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# Defining the cognitive enhancing properties of video games: Steps Towards Standardization and Translation

**Shikha Jain Goodwin**[1,2,3], **Derek Dziobek**[3,4]
[1]Department of Biomedical Engineering, University of Minnesota, Brain Sciences Center, VA Medical Center, [2]Department of Neurology, University of Minnesota Medical School, Minneapolis MN, USA, [3]Brain Sciences Center, VA Medical Center, Minneapolis MN,USA, [4]Graduate Program in Neuroscience, University of Minnesota, USA
**Email**: shikha@umn.edu

**Abstract**
Ever since video games were available to the general public, they have intrigued brain researchers for many reasons. There is an enormous amount of diversity in the video game research, ranging from types of video games used, the amount of time spent playing video games, the definition of video gamer versus non-gamer to the results obtained after playing video games. In this paper, our goal is to provide a critical discussion of these issues, along with some steps towards generalization using the discussion of an article published by Clemenson and Stark (2005) as the starting point. The authors used a distinction between 2D versus 3D video games to compare their effects on the learning and memory in humans. The primary hypothesis of the authors is that the exploration of virtual environments while playing video games is a human correlate of environment enrichment. Authors found that video gamers performed better than the non-video gamers, and if non-gamers are trained on playing video gamers, 3D games provide better environment enrichment compared to 2D video games, as indicated by better memory scores. The end goal of standardization in video games is to be able to translate the field so that the results can be used for greater good.

**Keywords** Video Games, Cognition, Dimensionality, Lure Discrimination Index (LDI), 3D vs 2D, Virtual Environment, Environmental enrichment.

Scientists have been interested in the effects of video games on the brain for decades. Recent research has associated video games with improved attention, visuospatial acuity, and the slowing of cognitive decline, among other things (Table1). The majority of studies train non-gamers over a period of time, while monitoring changes in performance in different cognitive domains (Supplementary Table in Latham et al. 2013)[1]. Considering the variety of games used and the great diversity of potential cognitive enhancements, it is unsurprising that there remains little standardization in the field [2]. Video game research can be made more translational and relevant if one-to-one correlations can be made between specific game properties and enhancements in distinct cognitive processes. A more systematized approach to which game archetypes are used, how individuals are screened, and what cognitive improvements are seen will yield more profound insights into how particular game styles improve particular cognitive capabilities in particular individuals (Figure 1).

Table 1. List of cognitive processes improved by video game playing (Summarized data from Oei & Patterson 2014; Latham et al. 2013)[1,8]

- Hand-eye coordination & reaction time
- Spatial visualization
- Visuospatial attention
- Visual anticipation & visual search strategies
- Temporal dynamics of sensory attention
- Exogenous and endogenous attention
- Task switching
- Visual perception & use of sensory evidence
- Contrast sensitivity
- Peripheral vision
- Divided attention
- Multiple object tracking
- Spatial cognition
- Distractor suppression

Clemenson and Stark (2015) make a valiant first step towards realizing such standardization using dimensionality as a way of differentiating types of video games [3]. Rodent literature has shown that enriched environments stimulate neuroplasticity and neurogenesis, thus improving hippocampal function [4]. Clemenson and Stark (2015) attempt to translate such a paradigm into human studies by using the richly stimulating environment of video games, in particular, by comparing the effects of 2D and 3D video games. The basic hypothesis of the authors is that the exploration of virtual environments while playing video games is a human correlate of environment enrichment.

The authors designed two experiments; the first of which compared self-reported video gamers to non-video gamers. In the second experiment, they trained naïve video gamers for two weeks on complex 3D video games and compared their performance with naïve video gamers, and to a group who were trained in 2D video games. The same basic task with two phases, encoding phase, and test phase, was used in both experiments. During the encoding phase, participants made judgments on 128 visual images of every object as being "indoor" or "outdoor". During the test phase, participants were again shown images of everyday objects, which included images which were the same, similar to, or different from those shown in the encoding; participants were required to classify them into one of three categories, "old", "similar" or "new", respectively. The authors used the Mnemonic Similarity Task (MST) as a measure of the ability to discriminate similar from new items. Two additional measures were derived from the subjects' performance on the MST, lure discrimination index (LDI) and recognition memory score. The LDI was calculated from the number of correctly identified "similar" objects from incorrectly identified "similar" objects. The recognition memory score is simply how well the subjects correctly identified the "old" objects (hits minus false positives).

