• Review Article •

Potential of video games for the promotion of neuroadaptation to multifocal intraocular lenses: a narrative review

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Received: 2019-02-15 Accepted: 2019-06-11

Abstract

• Multifocal intraocular lenses (IOLs) are currently usually implanted for the treatment of cataracts because they have been proved to be superior to monofocal IOLs with respect to spectacle independence. In turn, they are associated with a higher prevalence of dysphotopsia symptoms that is one of the most common causes of patient dissatisfaction. Neuroadaptation seems to play a major role in the optimal adaptation to multifocal IOLs. In this context, the development of strategies that facilitate the neuroadaptation process to multifocality might be an effective strategy to reduce patients' dissatisfaction. Video games have been proved to be effective for the improvement of visual acuity and for the promotion of neuroplasticity in elderly subjects and other populations with cortical-related visual impairment. This narrative review highlights the physiological potential of video games as a perceptual strategy to improve visual acuity and promote neuroplasticity in patients using multifocal IOLs, although research is still needed to confirm these benefits in this specific population, with only one comparative study to this date providing evidence of them.

• **KEYWORDS:** multifocal intraocular lens; dysphotopsia; photic phenomena; halos; video games; neuroadaptation; neuroplasticity

DOI:10.18240/ijo.2019.11.18

Citation: Coco-Martín MB, Valenzuela PL, Maldonado-López MJ, Santos-Lozano A, Molina-Martín A, Piñero DP. Potential of video games for the promotion of neuroadaptation to multifocal intraocular lenses: a narrative review. *Int J Ophthalmol* 2019;12(11):1782-1787

INTRODUCTION

Societies are progressively aging, which comes accompanied by an increased prevalence of age-related diseases[1]. Cataracts, that is, the degeneration and subsequent opacity of crystalline lens, are one of these diseases. In fact, they are among the leading causes of visual impairment, especially in developing countries[2-3].

Cataract surgery techniques have progressively improved, with around 90% of patients presenting optimal vision acuity afterwards[4]. The standard intraocular lenses (IOLs) traditionally implanted (monofocal IOLs) during cataract surgery have fixed refractive power and focal length, and consequently most patients using these IOLs need glasses to improve their vision at certain distances. In turn, multifocal IOLs offer full refractive correction at all distances, and are therefore superior to monofocal IOLs with respect to spectacle independence[5]. However, multifocal IOLs are associated with a higher prevalence of visual disturbances (*e.g.*, glare and haloes)[5], being low visual acuity and specially dysphotopsia symptoms the main causes of dissatisfaction in patients using these lenses[6-7].

The causes of the abovementioned multifocal-related visual problems remain unclear. Parameters such as visual acuity and other causes of impaired vision such as dry eye or retinal disease seem not to be related to the incidence of dysphotopsic symptoms and the associated dissatisfaction[6,8]. In turn, it

has been recently suggested that the activation of certain brain areas might play a role in the adaptation to multifocal IOLs. There is an association between multifocal IOL users' difficulties and the activation of cortical areas dedicated to attention (*i.e.* frontoparietal circuits), learning and cognitive control (*i.e.* cingulate), and task goals (*i.e.* caudate)[8]. Indeed, improving visual attention and procedural learning networks seems to be an essential part of the initial stages of neuroadaptation to multifocal IOLs, as these neural changes are associated with improvements in symptoms, visual acuity and contrast sensitivity independently of optical factors[9].

In this context, the development of strategies that facilitate the neuroadaptation process to multifocal IOLs might be an effective approach to reduce patients' dissatisfaction. The aim of this narrative review was to summarize the evidence on the potential effectiveness of video games for the promotion of neuroadaptation in the general population as well as in individuals with vision impairment, as well as to describe the characteristics of those video games that have shown beneficial effects. For this purpose, we performed a non-systematic review in PubMed using the terms "video games" or "computerized cognitive training" and terms such as brain plasticity, neuroplasticity, neuroadaptation, cognition, visual acuity, vision, visual impairment, cataract or amblyopia. Reference lists of relevant articles and reviews were also examined to find additional publications on the topic.

