Aspects of Cognitive Improvement: Brain-Hacking

Clark Jones

University of Antwerp, Antwerp, Belgium

*Corresponding Author**
Clark Jones
University of Antwerp, Antwerp, Belgium
E-mail: incomingstudents@uantwerpen.be

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Abstract

As demands for cognitive functioning increase in our advanced information culture, numerous methods for enhancing brain function have emerged. The effectiveness and potential risks of these methods have led to debates about their ethical, societal, and medical implications. Public discourse often treats cognitive enhancement as a uniform concept. However, a closer look reveals that cognitive enhancement is actually multifaceted, involving various types of interventions that fall into biochemical, physical, and behavioral categories. These enhancers vary widely in their mechanisms, targeted cognitive domains, timeframes, availability, side effects, and effects on different populations. This study explores the different aspects of cognitive enhancement, evaluates key examples across these dimensions, and proposes a framework for both theoretical and empirical research.

Keywords: Brain hacking • Neuro-ethics • Cognition • Memory • Working memory • Attention

Introduction

As cognitive demands, originally adapted for a different environment, rise in our increasingly complex world, the need for advanced cognitive abilities have become more pressing. In today's information-rich and postindustrial society, acquiring and maintaining cognitive skills often requires lengthy, labor-intensive, and expensive educational processes. Additionally, as the pace of development accelerates, these skills may become outdated or deteriorate due to natural aging. Individual differences in cognitive abilities also affect how quickly people can acquire new skills, significantly impacting their life outcomes.

Given these challenges, strategies to enhance the acquisition and preservation of cognitive skills are becoming more vital. While humans have sought to improve performance throughout history, today's unique context features rapidly evolving difficulties and technologies aimed at addressing them. More people are now exploring ways to surpass natural cognitive limitations or "hack" brain function, paralleling the hacking culture seen in technology fields. This advancement has generated both enthusiasm and concern, with polarized opinions on the feasibility, benefits, risks, and long-term effects of cognitive enhancement technologies.

The lack of concrete evidence contributes to these debates, making it easy to support any stance without empirical backing or to dismiss opposing views as irrational. Another major source of contention is the tendency to view enhancement as a monolithic phenomenon rather than recognizing it as a diverse set of methods with distinct implications. To foster a well-informed theoretical discussion and develop effective empirical research, it is essential to understand how specific enhancement techniques affect different cognitive functions, their side effects, and associated costs. Our review aims to establish a comprehensive framework to support both theoretical exploration and empirical investigation.

Action structure

Enhancement is commonly defined as interventions aimed at improving mental functioning beyond what is necessary for maintaining or restoring good health. The effectiveness of various non-pharmacological enhancement methods has been assessed in previous studies [1,2]. To better organize the diverse approaches to cognitive enhancement, we propose categorizing these solutions into three main domains based on their fundamental mechanisms of action: pharmacological, physical, and behavioral therapies. Although there are no strict guidelines, most cognitive enhancement techniques can be classified within these categories.

Biochemical approaches

Biochemical agents are frequently discussed as cognitive enhancers in public discourse, but they encompass more than just pharmaceutical "smart drugs." Everyday substances, such as oxygen, have been shown to enhance memory processes and neuronal activation in brain regions associated with memory [3-5]. Biochemical enhancements often involve specific nutritional components with historical significance, such as glucose and caffeine, both of which have been proven to improve cognitive function in various studies [6-8]. Additionally, beverages derived from caffeine-containing plants, like guarana, have also demonstrated cognitive benefits and non-caffeine elements in these plants might have their own cognitive advantages [9,10].

There is debate about whether commercially produced drinks offer cognitive benefits beyond caffeine, glucose, or guarana extracts. Nutritional components like flavonoids found in cocoa, curcumin in curry powder, folic acid, and omega-3 fatty acids have some evidence supporting their role in cognitive enhancement. Additionally, fasting and overall calorie restriction may improve memory in older adults. Traditional remedies, including herbs from Western, Chinese, and Indian medicine, such as *Bacopa monnieri*, have been linked to cognitive improvement, although well-known traditional Asian herbs like ginseng and Ginkgo biloba have not consistently demonstrated benefits in healthy individuals.

