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Review

Cognition enhancers between treating and doping the mind

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Abstract

Memory, attention and creativity represent three different cognitive domains, which are interconnected and contribute the "mental performance" of an individual. Modern neuroscience has investigated some of the neuronal circuits and of the neurotransmitters and molecular events underlying the above-mentioned cognitive functions. Within this renewed reference context, some of the properties of the components of the remedies to increase mental performance have been studied and validated in experimental models and, to date, these substances are named "smart drugs", "memory enhancing drugs" or "nootropic drugs" (from the Greek root *noos* for mind and *tropein* for toward). Recently pharmaceutical industries are increasingly focusing on the research for potential substances in this field: several "smart drugs" are in clinical trials and could be on the market in few years. Furthermore, a quick survey from Internet highlights the presence of a great variety of both approved and non-approved drugs, with some of them addressing to only medical and others to performance-oriented use, opening room to some reflections or speculations from scientific and ethical points of view.

In order to point out the effect of nootropic drugs on cognition of healthy people, we reviewed the literature on drug enhancement of various cognitive functions, including memory, attention and creativity. As their simplest, memory is regarded as the ability to remember events or learned material, attention is the cognitive process of selectively concentrating on one aspect while ignoring distracters and creativity could be described as the ability to create products or ideas which are original and which possess a social usefulness.

Reports from literature reveal that some medications currently available to patients with memory disorders may also increase performances in healthy people and that drugs designed for psychiatric disorders can also be used to enhance certain mental functions. However, the long-term effects of these drugs are unknown, but their apparent effectiveness allows room to their use and misuse. At variance with these literature data showing scientific, even if poor, evidence of the effect of smart drugs in the field of memory and attention, only indirect information on creativity can be obtained by studies of the effects of diseases and drugs on the artistic productivity of classic painters and famous authors, offering a link to understand the neuronal basis of this cognitive function and a cue to understand how drugs (used to correct the illness) may affect the function.

On the basis of these cues, in this review we will discuss some critical aspects of the different cerebral circuits and molecular events regulating memory, attention and creativity in order to outline the neurobiological bases of the effects of "smart drugs" on cognitive functions, and to evaluate their putative pharmaceutical development.

Keywords: Memory; Attention; Creativity; Cognitive enhancers; Neuroinformatics

Contents

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1. Introduction

This review has the aim to stimulate some reflections on the neurochemical and molecular bases of the human cognition and on the attempts that have been done and are actively pursued to modulate such function by the use of chemicals. While it is obvious to think to "memory pills" for the elderly, so popular in the last two decades, and to drugs to improve cognitive functions in demented people, the present trend and demand for drugs able to improve mental performance in normal adult people should also be carefully considered. In a quickly evolving and demanding society, the mass of information flooding daily from the media and Internet, and needed for the new generation of professionals is increasing the demand for drugs able to help the people to sustain mental performance. Moreover mental performance it is not just memory is also attention and problem solving ability (Fig. 1).

2. Drugs and memory

During learning and the formation of memories, our brain undergoes physical and chemical changes. Through a process called synaptic plasticity, involving signal transduction pathways and induction of gene expression, signal transmission at existing connections between certain neurons may become more efficient while other connections may be silenced, and new synapses may be formed between nerve cells. This process undergoes a continuous remodeling with time and new experiences. The ability to form memories of various types (for example short- or long-term memories) is a phenomenon observed in multi-cellular organisms from snails to man. Frequently the same fundamental molecules have been implicated in different kinds of memory and in species as different as fruit flies, sea slugs, snails, birds and mammals, suggesting that the molecular machinery for memory has been widely conserved. Memory is not a single entity; the acquisition, formation and recall of memories are a collection of complex processes involving diverse neuronal systems in the brain. Related to the duration, some memories may last for only a few minutes or hours (short-term or working memory) or may last days, months or even a lifetime (long-term memory (LTM)). In relation to the content we may distinguish implicit memory (also known as procedural or non-declarative memory) and explicit memory. The former is unconscious and refers to a heterogeneous collection of motor abilities, habits, emotional feelings and sensations. This memory is used in motor skills. Declarative or explicit memory deals with facts, ideas and events that can be called up into conscious recollection.

The process of memory formation seems to proceed through three general stages. The first stage – acquisition (learning) – involves the initial perception of a new experience. Second, a short-term memory (STM) of this newly acquired experience is

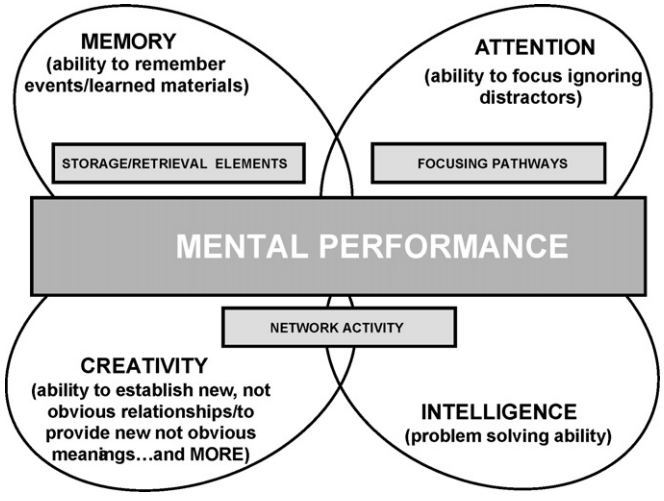

Fig. 1. Cognitive functions contributing to mental performance are distinct but heavily intermingled.