VIDEO GAMES, A POSSIBLE SOLUTION

The Role of Videogames in Neuroplasticity and Vision In this context, the development of strategies that facilitate the neuroadaptation process to multifocal IOLs might be an effective approach to reduce patients' dissatisfaction. Video games have been proved to promote brain plasticity. For instance, increases in gray matter in areas crucial for spatial navigation, strategic planning, working memory and motor performance (*i.e.*, right hippocampal formation, right dorsolateral prefrontal cortex and bilateral cerebellum) have been observed in young subjects after two months of video game playing[10]. Similarly, other authors reported an enhanced functional connectivity and grey matter volume in insular sub-regions and between the attentional and sensorimotor networks in young video game players[11]. Gaming can promote brain adaptations and improve functional connectivity even at advanced age[12]. It has proven to attenuate age-related deficits in neural signatures of cognitive control-reflected by enhanced midline frontal theta power and frontal posterior theta coherence measured by means of electroencephalography-as well as to improve sustained attention and working memory in older adults[13]. Moreover, increases in neural activity (anterior P3a amplitude) have been observed after a five-week intervention with a similar strategy, computerized cognitive training[14].

Owing to the effects that these 'therapies' elicit in a variety of brain functions such as attention, cognitive control and visuospatial skills[15], gaming and computerized strategies provide several benefits in cognition and vision in elderly subjects[16-20]. Moreover, not only they can improve vision in healthy individuals but also in clinical conditions, such as amblyopia[21]. Amblyopia is a developmental abnormality characterized by an alteration in the visual cortex that results in vision impairment (*i.e.*, low visual acuity and contrast sensitivity, and perception of crowding effect and suppression). The traditional treatment for childhood amblyopia was occlusion therapy (*i.e.*, patching the non-amblyopic eye), but more recent evidence demonstrated that the inclusion of perceptual strategies such as playing video games with the amblyopic eye can result in a more rapid improvement[22]. Indeed, it was traditionally believed that amblyopia was irreversible beyond the sensitive period of brain development during childhood. However, recent studies demonstrate that perceptual training strategies can also enhance visual plasticity and improve visual acuity and contrast sensitivity in adults with amblyopia[23-24].

Characteristics of Potentially Effective Video Games for the Promotion of Neuroadaptation Different types of video games can improve vision and cognitive function. Action video games, ones of the most popular among young subjects, are probably the most effective for this purpose, having proven to promote brain plasticity and enhance different variables such as speed of processing, perception, attention or cognition[25-27]. However, most action video games share some characteristics (are too fast, intense, unpredictable and sometimes even violent) that make them unsuitable for older adults, the population that most commonly suffer from cataracts. Indeed, this type of video games has been reported as less interesting -inducing therefore a lower compliance- than non-action video games in elderly adults[28-31], being intellectually stimulating games (*e.g.*, puzzle, simulation and strategy ones) the most appealing[28,32].

In this sense, non-action gaming strategies that include cognitive training for the improvement of mental abilities (the so called 'brain training' games), such as Nintendo game Brain Age or the commercial games Lumosity (https://www.lumosity.com), Cogmed (https://www.cogmed.com) or Fit Brains (http://www.fitbrains.com), which are also available as smartphone applications, have shown promising results in elderly subjects. This type of games has been reported to improve executive function, processing speed, attention and visual recognition memory, and working memory in this population[14,33-37], being the benefits greater than those provided by other common games such as the falling blocks (Tetris)[37]. Other authors observed a reduction of distraction

and an increase of alertness in older adults after 20 one-hour game training sessions compared to a control group[38]. Moreover, improvements in inhibition and inductive reasoning have also been reported in these individuals after this type of training when compared to a control group that watched a documentary[39]. Some benefits can also be obtained with driving simulation games, which have been reported to improve multi-task performance, cognitive control, enhanced sustained attention and working memory in older adults[13].

In summary, non-action video games such as simulation and especially cognitive training ones appear as a promising strategy for the improvement of vision in elderly subjects. However, as abovementioned, the impaired vision of individuals with multifocal IOLs seem to be largely related to a new and non-physiological focusing properties of the retinal image formation that need development of novel suppression and filtering strategies in the brain cortex, and consequently analyzing the gaming strategies and cognitive stimuli that have previously demonstrated to be effective in visual impairments related to cortical alteration, such as amblyopia, could be especially useful for the optimal design of video games in this population. Perceptual training, which can be conducted through playing video games, improves visual acuity in amblyopia, reducing spatial distortion (internal neural noise) and increasing sampling efficiency (the ability to extract stimulus information)[40]. Playing video games using only the amblyopic eye (*i.e.*, monocular training) has proven to enhance visual and positional acuity, spatial attention and stereopsis in adults through these neural adaptations[24]. However, a binocular alternative approach known as dichoptic training has also been recently proposed. During this intervention, high and low contrast stimuli are presented to the amblyopic and fellow eye, respectively, in order to balance the input from both and enable binocular integration. This strategy has also been reported to improve contrast sensitivity and visual acuity in adults with amblyopia[41-42], and seems to be more effective for the improvement of several visual functions than other strategies such as watching movies with a patch on the non-amblyopic eye[43] or monocular training[44].

