Original Article

Improvement of visual acuity in residual meridional amblyopia by astigmatic axis video games

Pradeep G Deshpande, Poonam C Bhalchandra, Aniruddha R Nalgirkar, Sandeep R Tathe

Purpose: This study was carried out to evaluate the efficacy of developed "astigmatic axis video games" in children and adolescents having meridional amblyopia, with the aim to improve the visual acuity (VA). Till date, no studies are available on the treatment of amblyopic meridian. Meridional amblyopia (MA) results when astigmatism remains untreated for a long period. The aim of the study was to assess the effectiveness of a set of novel video games, the astigmatism axis video games (AAVGs), in improving the visual acuity (VA) in MA. **Methods:** We included 50 eyes with residual myopic MA (cylinder ≥2.0 and ≤4.0 D) whose VA did not improve beyond 0.3 LogMAR equivalent, despite patching for 2 h/day for the preceding 3 months. Patients were subjected to AAVG in conjunction with best-corrected glasses and patching of the better eye for 2 h/day for 3 months. **Results:** Out of 50 eyes, 32 eyes were from children between 8 and 12 years and 18 were >12 years. Full improvement of LogMAR VA up to 0.0 was seen in 36/50 (72.0%) oblique astigmatism eyes. Partial improvement of LogMAR VA at least 0.3 LogMAR or more was observed in another 7 eyes (14%) eyes. The mean VA improved from 0.43 ± 0.1 LogMAR at baseline to 0.077 ± 0.08 at 3 months ($P < 0.001$). Good number of eyes ($n = 16$, 32%) showed speedy visual improvement between 2 and 4 weeks after initiation of AAVG. No adverse effects were observed. **Conclusion:** Satisfactory improvement in VA in eyes with residual MA provides preliminary data into the effectiveness of stimulation of the precise amblyopic axis by AAVG in conjunction with spectacles and "minimal patching" regimen of 2 h/day. Further comparative study is warranted.

Access this article online

Website: www.ijo.in

DOI: 10.4103/ijo.IJO_1096_17

Quick Response Code:

Key words: Astigmatic axis video games, astigmatism, meridional amblyopia, visual acuity

Prior research conducted by Mitchell *et al*.[1] and Freeman R.D.*et al*.[2] have shown that the orientation-dependent blur induced by uncorrected astigmatism during early development results in orientation-dependent visual deficits, referred to as meridional amblyopia (MA) if left untreated, best-corrected visual acuity (BCVA) does not reach normal levels despite emmetropization of the astigmatism at a later date due to irreversible neural adaptations. In addition, the reduction in acuity is directly proportional to the degree of astigmatism. Oblique astigmatism is purportedly more amblyogenic and difficult to manage by common strategies such as occlusion and patching.[3-9] Considering the slow improvement in the VA and the associated social stigma, patching time has been reduced from several hours to "minimal occlusion" (2 h/day), with almost equal efficacy in moderate amblyopia[8,9] In addition, according to Holmes *et al*.[10] there is a high risk (up to 25%) of amblyopia recurrence after cessation of passive treatment if not tapered properly. Besides patching, many active treatments tried in the past such as Cooper's pleoptics, the Bangerter method, CAM vision stimulation, and syntonic phototherapy have been found to improve vision in amblyopia[11] A review of active treatments for amblyopia by Suttle[11] and other recent studies suggest that perceptual learning is a potential treatment for amblyopia[12-14] Recently, a promising era for the treatment of amblyopia has started in which video games played on computers can be used as a tool to train visual skills.[15-22] Some studies on visual deficits in the fellow eyes of children with unilateral amblyopia show that playing binocular games can yield encouraging results,[23-27] to improve contrast sensitivity,[28,29] but the risk of addiction should be kept in mind.[30] These studies suggest that there are many active therapies used in conjunction with patching for the treatment of all types of amblyopia. Despite these encouraging results, there are no specific treatments for treating MA by specific active stimulation of amblyopic meridian in the affected eyes. Hence, we performed a study to evaluate the potential of an axis-specific video game in amblyopia reversal in a cohort of children and adolescents with MA.

Methods

This prospective, interventional study was undertaken from June from 2014 to May 2016. The study was approved by the Institutional Ethics Committee and followed the tenets of Declaration of Helsinki. Informed consent was obtained in the local language from all the parents or legal guardians.

Global Medical Foundation and Dr. Nayana Research Centre, Aurangabad, Maharashtra, India

Correspondence to: Dr. Pradeep Govindrao Deshpande, Raj Heights, 401, D-Wing, Seven Hills, Aurangabad - 431 003, Maharashtra state, India. E-mail: dpradeep_globaleye@yahoo.co.in

Manuscript received: 20.11.17; Revision accepted: 27.04.18

Cite this article as: Deshpande PG, Bhalchandra PC, Nalgirkar AR, Tathe SR. Improvement of visual acuity in residual meridional amblyopia by astigmatic axis video games. Indian J Ophthalmol 2018;66:1156-60.

