# The Neuroscience of Gaming:  Workshop in Brief

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# The Neuroscience of Gaming—Workshop in Brief

More than 1.2 billion people worldwide play video games (online, via console, mobile phone, and other wireless devices), and many may be unaware that programmers often incorporate neuroscience into game design. Given the high prevalence of gaming in today's society, the Institute of Medicine (IOM) Forum on Neuroscience and Nervous System Disorders hosted the Social Issues Roundtable at the Society for Neuroscience annual meeting on November 16, 2014, in Washington, DC, to explore the neuroscience of video games, with emphasis on relevant scientific, ethical, and societal issues. Jonathan Moreno, David and Lyn Silfen University Professor in the Department of Medical Ethics and Health Policy at the University of Pennsylvania Health System, and session moderator, noted the following objectives of the session:



1. Explore the use of neuroscience concepts in video game design, including (a) key structural features of gaming that are derived from neuroscience concepts, and (b) the physiological effects of gaming as a result of the game's structural characteristics (e.g., reward circuitry);
2. Discuss the positive and negative uses of neuro-science in video games;
3. Review the utility of gaming and opportunities in education, training, rehabilitation, and health;
4. Discuss the adverse consequences of problematic gaming, including (a) similarities of problematic gaming to other addictive behaviors (e.g., substance use), and (b) individual characteristics that may make a gamer at risk for problematic gaming; and
5. Consider the ethical and societal underpinnings of the use of neuroscience in gaming design for developers and gamers.

The discussions highlighted the critical need for improved, evidence-based studies to comprehensively assess risks and benefits of video games, noted Moreno. In addition, a few panelists discussed the potential to create regulatory pathways for combination therapies using video games that have been shown to be efficacious in the health sector. However, several panelists asserted that the ethical and societal implications of video games should be examined closely, given the potential side effects and consequences (intended and unintended) of video games to players.

## Societal Acceptance of Video Games

From a historical perspective, several societal changes have caused "moral panics," including the emergence of different types of music, literature, and dance, noted Daniel Greenberg, president of MediaRez, LLC, and now video games are among them, often scrutinized by the media and political stakeholders. He said significant attention has focused on the alleged negative effects of video games (e.g., violence), although much debate continues on whether

there is evidence of causation, and some, including the U.S. Supreme Court, argue that future research is needed.[1] According to Greenberg, this has led to unbalanced research that does not consider the total effects and potential benefits of video games. He asked what the ethical implications are of concentrating research resources on the presumption that the activities children, in particular, enjoy are intrinsically bad.

A high-quality video game should be designed with an optimal amount of complexity that is not too difficult to cause frustration among players, yet not too simple to cause boredom, noted Greenberg. The goal is to create manageable stress, where there is an appropriate challenge, and the necessary resources needed to meet the challenge are present—creating eustress. This state of emotionally engaged activity is an ideal state for learning to take place, based on the neuroscience of education, which highlights the role of emotional thought in cognition. Players quickly learn large amounts of information about the game's world and processes, though most of what they learn has little applicability outside of the game world. Greenberg said this gives games significant potential to teach, a potential largely untapped due to the stigma and moral panic against video games.

## Video Game Applications

### Educational Tools

From an educational standpoint, video games encourage participatory and experiential learning, noted Greenberg. Video games offer learning through engagement and discovery, providing cognitive benefits such as allocating attentional resources more efficiently, filtering out irrelevant information more effectively, and improving social and emotional competence, he added. Greenberg compared several principles of a Montessori education to gameplay (Table 1). Players rapidly learn materials and master complex systems through the interactive nature of video games. Similar to the scientific method, players confront an unknown phenomenon, act on it, observe responses, form hypotheses, test them in a framework of cause and effect, validate and revise the response, and then repeat the process, Greenberg explained.

**TABLE 1** Comparison of Montessori[a] Principles to Gameplay

| Montessori Principle | Gameplay Component | Characteristics |
|---|---|---|
| Human tendencies | Interface | • Exploration<br>• Purposeful activity<br>• Manipulation of the environment |
| Prepared environment | Game world | • Facilitates activity<br>• Removal of the extraneous<br>• In proportion to needs |
| Teacher as observer | Artificial intelligence | • Allows freedom (within limits) to make choices<br>• Artificial intelligence used to adapt |

[a] For more information about the Montessori Principles, go to http://amshq.org/Montessori-Education (accessed February 9, 2015).

SOURCE: Greenberg presentation, November 16, 2014.

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[1] See http://www.supremecourt.gov/opinions/10pdf/08-1448.pdf (accessed February 9, 2015).