Thus, dichoptic training providing different contrast stimuli for the operated and the fellow eye might be a potentially effective strategy for the promotion of neuroadaptation to multifocal IOLs, and consequently for the enhancement of visual acuity. For example, games in which subjects drive a vehicle and some objects are just seen with the 'bad' eye have been proved to be beneficial in amblyopia[45]. Similarly, the Tetris game with some blocks being presented to both eyes but others just to the amblyopic or the fellow eye at high and low contrast, respectively, is also an alternative strategy for the improvement of vision[41,46].

Therapies including perceptual learning signals have also shown remarkable results in subjects with myopia and amblyopia[23,44,47], and could provide benefits in patients with multifocal IOLs. In these games, subjects usually have to take decisions (*e.g.*, decide which button to click) depending on the Gabor patch presented, with Gabor stimuli varying in number, spatial arrangement, global and local orientation, target-flankers separation, exposure time or contrast and spatial frequency. Moreover, the combination of dichoptic training with perceptual learning might maximize the benefits[43-44]. Following the study of Vedamurthy *et al*[43] who demonstrated that this strategy is effective for the improvement of visual acuity in amblyopic adults, a discrimination perceptual learning task (*e.g.*, Gabbor patch) can be presented to the operated eye during the game so that the subject rapidly performs an action (*e.g.*, clicking a button or not) depending on its orientation.

Previous Experiences of Visual Training in Eyes Implanted with Multifocal IOLs The scientific evidence to this date of the use of visual training to improve the results of eyes undergoing cataract surgery with implantation of multifocal IOLs is scarce[48-49]. Kaymak *et al*[48] evaluated the effect of computer-based visual training in only one eye (with the fellow eye occluded) of patients undergoing bilateral cataract surgery with implantation of multifocal IOLs (apodized diffractive and bifocal diffractive designs). The untrained fellow eye served as control. The training was performed during a 6-week postoperative period and based on the concept of perceptual learning of discrimination line orientations. The presentation of the stimuli was done at a fixed distance of 1 m from the observer in a LCD 19" monitor (1280×1024 resolution, 75 Hz). These were the main characteristics of the stimuli presented: thin bright lines 1 arcmin wide presented on a dark surround, length of the lines of 50 arcmin, orientation of the lines controlled by a staircase procedure, and presentation time of 500ms. The patient had to decide in each presentation in which direction the bars were tilted by pushing either the left or right of two push buttons (left/right for vertical stimuli and left/right end lower to the other end for horizontal stimuli). The pause between stimulus presentation was of 300ms. The training was performed over 2wk in six sessions in one eye of each patient, with 7 blocks with 50 stimulus presentations each to be fulfilled in each session. Only one session per observer took place each day, with sessions following each other in intervals of no more than 3 subsequent days. The authors reported a significantly faster and larger improvement of orientation visual acuity, contrast sensitivity and near vision in the trained eyes compared to control eyes, with a mean duration of training sessions of 30±5min[48]. The superior function of the trained eyes was still present at 6mo after surgery[48]. A summary of this same research was reported by

