

# Video Game Use in the Treatment of Amblyopia: Weighing the Risks of Addiction

Chaoying S. Xu, Jessica S. Chen, and Ron A. Adelman\*

*Department of Ophthalmology and Visual Science, Yale School of Medicine, New Haven, Connecticut*

Video games have surged in popularity due to their entertainment factor and, with recent innovation, their use in health care. This review explores the dual facets of video games in treating vision impairment in amblyopia as well as their potential for overuse and addiction. Specifically, this review examines video game addiction from a biopsychosocial perspective and relates the addictive qualities of video games with their use as a therapeutic treatment for amblyopia. Current literature supports both the identification of video game addiction as a disease, as well as the therapeutic potential of video games in clinical trials. We show the need for clinicians to be aware of the dangers associated with video game overuse and the need for future studies to examine the risks associated with their health care benefits.

## INTRODUCTION

Video games have increased in popularity since the early days of Atari® and Pac-man® in the 1970s and 1980s. According to a 2014 report by the Entertainment Software Association (ESA†), 59 percent of Americans play video games [1]. Action and shooter games dominate the market by sales (Figure 1). The ESA, comprised of top video game makers, paints an optimistic picture: They point out that the majority of people play casual/social or board games (29 percent and 28 percent, respectively) in a survey of 2,200 households. However, when time spent is put into consideration, a different picture emerges. A national study of 1,178 American youth 8 to 18 years of age showed 88 percent played video games an average of 13.2 hours per week [2]. Boys significantly spent more time than girls on video games (16.4 hours compared to 9.2 hours/week,  $p < 0.001$ ) [2]. In one set of criteria, pathological video gaming is defined as having at least six of 11 symptoms under the following categories: disruption of academic performance or house

chores, preoccupation with gaming, mood modification (playing because of poor mood), withdrawal, and excessive monetary spending on games [2]. Under this definition, 11.9 percent of boys and 2.9 percent of girls were identified as pathological gamers [2].

Problematic video game use has become a global problem. The prevalence of video game consumption and addiction is highest in Asia [3-5]. Currently, the People's Republic of China holds the largest online gaming market and is expected to double from \$11.9 billion in 2013 to \$23.4 billion by 2018 [6]. An epidemiology study in Hong Kong reported 15.6 percent of grade 8 to 11 students have a video game addiction, using the Game Addiction Scale (Figure 2) [4]. Internet game parlors in China are commonly seen throughout the country's cities and are usually filled to capacity.

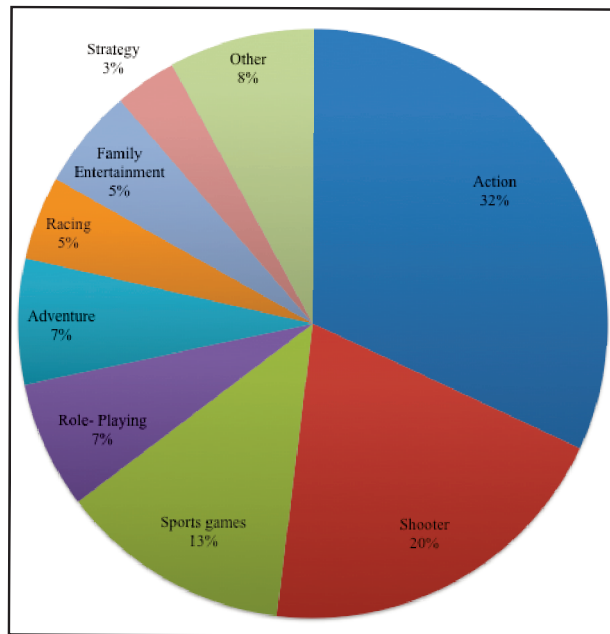
As video games increase in popularity, innovative ways to use them for productive purposes have arisen. The two main groups of video games are sedentary (controlled by finger movements through buttons on a controller or

\*To whom all correspondence should be addressed: Ron A. Adelman, MD, MPH, MBA, 40 Temple St., Department of Ophthalmology and Visual Science, Yale School of Medicine, New Haven, CT 06510; Tele: 203-785-2020; Fax: 203-785-7090; Email: ron.adelman@yale.edu.