The authors found that the video gamers performed better than the non-video gamers in their ability to correctly identify the similar objects (higher LDI score). There was no difference, however, in the traditional recognition memory measure. Furthermore, analysis of the video games (by dividing them based on their player viewpoint complexity) led the researchers to discover that the higher the complexity, the better the LDI score. In the second experiment, the authors directly compared dimensionality and concluded that the subjects who played 3D games have higher LDI scores than the subjects who played either no video games or 2D games. The authors recognized one specific game parameter (dimensionality) and demonstrated a cognitive benefit (game playing effect on hippocampus) as a result. This is a good first step toward establishing rigor in video game research by describing game archetype.

Experiment 1 relies on the difference between gamers and non-gamers. Since throughout the literature there is no standard for defining a "gamer," and the lack of a strict definition may cloud the interpretation and relevance of the apparent benefits of gaming. It is important to define these terms explicitly for their relevance to the experiments and their results, such as how much game playing is needed to yield cognitive benefits. Clemenson and Stark (2015) had non-gamers play video games for a period of 2 weeks for 30 minutes per day (3.5 hours/week), but Sobczyk et al. (2015) argued that a gamer should be someone that plays more than 5 hours a week of video games [2]. The supplementary table [1] outlines the results of video game training from only 0.5 hours per week to 10 hours per week and for periods ranging from 2 weeks to a year. There is no standard of number of hours for video games, thus, long-term research on the duration and length of playing video games is as essential as the consideration of the content of the video game play.

One notable feature of the image set the authors used during these, and previous, experiments were that the content of similar ("lure") images were typically old images that had been merely perturbed along one spatial dimension, e.g. objects slightly rotated, changing facial expressions etc. [5]. Thus, the LDI was essentially a measure of how well the subjects were able to recognize these highly nuanced alterations. Considering that 3D video games inherently allow the player to view objects from an infinite number of perspectives, it is unsurprising that gamers trained on 3D games have a better aptitude at identifying lure images. Therefore, It can be argued that playing 3D games specifically train the subjects to recognize such discrepancies. Thus, subjects should be assayed with a diverse set of tasks, rather than a single one, to determine the breadth and degree of cognitive enhancement.

Clemenson and Stark (2015) make an analogy, between environmental enrichment and rats, also between video games and humans, but what is so enriching about video games? The prevailing opinion is that video games have an extremely high density of stimuli and that video games provide some of the highest rewards per unit of time compared to everyday activities, with dopamine release comparable to the effects of certain drugs (Howard-Jones 2010). We propose a simple idea in which video game stimuli density scales as a multiple of the dimensions of movement, so a 1D game would have a stimulus density of $d$, a 2D game would have a density of $d^2$, and a 3D game $d^3$. Thus, the amount of stimulation increases exponentially. This model does not fully describe the type or complexity of gameplay, though, such as the challenges inherent to an action game or a strategy game.

In order to have a fully mature framework for video game research, we must have standardization of video game complexity and content. Clemenson and Stark (2015) attempt this by quantifying the complexity of games based on player viewpoint, e.g. 2D side-scrolling or 3D first-person, and they note that gamers who play more complex games (by their definition) tend to have an improved LDI. This is a promising start to game standardization, but it does not address gameplay content, which can be highly variable across game titles. It is highly possible that different game types could lead to different cognitive enhancement(s), so a way to standardize game content would lead to a more thorough understanding of which activities facilitate which cognitive processes. Consider Experiment 2, in which naïve gamers were trained on a 2D game (Angry Birds), a 3D game (Super Mario 3D World), or no game at all. Clemenson and Stark (2015) indeed found an improved LDI in the 3D game group relative to the others, but the findings could have been even stronger if the game content between the 2D and 3D games were more similar. For example, if the authors trained subjects on a 2D side-scrolling Mario game instead of Angry Birds, then the gaming content between the 2D and 3D groups would have been conceptually identical (jumping on anthropomorphic mushrooms).

