functioning when filter irrelevant information and that children in the low-education-mothers group showed lower ability to attend only one of the stories. This suggests that socioeconomic status might be one of the environmental factors affecting executive attention development. Again, it does not mean determinism: other experiences, similar to the ones provided by school, can change that scenario as it will shown in the following section.

Genetic factors also play a role in the development of attentional networks. Research has shown that genes can influence the development of attention and the brain regions involved in attention[19]. However, as with the socioeconomic status factor, genetic influence does not mean determinism: on the contrary, there is evidence showing a high malleability of attentional networks.

Training attentional networks

There are many ways of improving attentional networks' performance[2,20]. Experiences such as education (but also any other life experience), can alter attentional networks. The malleability of attentional networks was demonstrated in intervention studies in which networks were trained through specific activities, and attentional networks (as well as brain functioning related to those networks) were measured before and after the intervention.

For example, a study conducted in US[21], explores how an educational intervention might influence attentional networks development children of 4 and 6 years of age. To do that, 49 children were divided into two comparison groups (one of them did not receive any intervention while the other watched popular children's videos) and one group received the intervention 5 days a week over a 2- to 3-week period. The intervention consisted of computerized exercises with an increasing demand for attentional networks. Exercises included tracking with a mouse a cartoon on the screen was an exercise (orienting attention was mainly demanded) or clicking as fast as possible when there was a sheep but not if the cartoon was a wolf (mainly demanding the executive attention network). Before and after activities in control and intervention groups, performance on intelligence and on the three attentional networks was measured with a behavioral task, and also, brain functioning was registered (with an electroencephalogram) during that task. Genotyping of a dopamine-related gene (DAT1), and parental questionnaires relating to the child's temperament were also acquired. Comparison of performance before intervention in all groups, showed a strong improvement in executive attention and intelligence from ages 4 to 6 years, showing its accelerated development between those years of life. Also, temperament and genotyping seemed to be factors of importance for explaining individual differences. However, and this is key for education, both 4 and 6-year-olds showed better performance after the training than did the control groups. This finding applies to behavioral scores of the executive attention network as measured by the attention network test, as well as to brain functioning during that test. This study demonstrated that attentional networks can be trained, and that brain functioning associated with those networks can be changed, through educational interventions (besides genetic or temperamental individual differences).

Conclusion

There is a significant amount of neuroscience research on attention. Their efficacy will depend on biology but also on experiences (such as the ones provided by school). Thus, as part of teacher training, it could be important to include information about what attention is, what the forms of attention are, how they develop and work, and that they can be trained, based on our current neuroscientific understanding.

[1] In the context of this brief executive attention will be considered synonymous with selective attention, the process that allows an individual to concentrate on a particular input for further processing while simultaneously suppressing irrelevant or distracting information.

References

1 Rueda, M. R. et al. Development of attentional networks in childhood. *Neuropsychology*, **42**, 1029-1040 (2004).

2 Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L. & Posner, M. I. Training, maturation, and genetic influences on the development of executive attention. *Proc. Natl. Acad. Sci. U.S.A.*, **102**, 14931-14936 (2005).

3 Rueda, M. R., Checa, P. & Rothbart, M. K. Contributions of Attentional Control to Socioemotional and Academic Development. *Early Educ. Dev.*, **21**, 744-764 (2010).

4 Corbetta, M. & Shulman, G. L. Control of goal-directed and stimulus-driven attention in the brain. *Nat. Rev. Neurosci.*, **3**, 201-215 (2002).

5 Abundis-Gutiérrez, A., Checa, P., Castellanos, C. & Rueda, M. R. Electrophysiological correlates of attention networks in childhood and early adulthood. *Neuropsychologia*, **57**, 78-92 (2014).

6 Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I. & Posner, M. I. The activation of attentional networks. *NeuroImage*, **26**,

471-479 (2005).

7 Fan, J., McCandliss, B. D., Sommer, T., Raz, A. & Posner, M. I. Testing the Efficiency and Independence of Attentional Networks. *J. Cogn. Neurosci.*, **14**, 340-347 (2002).

8 Anderson, P. Assessment and Development of Executive Function (EF) During Childhood. *Child Neuropsychol.*, **8**, 71-82 (2002).

9 Rueda, M. R., Checa, P. & Combita, L. M. Enhanced efficiency of the executive attention network after training in preschool children: Immediate and after two months effects. *Dev. Cogn. Neurosci.*, **2**, 192-204 (2012).

10 Marrocco, R. T. & Davidson, M. C. The neurochemistry of attention. In *The attentive brain*. Parasuraman Ed., Cambridge (1998).

11 Johnson, M. H., Posner, M. I. & Rothbart, M. K. Components of visual orienting in early infancy. Contingency learning, anticipatory looking, and disengaging. *J. Cogn. Neurosci.*, **3**, 335-344 (1991).

12 Berger, A., Kofman, O., Livneh, U. & Henik, A. Multidisciplinary perspectives on attention and the development of self-regulation. *Prog. Neurobiol.*, **82**, 256-286 (2007).

13 Danis, A., Pecheux, M. G., Lefevre, C., Bourdais, C. & Serres-Ruel, J. A continuous performance task in preschool children: Relations between attention and performance. European Journal of Developmental Psychology, **5**, 401-418 (2008).

14 Lin, C. C. H., Hsiao, C. K. & Chen, W. J. Development of Sustained Attention Assessed Using the Continuous Performance Test among Children 6-15 Years of Age. *J. Abnorm. Child Psychol.*, **27**, 403-412 (1999).

15 Posner, M. I. & Rothbart, M. K. Research on attention networks as a model for the integration of psychological science. *Annu. Rev. Psychology*, ***58***, 1-23 (2007).

16 Clearfield, M. W. & Jedd, K. E. The Effects of Socio-Economic Status on Infant Attention. *Infant Child Dev.*, **22**, 53-67 (2013).

17 Mezzacappa, E. Alerting, orienting, and executive attention: Developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child Dev.*, **75**, 1373-1386 (2004).

18 Stevens, C., Lauinger, B. & Neville, H. Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: an event-related brain potential study. *Dev. Sci.* **12**, 634–646 (2009).

19 Fan, J., Wu, Y., Fossella, J. A. & Posner, M. I. Assessing the heritability of attentional networks. *BMC Neurosci.*, **2**, 1-7 (2001).

20 Posner, M. I., Rothbart, M. K. & Tang, Y. Y. Enhancing attention through training. *Curr. Opin. Behav.*, **4**, 1-5 (2015).

21 Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L. & Posner, M. I. Training, maturation, and genetic influences on the development of executive attention. *Proc. Natl. Acad. Sci. U.S.A.* **102**, 14931-14936 (2005).