## Health

According to Greenberg, the new gold standard in video game research goes beyond education, and video games are being used for behavior change and as interventions in health. For example, several video games have been designed to increase disease knowledge and medication adherence in patients, for pain management, smoking cessation, cognitive behavioral therapy for depression, and to better understand diseases (e.g., potentially creating environments that allow validated animal assessment tests to work in humans). One example Greenberg described was a video game for children with juvenile diabetes that simulates and models the actions needed for the child's health. Real-world consequences are depicted in the game, encouraging children to make failures in the virtual world of the game so they can be avoided in the real world. The game also serves as a safe place for children to face and master their fears about the disease. Greenberg noted that video games help players learn resilience, future orientation, and persistence. Unlike other forms of media (e.g., film, theatre, and literature), video game players directly experience the consequences of their actions. Video games can be designed to have a closed feedback loop that is more effective than self-tracking health apps, which often lack this feature.

## Cognitive Enhancement

Video games also have the potential to be used as cognitive enhancers, noted Adam Gazzaley, director of the Neuroscience Imaging Center and professor of neurology, physiology, and psychiatry at the University of California, San Francisco, and co-founder of Akili Interactive Labs. His research focuses on the development of effective approaches to enhance cognition in both healthy and impaired individuals. Gazzaley noted that the current approach to treating patients with mild cognitive impairment (MCI) is lacking. He provided an example of a 60-year-old patient with MCI going to the doctor because he is experiencing forgetfulness (e.g., going to the refrigerator and not knowing what he went there to get). In the current approach, the characterization of the episodes is likely to be poorly understood by the provider because it may be unclear what is exactly happening to the patient, noted Gazzaley. If the provider does decide to treat the patient using a drug, it is likely to be poorly targeted (e.g., not acting on the appropriate neural network), non-personalized (e.g., based on large population data), and unimodal. In addition, Gazzaley noted that the current open-loop approach lacks the feedback needed to adjust the treatment options based on the patient's needs. A new approach should be targeted, personalized, multimodal, and closed-loop, he added.

Pharmaceuticals, brain stimulation, physical exercise and nutrition, meditation, traditional education, and video games all have been shown to enhance cognition. Gazzaley noted that video games in particular are ubiquitous and can serve as powerful interactive tools that can guide behavior. Although views are mixed on whether video games have a positive impact, the health and education domains have been shown to be commercially acceptable to their potential applications, he added. The crossroad between the two domains is cognition. Brain plasticity is the brain's ability to modify its function, structure, and chemistry in response to new experiences, noted Gazzaley. Video games serve as an engine to harness the plasticity of the brain with interaction with the environment. Knowing this, Gazzaley and his colleagues worked to develop a custom-designed video game called NeuroRacer with the goal of enhancing cognition in older adults. Findings from a recent study showed that the video game was effective in improving multitasking skills in older adults, with results that were sustainable over a 6-month period (Anguera et al., 2013). Going forward, research suggests that understanding the specific design components needed to activate underlying neural and cognitive mechanisms will be important. Gazzaley noted that Akili Interactive Labs is working to create a regulatory pathway for health video games with the Food and Drug Administration to evaluate them as diagnostics and therapeutics in several areas, including attention deficit disorder, depression, traumatic brain injury, Alzheimer's disease, and autism.

Gazzaley noted that there is still much to learn in the field about the use of video games beyond entertainment. He opined that they should be validated, reproducible, and scalable to have real-world applications. Gazzaley emphasized the importance of game designers and scientists working collectively to build such video games. Many panelists added that the public should be cautious of claims that are being made, particularly about the effectiveness of "brain training" games, which might lack the scientific rigor to determine their effectiveness.

# The Negative Implications of Gaming

The advantages of playing video games far outweigh the disadvantages, noted Mark Griffiths, professor of Gambling Studies and director of the International Gaming Research Unit at Nottingham Trent University; however, it is important to consider that proportion of gamers who show characteristics of addiction. He noted that certain design features in video games play an important role in the "addictiveness" of the game (e.g., frequency of rewards). Technological addictions are operationally defined as non-chemical (behavioral) addictions that involve excessive human–machine interaction, noted Griffiths. They usually contain inducing and reinforcing features that contribute to the promotion of addictive tendencies. Griffiths noted that all addictions (chemical, behavioral, etc.) have six components (Table 2). The inconsistency in terminology used in the field (e.g., problem video game playing, problematic online game use, video game addiction, online gaming addiction, and excessive gaming) has resulted in overestimates of the true incidence of addictive gaming, he added.

Over the past decade, there have been several debates about gaming addiction and whether it exists. During the panel discussion, for example, Greenberg said the term "addiction" should be reserved for chemical and substance addictions rather than for behaviors. For example, the mood modification, withdrawal, and relapse from substance abuse are more severe than those from behavioral compulsions like problematic gaming, he added. Griffiths noted that prior to the publication of the *Diagnostic and Statistical Manual of Mental Disorders* (APA, 2013), there had been a debate as to whether "Internet addiction" should be introduced into the text as a separate disorder. "The Substance Use Disorder Work Group recommended that the DSM-5 include a subtype of problematic Internet use as an area that needed future research before being included in future editions of the DSM" (Griffiths, 2014). Griffiths noted that the proposed Internet gaming disorder criteria in the DSM-5 directly map to the six addiction components mentioned earlier (Table 3). On the contrary, Greenberg noted that the same "addiction" criteria could be made for other behaviors such as eating, shopping, sex, exercise, listening to music, and watching movies. He asked, is this really "addiction" or just compulsive behavior?

