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Mini Review

The Cognitive Training Quandary: 20 Years Summarized

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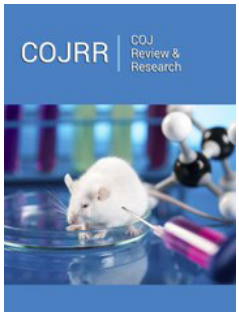

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Abstract

For the last 20 years, the plausibility to improve cognitive abilities by training has been a matter of discussion in the Cognitive Neuroscience research field. With a large number of published papers reaching opposite conclusions, the controversy seems to be far from over. Is cognitive training a powerful equalizer for society? Or should we stop investing resources in its research, due to the lack of generalized effects, as some scientists claim? In this mini review both sides of the debate are described and analyzed. Final remarks include a personal opinion, based on our experience developing and implementing a free cognitive training software proved successful to improve children's cognition through video games.

Keywords: Cognitive training; Video games; Executive functions; Children; Transfer

Abbreviations: EF: Executive Functions; WM: Working Memory; ADHD: Attention Deficit Hyperactivity Disorder

Introduction

Our behavior and actions are controlled by a group of mental processes critical for purposeful goal-directed behavior called Executive Functions (EF). They allow us to adapt to changing and challenging environments in order to achieve a broad range of everyday activities, such as modifying our route to work due to traffic or successfully studying for an exam [1]. The great variety of stimulus and experiences undergone during development shapes the brain and allows people to properly interact with the world and with other individuals [2,3]. Research has shown that certain socioeconomic contexts, such as living at risk, stress or early adversity, may act as negative modulators to EF development. Therefore, the problem of guaranteeing an equal access to this kind of 'environmental nutrients' arises. And cognitive training emerges as a potential powerful tool [4].

The effective exercise of EF is known as Cognitive, or Brain, Training and is based on the concept of neural plasticity: the remarkable ability the brain has to adapt to environmental changes, by for example enhancing performance in specific cognitive domains [5]. Just as athletes go to the gym to strengthen their muscles, which in turn allow them to run faster in the next race, stimulating certain mental processes through cognitive training may result in improvements in untrained aspects of cognition (phenomenon known as transfer [6]). During the last 20 years, research groups worldwide started to design and implement experimental protocols to elicit transfer. Interventions run in different populations confirmed that a positive impact can be achieved after training (not only in typically developing children, but also in children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD), Dyslexia, and even in adult patients with Alzheimer's disease) [7-10].

To date, numerous efforts have been made to understand how cognitive training works, but no consensus has been reached yet. The main concern is related to the transfer effects: are improvements in novel tasks really accomplished after training (i.e., far transfer)? Or are subjects just getting better in tasks similar to those practiced (i.e., near transfer)? Furthermore, can far transfer be truly reached through cognitive training?

Discussion

Arguments in favor of the effectiveness of cognitive training

Since the emergence of the idea that EF could be improved by training, many protocols have been designed and put to the test [11-13]. Those protocols are not homogeneous, and the diversity of their findings is not negligible. This is one of the most criticized aspects of this point of view. Several research teams have focused on developing cognitive training tools to stimulate one particular EF only: Working Memory (WM), our ability to retain and manipulate information for a very short period of time to accomplish a specific task [14]). WM training has shown to elicit far transfer to diverse areas, such as language acquisition, mathematical reasoning and novel problem-solving [15-17].

Other protocols intend to stimulate multiple cognitive aspects simultaneously and have shown promising results regarding far transfer [18]. Our research group, for instance, found improvements in untrained tasks that sometimes cascaded to real-world measures of school performance [19-21]. Moreover, a 2016 meta-analysis showed that the most effective interventions involve not only cognitive stimulation through gaming, but also strategies to reduce the impact of well-known negative modulators, such as stress or poor health [13]. The main criticism of multiple-domain training protocols is that many variables are manipulated in each experiment and the mechanisms for its effectiveness remain uncertain.

Arguments against the effectiveness of cognitive training

The first study that seriously questioned the effectiveness of cognitive training and, therefore, its ability to elicit far transfer was an online study performed in 2010 in which more than 10000 adults participated [22]. Results showed immediate improvements in trained tasks, but no impact in untrained capabilities. The conclusions were published in a prestigious journal and have since raised numerous methodological doubts which could explain the lack of evidence of far transfer. For instance, that the decision of which cognitive aspects to train, and for how long to do it, were not systematic but a player's choice instead [6,23].

Subsequently, research groups chose other strategies, and, in the past 10 years, many meta-analyses were published. Regarding the WM protocols aforementioned, for example, some of those studies argue that there is not enough evidence to ensure that the training transfers to other cognitive domains. Moreover, they discuss that other meta-analyses, which favor WM protocols' effectiveness, have inclusion biases and, sometimes, weigh evenly results from studies that include active control groups and studies which do not [24,25].

Another crucial argument of these meta-analytic studies points at the heterogeneity among training protocols. A 2015 paper analyzed some features of training protocols as modulators of far transfer. Results show that differences observed between training protocols were only due to the duration of each session and of the completion of the intervention [26]. Another recent experimental study evidenced a placebo effect related to subject's expectation of improving their cognition through training [27]. None of the mentioned published studies exhibited any evidence of far transfer. Most of the investigations described in this section, and other similar publications, suggest that no more resources should be invested to improve training protocols, due to the lack of evidence of far transfer effects. Nevertheless, many other studies propose interesting methodological improvements for cognitive training protocols that may allow us to end this controversy once and for all (e.g. [26-29]).

Meeting halfway

In 2014 an open letter authored by more than 70 researchers around the world argued that there is no evidence that cognitive training works nor that it impedes cognitive decline [30]. Months later, a letter in response, signed by a bigger group, was published enumerating the most important pieces of evidence which indicate that cognitive training does work, both in laboratory tasks and in real-life measures [31]. More importantly, researchers proposed a list of methodological standards in behavioral interventions for cognitive enhancement [32]. This list continues to expand, including various recommendations such as the implementation of active control groups. The validity of this debate, well represented in the previously mentioned discussion involving leading scientists around the world, evidences that the Cognitive training research area is still in an exploratory phase. Further complicating the discussion, focus is moving away from protocol details as the main cause of contradictory results. Recent research indicates that individual differences among subjects appear to be the main cause of noisy intervention outcomes [33,34]. The state of cognition prior to the intervention and the motivation to participate emerge as key to understanding why cognitive training does not always work for everyone [6]. The path now lies in deciding how those differences can be taken into account in order to design better, more personalized, training protocols.

Conclusion

The controversy surrounding the effectiveness of cognitive training is clearly still alive. In this mini review we tried to show some of the aspects that sustain this discussion, but there is still much work ahead. Just as in other topics of educational neuroscience, it is about time that the scientific community understands that the real world is much more complex than the laboratory. Prioritizing interdisciplinary exchanges between psychologists, biologists, educators, and other academics does not mean to lose scientific rigor. On the contrary, it adds a whole new plethora of points of view that opens the opportunity to novel solutions. We consider interdiscipline a necessity to solve real-world problems.

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