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# Selling points: What cognitive abilities are tapped by casual video games?

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ABSTRACT

The idea that video games or computer-based applications can improve cognitive function has led to a proliferation of programs claiming to "train the brain." However, there is often little scientific basis in the development of commercial training programs, and many research-based programs yield inconsistent or weak results. In this study, we sought to better understand the nature of cognitive abilities tapped by casual video games and thus reflect on their potential as a training tool. A moderately large sample of participants ($n = 209$) played 20 web-based casual games and performed a battery of cognitive tasks. We used cognitive task analysis and multivariate statistical techniques to characterize the relationships between performance metrics. We validated the cognitive abilities measured in the task battery, examined a task analysis-based categorization of the casual games, and then characterized the relationship between game and task performance. We found that games categorized to tap working memory and reasoning were robustly related to performance on working memory and fluid intelligence tasks, with fluid intelligence best predicting scores on working memory and reasoning games. We discuss these results in the context of overlap in cognitive processes engaged by the cognitive tasks and casual games, and within the context of assessing near and far transfer. While this is not a training study, these findings provide a methodology to assess the validity of using certain games as training and assessment devices for specific cognitive abilities, and shed light on the mixed transfer results in the computer-based training literature. Moreover, the results can inform design of a more theoretically-driven and methodologically-sound cognitive training program.


## 1. Introduction

During the last decade, the idea that video games can provide a cognitive benefit to those who play them has gained traction and led to a rapid proliferation of applications designed to "train the brain" and attract non-traditional gamers to the gaming community (see http://www.sharpbrains.com). However, many of these commercial programs are not based on reliable scientific research. Research showing that cognitive training protocols can improve visual attention, inhibition or conflict-related attention, working memory and reasoning occasionally show improvements limited to the trained tasks but rarely to broader abilities (Ackerman, Kanfer, & Calderwood, 2010; Ball et al., 2002; Boot et al., 2010; Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Green & Bavelier, 2003, 2006, 2007; Lee et al., 2012; Mackey, Hill, Stone, & Bunge, 2011; Owen et al., 2010; Willis & Schaie, 1986; Willis et al., 2006). Many such programs also suffer from methodological problems (see Boot, Blakely, & Simons, 2011) and replication failures (Chooi & Thompson, 2012; Redick et al., 2012; Shipstead, Redick, & Engle, 2012). In addition, the finite set of training programs often employed in training studies limits continued progress or efficacy; computer programs or games employed are often built from scratch by the researchers, a process that can be time-consuming and resource-expensive. A less professional or visually appealing interface also limits the ability of some games to engage and potentially motivate users, especially in younger generations and a technology-savvy society that is heavily exposed to the rich visual stimuli used in commercial video games. Scientists can partner with professional game developers to create more research-informed games (e.g. Brain Fitness Program, Posit Science, San Francisco, CA; Cogmed Working Memory Training, Cogmed Systems; Lumosity, Lumos Labs, 2012), although funding and resource concerns often make this approach impractical. As *one possible means* of overcoming these issues, in the current work we propose an alternative approach that uses existing, widely available games on the web as a toolbox for developing training

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protocols. The aim of this study was *not* to test the training and transfer efficacy of these games per se, but to first evaluate the cognitive processes that they recruit. Specifically, we sought to systematically examine the possible overlap in the cognitive processes required for successful game play and successful completion of laboratory-based cognitive assessment tasks. Unlike previous training studies that build "games" from laboratory tasks known to measure specific cognitive abilities, or studies that take off-the-shelf games and conduct intuitive task analyses to assess a game's validity for training particular cognitive abilities, we employed statistical techniques to validate the cognitive abilities related to game performance.

We selected from a wide variety of "casual games," which are games that are often catered to non-gamers and involve simple rules that allow for game completion in reasonably short periods of time (e.g., Bejeweled, Solitaire, Minesweeper, etc.). Casual games range in genre and are platform-agnostic, such that they can be played on the Internet, and on most operating systems, game consoles and mobile devices. They are widely available and are typically available at no cost. The Casual Games Association estimates that 200 million people worldwide play casual games via the Internet, with many players over age 30 and female (http://www.casualgamesassociation.org). Although relatively simple, casual games can involve multiple cognitive skills and increasingly challenging levels of performance (i.e. adaptive difficulty based on performance), an important aspect in enhancing training (Brehmer, Westerberg, & Backman, 2012; Holmes, Gathercole, & Dunning, 2009). While intensive action video games have been shown to improve aspects of attention and perception (Green & Bavelier, 2003), little is known about the effect of casual or "mini-games" on these functions and others. Mini-games range from casual video games to games adapted from psychological experiments, and there is a need to better identify useful games for training, as well as tests to assess transfer of training. Mini-games have been developed based on neuropsychological tests of working memory and attention (Owen et al., 2010; Lumosity, Lumos Labs; Jaeggi, Buschkuehl, Jonides, & Shah, 2011). However, since neuropsychological assessments served as templates for game development, outcome measures closely mirrored the games or structure used for training, and as such limit the assessment of "true" transfer to an underlying ability. Similarly, studies that specifically train working memory (WM) and interference control, attention, reasoning and speed of processing, show limited transfer beyond very similar measures and tasks (Ball et al., 2002; Boot et al., 2010; Lee et al., 2012; Owen et al., 2010; Willis & Schaie, 1986; Willis et al., 2006). Many of these training programs attempt to train the same set of processes — which is likely to lead to task specialization. Moreover, training protocols that lack an adaptive component can lead to automatization in task performance.