†Abbreviations: ESA, Entertainment Software Association; DSM, Diagnosis and Statistical Manual for Mental Disorders; EEG, electroencephalogram; MRI, magnetic resonance imaging; PET, positron emission tomography; PNS, peripheral nervous system; ADHD, Attention Deficient Hyperactivity Disorder; I-BiT®, Interactive Binocular Treatment; tDCS, transcranial direct current stimulation.

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**Figure 1.** Best-selling video games in 2013 by genre in America as published by Entertainment Software Association [1].

keyboard) and active input (controlled by larger body movements). Active input games on Nintendo Wii® and other simulators have been used to simulate laparoscopic and microscopic surgery for training surgeons [7,8]. Another active input video game on Xbox Kinect® has shown to be effective in improving driving skills [9]. Simulators in the form of computer games also have been used to train pilots and astronauts [10,11]. However, only recently have sedentary video games shown potential in treating patients with amblyopia, a neurodevelopmental disease affecting vision. Ubisoft®, a video game company, and its partners are currently seeking approval from the U.S. Food and Drug Administration for a tablet game in the treatment of amblyopia [12].

Given its potential for therapy and pathology, this review explores the complex role of video games in causing addiction and in alleviating amblyopia. Specifically, this review examines video game addiction from a biopsychosocial perspective and relates video games' addictive qualities with their use as a therapeutic treatment. This review includes sedentary video games (i.e., Internet, computer, console, and tablet games) but excludes active input video games, as these have not been identified as addictive.

## VIDEO GAME ADDICTION: WORKING TOWARD A CLINICAL DEFINITION

Since the first paper describing video game addiction in 1983, researchers have struggled to agree on a set of diagnostic criteria for video game addiction [13]. Video game addiction, problematic game playing, pathological video gaming, and Internet gaming disorder are different terms used to describe the same phenomenon whereby

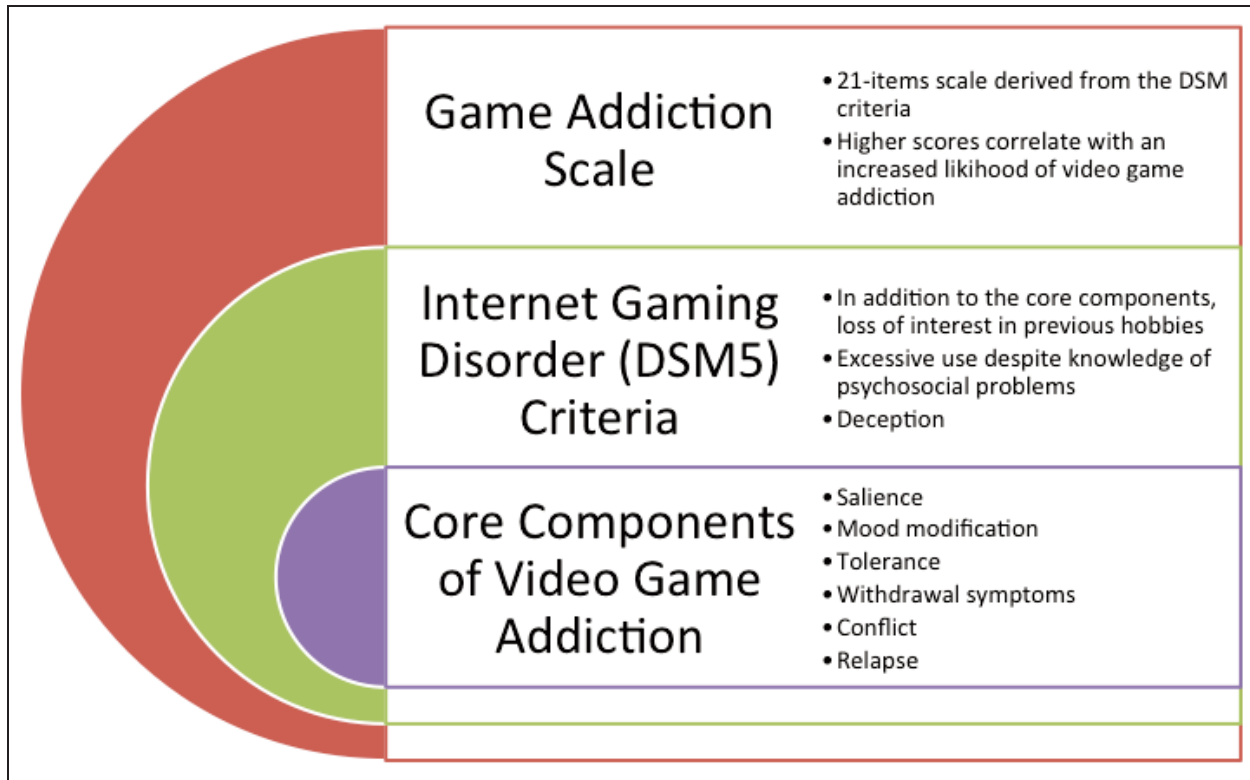
game players persistently engage in games despite significant negative consequences. In the *Diagnostic and Statistical Manual for Mental Disorders-5* (DSM-5) appendix, Internet gaming disorder nests within the section on Condition for Further Study in the diagnostic category of Substance-Related and Addictive Disorders. It refers to the “persistent and recurrent use of the Internet to engage in games, often with other players, leading to clinically significant impairment or distress as indicated by five (or more) [criteria] in a 12-month period” [14].

