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Computerized working memory training and cortex neuroplasticity: A review article

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SUMMARY

Sufficient and effective computerized working memory training can lead to an increase in the brain activity especially in a neural network underlying working memory, by increasing levels of neurotransmitters such as dopamine, that causes neuroplasticity which activates transferring of effects to near and far cognitive tasks, the great effects of computerized training can be adapted automatically with the performance level of subjects; to optimize training effects.

Keywords: Working memory (WM); Computerized training; Neuroplasticity; Dual n-back training

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INTRODUCTION

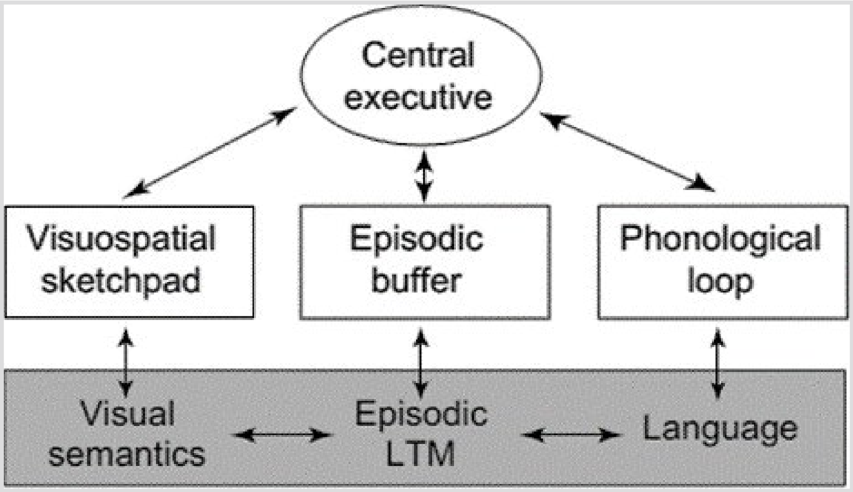
Working memory (WM) generally refers to a cognitive system with a limited capacity that is responsible for active temporary storing, manipulation, and retrieving of information in a simultaneous way in services of ongoing cognition [1-4]. Working memory is considered a core of human cognition because it receives information from attention and perception to store and manipulate it, then transfers it to long-term memory (LTM) to store in a permanent way or to make interference between the newly accepted information and the content of long-term memory (**Fig. 1**) [5].

According to Baddeley's Hitch multi-component model, working memory consists of a supervisory component called the central executive, it considered as an attentional control system, also it is responsible for other regulatory functions such as control of action, problem-solving, coordinating between other slave components, regulating relationships between working memory and long-term memory. Working memory also consists of [3] slave components, the first one is a phonological loop (PL) that is responsible for storing information with phonetic and verbal codes for a brief period, the second one is visuospatial sketchpad (VSSP) which is responsible for holding visual and spatial information. Both phonological loop and visuospatial sketchpad have limited storing capacity. The last slave component called an episodic buffer that is responsible for integrating information from a variety of sources; to form meaningful chunks, and it forms an interface between long-term memory and the rest components of working memory [6-8].

Working memory capacity (WMC) has emerged in the past +30 years as a strong predictor for many cognitive tasks [9]. The term working memory capacity is used to refer to a domain-general ability that coordinates attention and working memory in order to control cognition and action [10]. Working memory capacity predicts a wide range of cognitive abilities such as reading comprehension and problem solving [11,12]. Also predicts reasoning and fluid intelligence (gf) [13-15]. Many studies documented relationships between working memory capacity and attention, the focus of attention [16], avoiding powerful stimuli that cause distraction [17], also predicts the ability to suppress reflexive movements [18].

There is a general assumption that working memory is considered as a general resource, this means that if working memory training is successful, the training effects

Fig. 1. The Multi-component working model [5].



will transfer to untrained tasks [19]. Such transferring of training effects will happen if this training leads to improve the domain- general attentional capacity, which is responsible for performing many different tasks, for example, improvements on visuospatial working memory after training on verbal working memory, and this is considered as a near transfer effect, whereas far transfer effects will appear on tasks almost different from those trained such as general intelligence [20].

Working memory depends mainly on appropriate neurotransmission of dopamine [21]. Approved that training of working memory improves working memory capacity by training for 14 hours over 5 weeks, and this was associated with changes in the density of cortical dopamine D1 receptors, especially in the prefrontal and parietal D1 binding potential.

In the field of cognitive training in general and specifically working memory, the training methods vary widely, but computerized working memory training is still the most important and effective strategy. Klinberg et al., Stated that computerized training can be adapted in automatically and continuous way to adjust with the performance level of the trainer to optimize the training effect [22].