Recent studies provide motivation for examining mini-games as a means to implement a variety of training via short games in a given training session. A study that trained reasoning and processing speed in children using a variety of games in each training session (computerized, Nintendo-based, individual and group non-computerized games) showed promise in improving the targeted ability (Mackey et al., 2011). Similar to Mackey and colleagues, we hypothesize that maintaining challenge and motivation via "cross-training" will produce maximal gains in the targeted abilities. We also believe that the more diverse nature of the processes tapped and the integration of such processes in relatively more applied situations can engender broader improvement in cognitive skills, and perhaps even to executive function skills crucial to performance in daily life, school and the workplace (Diehl et al., 2005). In one study, Schmiedek, Lövdén, and Lindenberger (2010) found that training on a variety of perceptual speed, working memory and episodic memory tasks resulted in gains not only in the trained cognitive abilities, but also in a latent factor for fluid intelligence. Additionally, compared to games based on psychological tasks, casual video games are more likely to engage individuals, which has implications for efficacy and adherence to cognitive training programs.

In this study, we did not attempt to test the effectiveness of the casual games for training different constructs, but to first examine how the games relate to abilities that are often targeted for training, such as executive function. As executive function relates to a broad set of abilities (Miyake et al., 2000; Salthouse, 2005), in this study we examine cognitive constructs of fluid intelligence, reasoning, working memory and various types of attention. The breadth of relationships examined in this study can be useful in evaluating results from a training program derived from this set of games or similar paradigms. Because the training games and assessments differ substantially in context and task-specific characteristics, one can better infer transfer to the targeted ability. Moreover, insight into other cognitive abilities related to game performance (in addition to the primary cognitive ability targeted at initial game play) provides a framework in which to interpret the breadth of transfer.

In the current project, we administered casual games in a controlled setting. In this first validation phase, we used factor analytic and correlation techniques to shed light on the nature of the abilities that are emphasized in each game. In order to measure perceptual and cognitive performance, we chose well-normed laboratory tasks that measure fluid intelligence, perceptual speed, episodic memory and vocabulary (Salthouse, 2004, 2005, 2010; Salthouse & Ferrer-Caja, 2003), and cognitive tasks that measure additional executive control abilities such as various aspects of attention, inhibition, working memory and task switching. We then selected casual games from categories on the Cognitive Media website (www.cognitiveme.com): executive function and reasoning, working memory, attention and perceptual speed. These groupings were informed by a cognitive task analysis that mapped the specific tasks required for game play to the cognitive abilities that these tasks presumably engage (see Militello & Hutton, 1998 for a review of such an approach). We measured game and task performance from 219 subjects in order to provide sufficient power for us to examine the abilities tapped by these games and assess the validity of using repeated game play to exercise certain cognitive abilities. Importantly, our results highlight the relative importance of different cognitive abilities in the games and as such help shed light on the mechanisms that may develop over training.

## 2. Methods

### 2.1. Participants

219 participants (ages 18–30) were recruited from the Champaign–Urbana community and were paid $10/h for all sessions. To encourage completion of the study, participants were informed that if they discontinued participation before the last session, payment would be $5/h instead. Three subjects were disqualified after the first testing session due to participation in a game training study (Space Fortress) that used a subset of similar assessment tasks. Seven subjects dropped out at different points of the study and their data was included in the separate analyses of tasks and games. However, data from these seven subjects was not included in the combined task and game analyses, resulting in a final combined sample of 209 participants (33% male; mean age = 21.68, SD = 2.9; mean years of education = 14.91, SD = 1.92). Game data for one or two sessions was not collected for 33 individuals due to technical recording errors or experimental error. Listwise and pairwise exclusion analyses were performed accordingly to account for the missing data. Descriptive statistics of all measures can be found in Appendix A.

Recruitment was conducted through flyers posted in campus buildings and businesses, and through advertisements posted to online bulletin boards and community newspapers. Study requirements were stated as completion of paper–pencil and computer-based games and tests. Individuals responding to these postings were then asked to complete a demographics form and a survey of their video game habits, and