The exact criteria of video game addiction have been debated in the literature. The three most prevalent diagnostic criteria and scale are listed in Figure 2. The core components of video game addiction formulated by Griffiths are salience, mood modification, tolerance, withdrawal symptoms, conflict, and relapse [15]. In contrast, the DSM-5 criteria for Internet gaming disorder have additional components that specifically point to loss of interest in previous hobbies, excessive use despite knowledge of psychosocial problems, and deception (deceiving family members and others regarding time spent on video games) [14]. The diagnosis is considered to be confirmed by meeting at least five of the criteria. Finally, the Game Addiction Scale is a 21-item scale derived from DSM-based criteria that correlates strongly with problematic video game use, as well as video game usage, loneliness, life dissatisfaction, social incompetence, and aggression [16]. Similarly, another questionnaire, the Video Game Addiction Test, is derived from the Compulsive Internet Use Scale. It is a 14-item questionnaire with higher scores correlating with greater time spent on video games and worse psychosocial outcomes [17].

In summary, a variety of criteria and tests have been proposed for the diagnosis of problematic video game use. Although time spent on video games strongly correlates with problematic use, it is ultimately the negative psychosocial impact on one's life that distinguishes excess gaming from problematic video game use [15].

## THE NEUROPATHOLOGY OF VIDEO GAME ADDICTION

Several studies have investigated brain imaging to clarify the neuropathology of problematic video game use and reveal its addictive neurological impact. Electroencephalograms (EEG), magnetic resonance imaging (MRI), and positron emission tomography (PET) have all been used to understand video game addiction [18,19]. Research suggests that video game addiction follows the same neural pathways as many other addictions [19,20]. PET scans of healthy volunteers playing a computer tank game show increased dopamine release in the striatum in amounts comparable to that released by amphetamines or methylphenidates [18]. A controlled fMRI study of 22 male gamers and 23 male controls showed reduced brain activation in the left inferior frontal gyrus as well as the right inferior parietal lobe [21], a finding in line with an-



**Figure 2. Three prevailing criteria for video game addiction.** Core Components of Video Game Addiction includes the six basic components of addiction. The DSM-5’s Internet Gaming Disorder definition includes three additional criteria, and finally the Game Addiction Scale is the most inclusive scale with a 21-item questionnaire. Adapted from [14-16].

other study that correlated problematic gaming with reduced cortical thickness in these same locations [22].