Having established the environmental complexity, it is critical to understand the role it plays in increasing LDI score. It is important to understand what this means and why there is a difference in these measures between gamers and non-gamers. The LDI score, but not the recognition score, is different between gamers and non-gamers because LDI score relies on the subjects' ability to perform pattern separation, which is one step above just the simple task of recognition. Pattern separation is the process of transforming similar vs. non-similar memories and is shown to involve human hippocampus CA3 and dentate gyrus [7]. Rodent studies show environmental stimulation is linked to the formation of new neurons, which is in turn linked to better LDI score. Clemenson and Stark (2015) claim that training on video games helps with neurogenesis, especially in the hippocampal CA3 region, which in turn improves the LDI score in 3D video gamers.

Clemenson and Stark (2015) used 3D video games as a human correlate of environment enrichment. To our knowledge, this is the first study in the field to classify the video games on the basis of dimensionality. Clemenson and Stark (2015) suggest that using video game play can provide a way to stimulate hippocampus and generate new neurons. In order to establish and maintain a field of research that can be widely applicable, future video game studies need good controls (difference between video gamers, and non-video gamers), a way to consistently replicate experimental parameters, to show the results are more general than specific, to use a battery of cognitive tests—rather than a specific task, and a precise way to characterize game features and archetype. In order to understand the general cognitive benefits of gaming, we need to separate differences between individual game, gamer, as these things normally tend to get mixed up in video game research. The goal is to establish and maintain a field of research that can be widely applicable and results that can be more translational in nature.

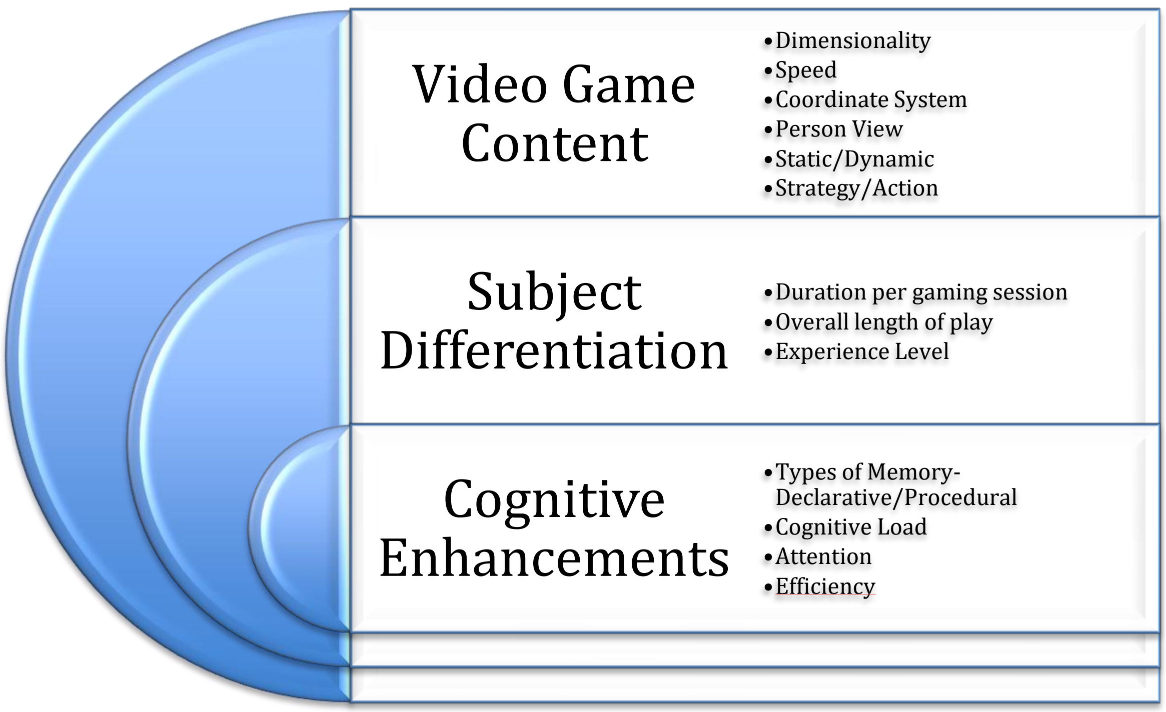


**Figure 1 Consideration for future Video Game Studies**

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