Astigmatism is a refractive error due to the curvature of cornea or lens which is known to deliver different distorting and defocused images which remain chronically blurred, therefore, during development, these individuals may experience a very specific visual blur. Results into an astigmatic-related amblyopia (MA).

Oblique/nonoblique astigmatism

Axis of astigmatism of 180°/90° or maximum 10° eccentric to these principle meridians were included as non-oblique Astigmatism and others as Oblique astigmatic eyes.

Participants

All patients regularly attending amblyopia clinic at our institute were invited to participate in the study. Children aged 8–12 years (children group) and adolescents aged 13–20 years (adolescent group) with cylindrical correction ≥−2.0 and ≤−4.0 D having residual myopic MA of moderate grade, in whom the LogMAR BCVA remained within 0.3–0.6 levels in spite of near vision exercises in conjunction with 2 h daily patching for 3 consecutive months. Mild grades of amblyopia eyes with LogMAR VA up to 0.2 units are not included and whose parents were graduates and willing to consent for participation were recruited for the study. Participants who had not undergone treatment as per the norms, or did not come for follow-up regularly within 3 months were excluded from the study. Physically or mentally unfit children with severe allergies, strabismus, and keratoconus were also excluded from the study. Six children, who abandoned treatment in the 1st week due to vague reasons such as general health issues, were also excluded from the study. After inclusion, participants demographic data recorded were name, date of birth, gender, residential address, phone number, E-mail of parents, educational status of the child (current class) and parents (highest degree), past significant ocular history, and relevant history of systemic diseases if any. We also inquired whether the child played any video games on any media (including smartphones/tables/laptop computers) in the past. Then, participants underwent comprehensive ophthalmic examination including the recording of ocular symptoms, Hirschberg test and fixation patterns, dilated refraction, slit lamp examination of the anterior segment examination and fundus evaluation using indirect ophthalmoscopy.

Refractive status

Refractive status was determined using cycloplegic (cyclopentolate 1%) retinoscopy for 8–12-year-old children and using tropicamide 0.80% for children above 12 years of age. Participants were recalled for a postmydriatic test, and the axis was confirmed through streak retinoscopy, mean value of multiple readings by an auto refractometer, Jackson's cross cylinder, and astigmatic fan. Best-corrected glasses were prescribed at this time.

Management by a novel astigmatic axis video games

A video game is an electronic game that involves interaction with a user interface to generate visual feedback on a video device such as a TV screen or computer monitor or any type of display device that can produce two- or three-dimensional images. A mobile game is also a video game played on a feature phone, smartphone/tablet, smartwatch, PDA, portable media player, or graphing calculator.

The astigmatic axis video game (AAVG) (1st author's intellectual property, subjected to patent) is also an electronic game that involves interaction with a user interface to generate visual feedback on a device such as computer monitor/laptop or 10'' tablets to achieve a desired effect.

Principle of the astigmatic axis video game

The games of common interest of the children are modified with the aim to stimulate the exact axis of astigmatism by a linear illuminating object of 2–3 mm breadth, which varied as per the monitor size. The observer is compelled to concentrate or gets attracted toward the aimed linear object that remains the part and parcel of the game throughout the game duration. The axis can be adjusted from 0.0 to 180, and the linear object can be in any color. The games are designed with the aim to stimulate the fovea by multicolored objects, to improve concentration, contrast attention, color contrasts recognition, perceptual attention, eye-hand coordination, drag and drop exercises, as per the age and the level of understanding of course modified by astigmatic axis stimulation goal. For the study, we have used specific AAVG Games introduced by Mobi-Clouds Pvt., Ltd., (India) and provided by Pradeep Vision Stimulators private Limited India with an inbuilt program [Fig. 1].

Playing conditions and play time

Participants were advised to use prescribed spectacles with antiglare glass and patching to the better eye while playing. Playtime was restricted to 1 h sessions, enforced by an auto-shutdown mechanism. Participants were locked out of the game for at least 15 min before being allowed to start another session but compelled to complete 2 h a day, at least in continuity, for 15 days at our institute in climate-controlled, private rooms with low illumination and light music and then at home maintaining the same norms. All the participants were called back for a weekly follow-up at the institute for a detailed evaluation. We added newer axis games as per the participants' taste and level of understanding every week to maintain the motivation playing the games as prescribed and maintain regular follow-ups too.