Han et al. found that subjects both with and without meeting proposed criteria for problematic use had altered brain activity after a 6-week period of playing video games [23]. However, upon exposure to cues, subjects with problematic video game use had significantly increased anterior cingulate and orbitofrontal cortex activity in the brain compared to subjects without problematic use. The increased anterior cingulate activity was correlated to increased craving for the video games [23].

Coyne discovered physiological predictors that reflect the biological nature of video game addiction. Normally when faced with a novel task, the subject experiences a peripheral nervous system (PNS) withdrawal, measured by respiratory sinus arrhythmia. This withdrawal is blunted in subjects with substance use addiction [24]. Coyne showed that adolescent subjects with greater video game addiction symptoms experienced a similar blunted PNS withdrawal [25].

Finally, research suggests that the neuropathology of problematic video game use can be reduced with pharmacological treatment. Han et al. showed that after a 6-week period of bupropion treatment, 11 subjects who fit criteria for video game addiction were shown to have decreased craving for video game play, total game time, and decreased cue-induced activity in the dorsolateral prefrontal cortex [26]. In another study, Han treated 62 children who were diagnosed with both Attention Deficient Hyperac-

tivity Disorder (ADHD) and video game addiction with the stimulant methylphenidate. After 8 weeks of treatment, video game addiction scores and Internet use time were significantly reduced [27]. However, as neither study had a control group of problematic gamers, future research should use randomized controlled trials to avoid bias and confounding factors.

## RISK AND PROTECTIVE FACTORS

Both game and player characteristics play a role in modulating the risk of video game addiction. The appeal of many video games for addicted and non-addicted gamers often include acquiring power and status in the game, advancing in the plot line, and gaining reputation and admiration from other players [28]. In addition, game play offers exploration, role-playing, and escapism (immersion in virtual world free of real-life problems) [28,29]. Another motivating factor is socialization in the online gaming community through in-game chats and cooperation on quests [28,30]. Of the above motivations for game play, the following were found to be associated with excessive gaming: socialization within the virtual gaming community, motivation to compete and master the mechanics of the game, and escapism [28,31-33].

A study of 123 university students in the United Kingdom found that Game Addiction Scale score correlated with personality traits, including neuroticism (emotional instability), anxiety, sensation seeking (attraction to novelty),

and aggression [34]. Age was also a risk factor, with those younger than 27 significantly correlating with higher addiction scores [35]. Recently, studies identified two additional risk factors for video game addiction: ADHD [36,37] and autism [38]. A 2013 study on boys with either autism spectrum disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), or typical development (control) showed greater addictive video game use for both ASD ( $p = 0.001$ ) and ADHD ( $p = 0.03$ ) compared to control [38]. Though the study reveals an important at-risk population that should be monitored for signs of addiction, more research is needed to determine the consequences of addiction for individuals who have existing psychological vulnerability and whether video games will worsen the inattention, introversion, and hyperactivity in these conditions.

Interestingly, a study of 3,105 Dutch students found that extraversion and conscientiousness decreased the odds ratio for addiction to Internet games, suggesting that these traits may be protective factors for video game addiction [39]. However, the study did not account for gender and age, two potential modifiers in the model, and the direction of causality is unclear. It may be that an addiction to gaming causes a change in personality, so that a previously extroverted individual becomes more introverted, neurotic, and/or anxious after prolonged addictive behavior.

Characteristics of games that increase the risk of developing video game addiction include positive reinforcement (e.g., frequent easy targets in a shooting game or small wins in slot machine) [40] and a virtual persona the gamer can identify with [35]. Similar rates (4 to 5 percent range) of addiction were found in those who play arcade, computer, or online games [41]. Structural characteristics of video games that make them appealing include social features (e.g., high score board, multiplayer options), presentation (sound effects, high quality graphics), reward and punishment features, narrative and identity features (e.g., customized avatar), and manipulation and control (e.g., checkpoints and autosaves) [42]. All of these provide strong motivation for game play. Social, reward, and punishment features are related to risk of addiction [30,43].