In a study by Olsen et al., working memory training's effect on brain activity was assessed by functional magnetic resonance imaging (FMRI), two experiments were carried out on healthy adult human subjects who practiced working memory tasks for 5 weeks [23]. Brain activity assessed before, during, and after training by FMRI, results indicated that an increase in working memory performance after training was related to increased brain activity in the middle frontal gyrus, superior and inferior parietal cortices. They concluded that changes in cortical activity might be an indicator of plasticity in the neural systems underlying working memory.

"Neuroplasticity refers to the brain inherent ability to adapt with microscale changes in response to altered environmental demands" [24].

Klinberg also indicated that working training related to changes in brain activity in the frontal, parietal cortex, and basal ganglia, which accompanied with changes in dopamine receptor or density, the training-induced plasticity in a common neural network for working memory causes transfer of the training effect to the non-trained working memory task [25].

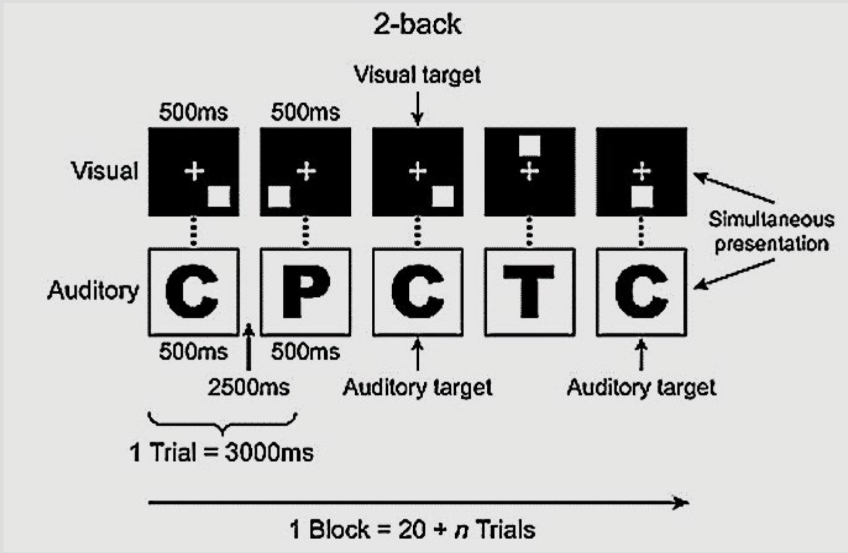
DUAL N-BACK TRAINING

One of the most important and effective adaptive computerized training programs for working memory is Dual n-back. The dual-n-back task has a complex nature depends on different executive functions because it consists of two n-back simultaneous tasks, the first one is a visuospatial task and the second is an auditory-verbal task, to perform a dual n-back task many executive functions will participate, such as working memory updating, monitoring of ongoing performance, divided attention and suppression of irrelevant stimuli [26]. The most popular method to apply dual n-back is to order volunteers to monitor a series of stimuli on a computer screen and respond whenever a stimulus is presented, which is the same as the one presented in trials previously, the symbol n represents pre-specified trigger 1, 2, or 3. The task depends on monitoring, updating, and manipulation of temporarily stored information [27].

The way that task is applied practically in the laboratory is explained by Jaggei et al. [26] (**Fig. 2**). In the dual n-back task, volunteers see two series of stimuli present in a simultaneous way at the rate of 3 seconds per stimulus, one series contains a single letter (verbal stimulus), and the second series contains visuospatial tasks (visuospatial stimulus) on a screen. The participants were ordered to decide for each string whether the current stimulus matched the one that presented (n) items back in the series according to the performance level of each participant the value of (n) changes automatically if this performance level increased; the value of (n) will increase transferring from (1n) to (2n)…etc, and vice versa; so the task difficulty changed in an adaptive way, these two simultaneous tasks activates executive functions required for each task.

The visual stimulus used in dual n-back is a box

Fig. 2. The dual n-back task [26].



presented in one of eight locations around the periphery of the screen, but the auditory stimulus is one of eight letters, each session in the training consists of 20 trials blocks. In the adaptive form of dual n-back participants have to do a pretest session, each trial lasted for 3 seconds, 500 milliseconds for item presentation time, and 2500 milliseconds for responding time. The participants were instructed to respond by using the keyboard, if the participants achieved each block trial with errors less than three auditory targets and three visuospatial targets, the training transfers automatically to the next level, and the (n-back) increases from (1) to (2)…etc, but if the participants made more than five errors in total; the n-back level was decreased by one [28].

CONCLUSION

According to importance of working memory, and its central role in human information processing system; many studies in recent time investigated the working memory training, specially an adaptive computerized training that was associated with changes in the density of dopamine neurotransmitter specially in the frontal and parietal cortices; and this may lead to a neuroplasticity in the neural systems underlying working memory.

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