Recreational drugs with a history of use, such as nicotine, which can improve attention and memory, and alcohol, which may enhance certain cognitive functions like creativity or memory in retrospect, also fall into this category. Pharmaceuticals are often perceived as prime cognitive enhancers by the public, including synthetic stimulants like amphetamines, methylphenidate, and modafinil, as well as dementia treatments like acetylcholinesterase inhibitors and memantine. However, evidence of their effectiveness in enhancing cognition in healthy individuals often falls short of theoretical expectations. Notably, the placebo effect can be significant; for instance, individuals who believed they were taking mixed-amphetamine salts reported improved performance and showed minor objective gains, regardless of their actual medication status.

In addition to traditional neurotransmitters, brain signaling molecules like adrenaline, GABA, glucocorticoids, ovarian hormones, and other neuropeptides have been explored as potential cognitive enhancers.

Genetic modifications, which have improved various learning and memory functions in animal models, represent another pharmacological approach to enhancement. Despite advances in understanding the genetic underpinnings of cognitive traits in humans, genetic modifications remain a prospective rather than current enhancement strategy.

Physical techniques

Currently, brain stimulation devices are among the most widely discussed physical treatments for cognitive enhancement. While invasive techniques like deep brain stimulation are typically reserved for individuals with pathological conditions, several noninvasive stimulation methods are increasingly being used on healthy individuals. These methods include electrical stimulation techniques such as Transcranial Direct Current Stimulation (tDCS55), Transcranial Alternating Current Stimulation (tACS56), Transcranial Random Noise Stimulation (tRNS57), and Transcranial Pulsing Stimulation (tPS57) (MNS61).

Key aspects of these stimulation protocols are crucial: commercial do-it-yourself electrical brain stimulators might cause harm rather than cognitive improvement, and systematic evaluations have raised doubts about whether electrical brain stimulation has a clear and consistent enhancing effect across various cognitive domains, even under controlled laboratory conditions. Recent studies have questioned the neurophysiological relevance of some of the most commonly used electrical brain stimulation configurations. In response, the development of noninvasive deep brain stimulation utilizing temporally interfering electric fields could offer a more systematic and targeted approach than current methods.

Domain of consciousness

The human mind comprises a variety of cognitive processes rather than functioning as a unified whole. Consequently, no single cognitive enhancer benefits all cognitive functions equally. Instead, most cognitive enhancers exhibit varying levels of effectiveness across different cognitive domains. For instance, mnemonic strategies enhance memory but do not affect meditation skills, while meditation training improves attention but does not impact mnemonic strategies.

Conclusion

Enhancing one's cognitive abilities is clearly a multifaceted endeavor. For every theoretical or empirical study subject, however, not every dimension is relevant. Many empirical cognitive enhancement researchers, for example, are primarily concerned in studying the neurobiological and psychological factors that underpin cognitive functions. The characteristics of availability and social approval are mainly unimportant for this goal. Many theorists, on the other hand, are concerned in the social and ethical implications of cognitive improvement, as these aspects may be particularly important. Side effects and temporal aspects may be of secondary value to empirical researchers interested in the neural mechanics of specific cognitive processes, but they are critical for users considering which cognitive enhancement approach to utilize for a specific goal. Direct comparisons between cognitive enhancement strategies with radically different modes of action have been rare up to now, and more comprehensive comparisons across dimensions may be difficult: practical issues of information availability from different dimensions aside, interventions typically differ on different dimensions, making global comparisons difficult. Furthermore, there are various interactions between different enhancers, further complicating the situation. Interactions between glucose and coffee, food and exercise, exercise and working memory training, video games and sleep, video games and brain stimulation, exercise and brain stimulation, and brain stimulation and sleep have all been observed.

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