## PSYCHOSOCIAL CONSEQUENCES

A number of negative psychosocial associations have been established with problematic video game use, including social anxiety [44], loneliness, negative self-esteem [45], sleep problems [46], conduct problems [47], and depressed mood [45,48]. Nicotine, alcohol and cannabis use in boys were twice more likely in those with problematic video game use [45]. Given that these studies were cross-sectional, a longitudinal study has yet to confirm a temporal relationship between video game addiction and these factors.

Problematic video game use has been strongly linked to poor academic performance such as decreased SAT scores, GPAs, and decreased engagement in college [36,49-51]. In a 2015 cohort study of 477 first-year stu-

dents at an all-male liberal arts college, students were surveyed regarding their video game use on their first day of college orientation. At the end of the first year, cumulative GPA was collected from the school. Schmitt found that even after controlling for high school GPA, a powerful predictor of college GPA, problematic video game use negatively correlated with GPA after 1 year ( $P < 0.01$ ) [50].

Research has identified another negative consequence of video game playing: aggression [49,52,53]. After some controversy on whether violent video games can cause aggression, Anderson performed a meta-analysis of studies of 130,000 participants across Western and Eastern cultures that included experimental, observational, cross-sectional, and longitudinal data. He reported that playing violent video games can increase aggression over time, regardless of sex, age, or culture [53].

Conversely, longitudinal and experimental studies also have shown that playing pro-social video games increases empathy and altruistic behavior [54,55]. Thirty-six participants were randomly assigned to a pro-social or neutral game (Tetris®). The pro-social game involved promoting the security of a city in various rescue efforts and collaboration with various city staff, such as firefighters and the police. Participants who played the pro-social games were more likely to help a harassed woman (experimenters role-played without the subject's knowledge). Subsequent experiments showed that pro-social video gamers were more likely to help after a mishap [52,54,56]. Overall, research supports that the content of a video game can positively or negatively affect social behavior. Given that the majority of best-selling video games are violent (Mature 17+ rating) [57], it is not surprising that literature suggests a causal relationship between problematic video game use and aggression [34,47].

## A GAP IN THERAPY FILLED BY VIDEO GAMES: WHAT IS AMBLYOPIA?

Researchers have harnessed the visually captivating and psychologically enticing aspects of video games. A number of clinical trials have shown benefits of using video games to treat amblyopia. Amblyopia is a neurodevelopmental disease of the visual pathway that arises when binocular visual experience is disrupted in early childhood. The process begins as one eye is weakened by factors that cause a mismatch of images between the eyes such as strabismus ("lazy eye"), anisometropia (unequal refractive power between eyes), cataract, or high refractive error during the first few years of life. The strong fellow eye responds by suppressing input from the weak eye and leads to changes in the visual cortex and lateral geniculate nucleus [58-61]. Overall, this process contributes to a structural and functional impairment of vision, usually occurring within the first 3 years of age [61]. If uncorrected, amblyopia can lead to irreversible vision loss, particularly impaired visual acuity, and stereoscopic depth perception. The impairment can ultimately impact patients' daily function and limit career

options [62]. An epidemiology study in 2014 estimated the prevalence of amblyopia to range from 3.0 to 5.4 percent in preschoolers in the United States [63].

The current treatment for amblyopia centers primarily on optic correction followed by occlusion of visual input from the healthy fellow eye through the use of a patch. However, despite patching, 15 to 50 percent of children fail to achieve normal visual acuity after extended periods of treatment [64-72]. The failure rate increases past age 7, as the visual system matures around 7 to 10 years of age [73]. Contributing factors of the high failure rate include non-compliance as well as a decrease in neuronal plasticity after early childhood [68,73-77]. Perceptual learning is an effective, alternative therapy to patching for adults with amblyopia. Patients repeatedly practice with a demanding visual task such as identifying letters with difference sizes and contrast levels [78]. However, this therapy is limited by boredom and a lack of compliance [79]. To overcome the limitation in compliance as well as the decrease in neuroplasticity with age, video games recently have emerged as an experimental treatment modality for amblyopia.

