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Video games, cognitive exercises, and the enhancement of cognitive abilities

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In this review we explore the emerging field of cognitive training via distinct types of interactive digital media: those designed primarily for entertainment ('video games') and those created for the purpose of cognitive enhancement ('cognitive exercises'). Here we consider how specific design factors associated with each tool (e.g., fun, motivation, adaptive mechanics) and the study itself (e.g., participant expectancy, dose effects) can influence cognitive enhancement effects. We finally describe how the development of hybrid interventions that capitalize on strengths of each type of interactive digital media are anticipated to emerge as this field matures.

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There are a number of interventions that have demonstrated the potential to enhance cognitive abilities, ranging from the more traditional (e.g., nutrition, exercise) to the more technological (e.g., pharmaceuticals, genetic therapies, neurostimulation). One approach, although still controversial [1], that has been gaining momentum is the use of interactive digital media to augment cognition, typically referred to as cognitive training. Over the last decade, there has been a surge in the number of interactive software programs created with claims of their ability to improve fundamental aspects of cognition known as cognitive control (i.e., attention, working memory, and goal management (multi-tasking/task-switching)). Although there have been promising results, few studies have successfully demonstrated clear improvements on untrained cognitive tasks (what we refer to as cognitive enhancement, generalized benefits or transfer [2•,3]), and often not even for abilities that are highly related to training itself (i.e., near transfer [3–6]). In this review we differentiate between two types of interactive digital media: those designed primarily for entertainment [7•] ('video games') and those created for the purpose of cognitive enhancement ('cognitive exercises'). Exploring this dichotomy, we will consider how certain factors associated with each type of intervention and corresponding study designs may influence the potential for cognitive enhancement and for validating it experimentally.

Video games and cognitive exercises

In general, video games are designed with two primary goals: enjoyment and sustained player engagement. Many of today's most popular video games involve high levels of art, captivating music, and intricate storylines to create immersive environments for an enhanced player experience. Such video games typically involve carefully designed game mechanics that drive game play to be both challenging and fun, with careful considerations of reward cycles that deliver positive and negative feedback at appropriate times. Cognitive exercises share many, but not all, of these elements: these tools are more focused at challenging underlying neural systems or specific cognitive abilities due to their targeted approach, but often without the immersive elements that are core to entertainment video games. The dichotomy between video games and cognitive exercises can perhaps best be appreciated from the perspective of their physical analogies: a running-based treadmill program is a physical exercise targeting clear health outcomes, but is often laborious and not fun, despite anticipated benefits. Alternatively, playing a running-based sport (e.g., soccer) is often quite fun, but not inherently designed as a training tool to engender specific health benefits. Of course, there is subjectivity in assigning examples of interactive digital media into these categories, but this division provides a starting point for the following discussion.

One of the first examples of interactive digital media being used as a tool (in this case, for understanding training-related strategies) was Space Fortress [8], developed in 1983. It was carefully designed to intensely challenge several cognitive abilities through repetitive interactions, with the direct goal of examining different training strategies to accelerate learning. This approach, along with the state of video game industry at the time, explains why there were minimal elements directly promoting fun or engagement compared to modern video games. Cognitive training using Space Fortress has shown some positive effects on aspects of cognition [9,10], but transfer has not been attained consistently [11–13]. Since then, a plethora of cognitive training studies have emerged using this type of approach, several of them demonstrating positive training effects involving attention [14–16], working memory [17–19], and even intelligence [20,21•] (although see [22•,23]). Some, although not all, of these approaches have attempted to 'gamify' the training platforms via the inclusion of low-level reward mechanisms like points and colorful environments to increase participant engagement. The popularity of this gamification approach suggests that design factors typically found in entertainment-based video games are widely thought of as beneficial for cognitive enhancement.

There have also been notable reports of enhancements in the cognitive control abilities being induced by entertainment-designed video games. Starting with the seminal work of Green and Bavalier [24], positive effects have been found in those playing first-person shooter video games, such as heightened cognitive control compared to non-video game players and individuals training on other types of video games [24,25]. Along the same lines, recent work by Oei and Patterson demonstrated that video game training (primarily 'action' games, although effects were found with non-action games) with games downloaded from iTunes to an iPhone/iPod led to positive effects on attention and working memory abilities [26•,27]. While these results are encouraging, there have also been a number of video games training studies that have not observed beneficial effects beyond improvements on the game itself, including for action-based games [28]. For example, work by Boot and colleagues failed to show evidence of transfer to any test of cognitive control abilities following ∼20 h of game play in young adults on *Medal of Honor* (a first-person shooter game) or *Rise of Nations* (a real-time strategy game [29]; however, see [30]). Similar lack of effects were shown with younger adults after 15 h of playing web-based 'casual' games (e.g., puzzle or reasoning-based games [31]). Perhaps the most compelling data on this topic for older adults involves recent meta-analyses detailing a range of observed effects (both positive and negative) following video game training studies [32•,33]. These results remind us that the use of these platforms is not a 'sure thing' with respect to evidencing cognitive enhancement [34•], and that not all types of entertainment-based video games ('action' versus 'strategy' versus 'casual' games) lead to similar effects.

Intervention design factors

A broad view of the data generated by cognitive training studies suggests that the repetitive use of interactive media that requires rapid decisions in demanding environments leads to the best chance of engendering cognitive enhancement effects [35]. However, there are a number of factors related to qualities of the cognitive training intervention that are worth considering, such as fun, motivation to play, and underlying game mechanics in the form of adaptivity. The role of fun is one that is often touted, but is notably difficult to properly assess given the inherent intrinsic evaluation of fun by each individual. Both educators and the video game industry have recognized for years the importance of incorporating fun into their respective workspaces to achieve optimal outcomes [36–39], making a clear case for its importance in cognitive training studies. However, it is still unclear exactly how fun factors into cognitive training given that training participants often report similar levels of engagement as individuals playing control games [40•,41,42], yet they show distinctly different levels of improvement. These types of results warrant future work in which the active ingredients of a training intervention are the same (e.g., motivation, game mechanics, etc.), but the amount of fun differs.

Highly related to this concept is the factor of motivation, an important extrinsic quality deeply embedded in video games through carefully crafted reward structures that engender player engagement. Video games are inherently designed to have high motivation levels thanks to their immersive game elements, in contrast to many cognitive exercises. A recent study by Dorrenbacher *et al.* suggested that the motivational setting can have a positive effect on near-transfer benefits, but does not appear to contribute to abilities outside of those trained directly (e.g., far transfer [43]). These findings are interesting when considering work by Prins *et al.* [44], who examined motivational effects within a working memory cognitive exercise. These authors reported that high motivation led to individuals voluntarily training more and subsequently outperforming a low-motivation group in terms of in-game performance and transfer effects. However, recent work by Katz *et al.* [45] suggests that specific types of motivational elements like real-time scoring can actually hinder cognitive training effects, a broad implication for both researchers and game designers that warrants further investigation. These findings suggest that motivational biases may aid individuals playing video games in reaching greater outcomes versus those engaged in cognitive exercises.

Another factor frequently employed in video games to enhance the playing experience is the titration of game difficulty to encourage subsequent play. This is known as adaptivity, and is defined as the modification of stimuli or responding characteristics of the challenge as determined by an individual's performance. This tool is also commonly used in the development of cognitive exercises, where it is often assumed to be core for an optimal training experience. A recent example of the selective benefits of adaptivity with a cognitive exercise was dem-