**TABLE 2** Addiction Components

| Component | Characteristics |
| --- | --- |
| Salience | When the particular activity becomes the most important activity in the person's life and dominates their thinking, feelings, and behavior |
| Mood modification | The subjective experience that people report as a consequence of engaging in the particular activity |
| Tolerance | The process whereby increasing amounts of the particular activity are required to achieve the former effects |
| Withdrawal | The unpleasant feeling states and/or physical effects that occur when the particular activity is discontinued or suddenly reduced |
| Conflict | Conflicts between the addict and those around them (interpersonal conflict) or from within the individual himself/herself (intrapsychic conflict) about the particular activity |
| Relapse | The tendency for repeated reversions to earlier patterns of the particular activity to recur and for even the most extreme patterns typical of the height of the addiction to be quickly restored after many years of abstinence or control |

SOURCE: Griffiths presentation, November 16, 2014; adapted from Griffiths, 2005.

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**TABLE 3** Related Addiction Components to the Proposed DSM-5 Criteria for Internet Gaming Disorder

| Addiction Component | Proposed DSM-5 Characteristics |
| --- | --- |
| Salience | Preoccupation with Internet games |
| Mood modification | Use of Internet gaming to escape or relieve a negative mood |
| Tolerance | The need to spend increasing amounts of time engaged in Internet gaming |
| Withdrawal | Withdrawal symptoms when Internet gaming is taken away |
| Conflict | • Loss of interest in hobbies and entertainment as a result of, and with the exception of, Internet gaming;<br>• Continued or excessive use of Internet games despite knowledge of psychosocial problems;<br>• Deception of family members, therapists, or others regarding the amount of Internet gaming; and<br>• Loss of a significant relationship, job, or educational or career opportunity because of participation in Internet games |
| Relapse | Unsuccessful attempts to control participation in Internet gaming |

SOURCE: Griffiths presentation, November 16, 2014; adapted from APA, 2013.

**Associated Risk Factors That Might Lead to Gaming Addiction**

According to Griffiths, several risk factors may facilitate online addictions, including access, affordability, anonymity, convenience, disinhibition, escape, and social acceptability. In addition, several studies have found that gaming addiction is associated with various personality traits—introversion, sensation seeking, neuroticism, state/trait anxiety, low emotional intelligence, and social inhibition. Griffiths also found that males were more likely to develop a gaming addiction, compared to females. In addition, research suggests that online addictions are specific rather than generalized.

**Screening for Gaming Addiction**

Nearly 25 screening instruments have been developed to assess problematic, pathological, and/or addictive gaming. Collectively, they have been used in more than 60 studies. Griffiths noted that the main strengths of the instrumentation included: brevity and ease of scoring; excellent psychometric properties (e.g., convergent validity and internal consistency); and robust data that will aid in the development of standardized norms for adolescent populations (Griffiths, 2014). The main weaknesses that were identified in a review of the instruments included: inconsistency among core addiction indicators across studies; a general lack of any temporal dimension; inconsistent cut-off scores relating to clinical status; poor and/or inadequate interrater reliability and predictive validity; and untested and inconsistent dimensionality (Griffiths, 2014).

## Ethical and Social Implications

If video games are effective in changing neural processes in ways that are intended, and even in those that are not, the field should consider the side effects and possible unintended consequences that might occur, noted Martha Farah, Annenberg Professor of Natural Sciences and director of the Center for Cognitive Neuroscience and Society at the University of Pennsylvania. She noted that there may be different effects to individuals and society depending

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on the video game type, target population (e.g., healthy vs. developmentally impaired), and desired outcome(s) (e.g., improved executive function vs. enhanced social skills).

Although evidence shows that some video games designed for health and educational purposes are effective, many of the assessment studies and trials that have been conducted are not of equal quality and often lack a control group and adequate power, noted Farah. Isolated studies are difficult to interpret, and replicability in real-world application issues remains a concern. In addition, Farah noted that some of the leading researchers in the video game field have vested interests in which they may want to commercialize their product, once positive results are found.

In terms of policy implications, Farah noted that video games are not in a one-size-fits-all domain. Given the diversity in the types of games and targeted populations, there are a multitude of factors to consider in regard to protecting the consumer. Because research has shown that gaming has the ability to manipulate neurological processes, transparency among game designers regarding the purpose and intended effect of a game to users is important, noted Farah. In addition, evidence-based research with scientific rigor is important to determine the effectiveness and potential negative consequences before they are marketed to the public, she added.[2]

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[2] See http://longevity3.stanford.edu/blog/2014/10/15/the-consensus-on-the-brain-training-industry-from-the-scientific-community-2 (accessed February 9, 2015).

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