### THE USE OF VIDEO GAMES: TREATMENT FOR AMBLYOPIA

The same aspects of video games that make them potentially addictive also make them an ideal platform for a highly compliant treatment: attractive graphics requiring visual discrimination in the game play, varied visual task, immediate feedback, and reward for the visual task, among other appealing game characteristics. In addition, video games have shown to improve contrast sensitivity that are long-lasting and have been postulated to induce cortical plasticity [80]. Table 1 shows a summary of video games studied so far in the treatment for amblyopia. In a study by Li et al., subjects played Medal of Honor® or Simcity® for a total of 40 hours (2 hours per day) using the amblyopic eye while the fellow eye was patched. Twenty patients (15 to 61 years of age) significantly improved their visual acuity by a factor of 1.6, roughly two lines on the LogMAR letter chart. In addition, subjects had significant improvements in positional acuity, spatial attention, and stereopsis [81]. In effect, such recovery rate is approximately five times faster than that observed in children treated with conventional eye patching [68].

As binocular game play was shown to be superior to monocular game play in visual acuity and stereopsis improvement, researchers began to develop dichoptic games [82]. These games achieve their therapeutic effect by presenting a different image to each eye, thus rewarding the patient when both eyes work together to win the game. For instance, in the Tetris® game, some of the blocks seen by the amblyopic eye are in high contrast, while other blocks in lower contrast are seen by the healthy eye. The contrast level in these games can be modified based on each patient's burden of disease [82]. A variety of platforms have arisen including the iPod [83-86], head-

mounted video goggles [82,85], and a specialized Interactive Binocular Treatment (I-BiT®) system with 3D glasses [87-89].

Initially, the most common dichoptic game used was Tetris®, but recently, modified action games such as Unreal Tournament® have been added to the repertoire [90] (Table 1). Adjunct therapy with transcranial direct current stimulation (tDCS) of the visual cortex has shown additional benefit in improving stereoacuity, possibly by enhancing the effect of video game on neuronal plasticity [83]. Although current studies have been limited by small sample sizes and external controls, these preliminary studies collectively support the role of video games in the treatment of amblyopia.

### DISCUSSION AND OUTLOOK

Our review of the literature shows that video game consumption can lead to an addiction, especially in the presence of certain risk factors. However, the appealing features of video games also have been channeled into creating an innovative therapy for amblyopia with compliance.

More research is needed on the health benefits and harms of video games. To investigate the full effect of video game in treating amblyopia, a large-scale, randomized controlled trial is needed to confirm the benefits of video game on vision in comparison to other visual activities such as reading a book on the same electronic platform. A randomization process should be in place to minimize selection bias for patients who are highly motivated to play video games. These patients may use video games longer than intended, thus overestimating study effect and compliance rate with therapy.

The interaction between the beneficial and harmful uses of video games is particularly interesting and may shape the prevalence of video game addiction. Video games reintroduced as therapy may portray game play as socially acceptable and lead to increased consumption. Currently, there are an estimated 15 million children under the age of 5 who have amblyopia [91]. The market size for therapeutic video games is even larger, considering older children and adults with amblyopia. These individuals may have risk factors for video game addiction mentioned in this review. Studies also have suggested that higher social acceptance of gaming correlates with a higher prevalence of gaming problems, as seen in southeast Asian countries [4,5]. Whether the therapeutic use of video games will lead to an increase in video game addiction remains to be investigated.

The combination of potential addiction and potential therapy in video games raises concern for primary care providers, psychiatrists, and ophthalmologists. In the studies reviewed, the maximum time spent on the video game therapy was 2 hours/day for a total of 80 hours. There has been no study examining a plateau in its therapeutic gains or the long-term benefits and risks of the video game therapy. The question remains: How much should one play