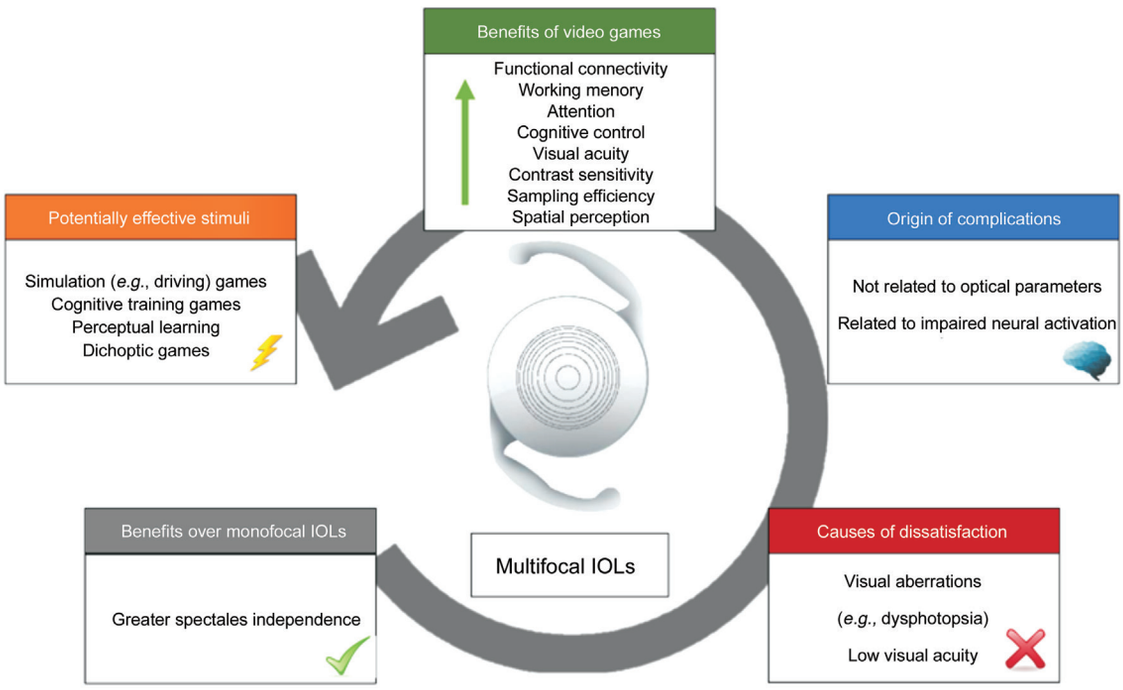

Figure 1 Graphic summary of multifocal IOLs-related pros and cons, and of the potential benefits of video games in these patients.

this research group in another journal, indicating that the mean improvement of orientation discrimination in the trained eyes was 44%, which was significantly higher compared with the control eyes (9%)[49]. The potential effect of this training may have been magnified by gamifying the training procedure. This combination of visual training based on perceptual learning and gamification is a potential research area that may facilitate a better and more satisfactory visual outcome of eyes undergoing cataract surgery with implantation of multifocal IOLs.

CONCLUSIONS AND FUTURE PERSPECTIVES

The popularity of multifocal IOLs implantation after cataract surgery is rapidly growing because they have proven superior to monofocal IOLs with respect to spectacle independence. However, they are associated with a higher prevalence of other complications such as low visual acuity and visual complains (*e.g.*, dysphotopsia symptoms).

Promoting neuroadaptation to multifocal IOLs seems to play a major role in the presence of symptoms in patients using these lenses, and video games appear as a promising strategy for this purpose (Figure 1). As shown in this narrative review, some evidence suggests that gaming strategies might be effective for the promotion of neuroplasticity and for the improvement of vision in elderly subjects and in populations with cortical-related visual impairments such as amblyopia. Games including cognitive training stimuli seem to be the most effective for the enhancement of neuroplasticity in elderly subjects, as well as the most appealing to this population. These benefits might be applicable to patients using multifocal IOLs, as demonstrated initially by a first comparative study. The benefit in these eyes may be in terms of visual performance as well as in terms of less perception of photic phenomena.

Notwithstanding, despite the potential of video games for the promotion of neuroadaptation to multifocal IOLs, research is still needed to confirm if they can effectively improve visual acuity in these patients and decrease multifocal IOLs-related adverse effects or reduce the postoperative time to reach satisfaction with vision performance. Specifically, clinical trials are needed to provide more consistent evidence of the use of this type of training with video games in eyes implanted with multifocal IOLs.

ACKNOWLEDGEMENTS

This article is part of the research performed in the context of the Project OPTiTRAIN, ("Neuroentrenamiento visual en pacientes operados de cirugía de cataratas e implantados con lente intraocular multifocal", application number 106153).

Foundation: Coco-Martin MB, Maldonado-López MJ, Molina-Martín A and Piñero DP are supported by CDTI (Centro para el Desarrollo Tecnológico Industrial, Ministry of Economy and Competitiveness of Spain) by means of the program PID ("Proyectos de Investigación y Desarrollo"); The author Piñero DP has been also supported by the Ministry of Economy, Industry and Competitiveness of Spain within the program Ramón y Cajal (RYC-2016-20471); Valenzuela PL is supported by a contract granted by University of Alcalá (FPI2016).

Conflicts of Interest: Coco-Martín MB, None; **Valenzuela PL,** None; **Maldonado-López MJ,** None; **Santos-Lozano A,** None; **Molina-Martín A,** None; **Piñero DP,** None.

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