**Table 1. Summary of clinical trials examining the therapeutic effect of video games.**

Study	Study Design	n	Age range (years)	Monocular or binocular game play	Intervention (total hr)	Comparison	Results*	Limitation
Li et al. (2011) [81]	Cross-over study	20	15-61	Monocular	Action game: Medal of Honor® (40-80h) and/or non-action game: Simcity® (40h)	Intervention vs 20 h of other visual activities (e.g. watch TV, read) after cross-over	Average improvement of visual acuity by 1.6 lines, positional acuity by 16%, spatial acuity by 37% and stereopsis 54%	Unbalanced sample size among groups, small sample size, lacks randomization
Waddingham et al. (2006) [87]	Non-randomized trial	6	5-7	Binocular	Watch movie and play video games on I-BiT system® (3-7h) ‡	Pre- vs post-intervention	Average improvement of visual acuity by 3.25 lines in 5/6 patients	Small sample size, lacks control
Cleary et al. (2009) [88]	Non-randomized trial	12	6-11	Binocular	Watch movie and play a racing game on I-BiT system® (4h) ‡	Pre- vs post-intervention	Improvement in visual acuity by at least 1 line in 7/12 patients	Small sample size, lacks control
Herbison et al. (2013) [89]	Non-randomized trial	10	4-8	Binocular	Watch movie and play video games on I-BiT system® (3h) ‡	Pre- vs post-intervention	Average visual acuity improvement of 1.3 lines in 6/9 patients	Small sample size, lacks control
Knox et al. (2012) [85]	Non-randomized trial	14	5-14	Binocular	Tetris® on head-mounted video goggles (5h)	Pre- vs post-intervention	Improvement in visual acuity by at least 1 line in 6/14 patients, and in stereopsis in 3/14 patients	Small sample size, lacks control
Li et al. (2013) [82]	Cross-over study	18	21-31	Binocular	Tetris® on head-mounted video goggles (10h)	Binocular vs monocular game play (patching)	Improvement in visual acuity and stereopsis (binocular > monocular game play)	Small sample size, lacks randomization
Spiegel et al. (2013) [83]	Sham-controlled, cross-over, double-blind study	16	18-31	Binocular	Tetris® on iPod touch with lenticular screen (11h) ± adjunct therapy with transcranial direct current stimulation (tDCS) of visual cortex	Patients with vs without adjunct therapy after cross-over	Average improvement of visual acuity by 3 line and stereopsis. Additional improvement in stereoaucuity with adjunct therapy	Unclear randomization process, small sample size
Hess et al. (2014) [86]	Non-randomized trial	14	13-50	Binocular	Tetris on iPod touch with lenticular screen (10-30h)	Pre- vs post-intervention	Average improvement of visual acuity by 1.1 lines and stereopsis in 13/14 patients	Small sample size, lacks control
Li et al. (2015) [92]	Non-randomized trial	30	18-31	Binocular	Tetriscon iPod touch with lenticular screen (10-30h) with adjunct therapy with tDCS or on head-mounted video goggles (10h)	Pre- vs post-intervention	Improvement in contrast sensitivity across all spatial frequencies	Lacks randomization
Vedamurthy et al. (2015) [90]	Non-randomized trial	23	19-62	Binocular	Tailored action game: Unreal Tournament® video game (40h)	Pre- vs post-intervention	Improvement in visual acuity by at least 1 line in 17/23 patients and in stereopsis in 9/23 patients	Small sample size, lacks control

Note: PubMed database was searched up to February 2015 using the keywords "video game and amblyopia" and "computer game and amblyopia." To be included, the study used video game as a treatment for patients with confirmed diagnosis of amblyopia. \*Visual acuity were measured using LogMAR crowded Keeler chart. ‡Interactive Binocular Treatment (I-BiT®); patient views 3D images through 3D shutter glasses on a monitor.

video games for therapy before the benefits to vision are outweighed by the negative consequences and risk for addiction? As various factors contribute to video game addiction, guidelines should be in place to help patients and parents navigate this question. Ophthalmologists should weigh the risk of video addiction against the benefits to vision when offering video game as a therapy and inform patients and/or parents of the risks. Given the prevalence of video game use, pediatricians, psychiatrists, and primary care providers should be aware of its impacts and recognize the signs of such an addiction. More research is needed to provide screening tools for clinicians to identify and refer patients with video game addiction.

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