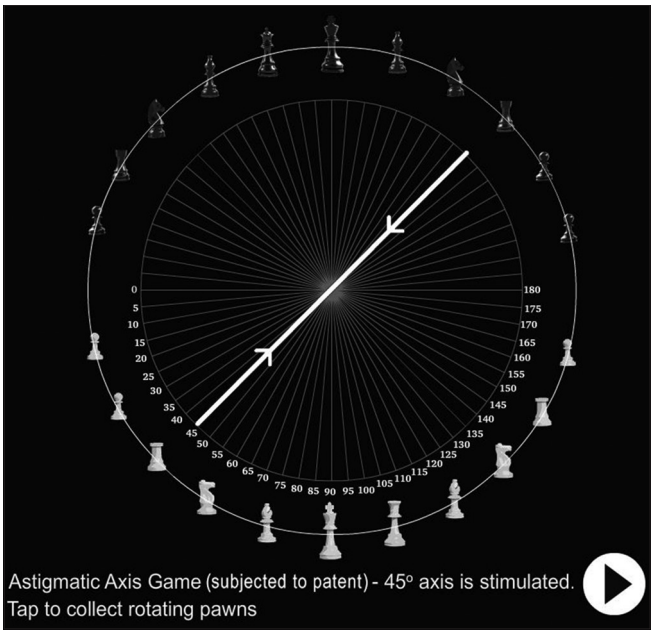

Figure 1: Principle of astigmatic axis games

Follow up visits

Best-corrected VA assessment was performed before the treatment by LogMAR chart and repeated during each follow-up visit at 1, 2, 4, 6, 8, 10, and 12 weeks on the same charts by two ophthalmologists. Improvement in BCVA at 12 weeks using the LogMAR chart was the primary outcome measure. The full improvement was defined as BC LogMAR VA improved up to 0.0 level or partial improvement means improvement of LogMAR VA at least 0.3 units from baseline or more but not up to 100%. Worsening of VA by 0.2 or more LogMAR after improvement during the study was considered as regression.

Statistical analysis

The collected data were compiled into MS excel sheet, and SPSS Version 24th was used for data processing. Categorical variables were represented as percentages and continuous data as mean and standard deviation. To evaluate the significance of VA before (at baseline) and after treatment (at 12 weeks) the Paired *t*-test was applied. $P < 0.05$ was considered as statistically significant.

Results

Fifty participants were included in the study (36 anisometric eyes and 14 eyes from isometropic astigmatism group of which 24 eyes (48%) were from 22 boys, and the remaining 26 eyes (52%) were from 21 girls. Nearly two-third participants were in the 8–12 years of age group (n = 32 eyes, 64%) and the remaining were in the 13–20 years of age group. A large proportion of parents (84%) reported their children having played some video games in the past 1 year. Adherence to the recommended time of use of the AAVG was seen in 100% participants. At 12 weeks, 36 eyes showed full improvement (72%), another 7 showed partial improvement (14%) whereas 7 eyes (14%) showed no improvement and were considered as treatment failure. Table 1 shows gender and age group wise response to treatment to the AAVG. Children between 8 and 12 years of age responded more favorably to the video games compared to those in the adolescent age group. There were no gender-wise differences in the response to video game stimulation. In terms of astigmatism, 43 eyes (86%) had oblique astigmatism and 7 had nonoblique astigmatism. Table 2 shows the distribution of improvement with respect to the type of astigmatism. All treatment failures were in the oblique astigmatism group whereas all eyes with nonoblique astigmatism showed full improvement.

The mean visual acuity (VA) at baseline and at each time point during the study is shown in Table 3. Number of eyes that showed visual improvement at each time point during the study [Fig. 2]. Although some eyes started showing some improvement in vision at the end of the 1st week itself (n = 7 eyes), the maximum improvement was noted between 2 and 4 weeks (n = 16 eyes), and some eyes required a longer time to show improvement. Some regression and improvement of VA up to 0.1 LogMAR line was observed in six eyes during the follow-up visits, but BCVA of 0.0 LogMAR was maintained at the end of 12 weeks.

Table 1: Fully or partially improved of visual acuity according to gender and age group

Variable	Fully or partially improved (n=43), n (%)	Not improved (n=7), n (%)	P
Gender			
Male	19 (79.17)	5 (20.83)	0.43
Female	24 (92.31)	2 (07.69)	
Age group (years)			
8-12	29 (90.62)	3 (09.38)	0.03
13-20	14 (77.78)	4 (22.22)	

Discussion

In our study, using a set of innovative AAVGs for the management of MA, we found that almost three-fourth (72%) of the affected eyes showed excellent improvement in vision, another 14% showed partial improvement while the remaining 14% eyes did not respond to the video game stimulation. This was despite the majority of children already having played some of video games in the past 1 year. Children between 8 and 12 years of age benefitted more than those >12 years and visual improvement was seen as early as 1 week following therapy in a few eyes, but the most improvement was seen between 2 and 4 weeks after onset. All eyes with nonoblique astigmatism showed full improvement in vision as per our predefined criteria, whereas two-third (72%) eyes with oblique astigmatism showed full improvement.

A proper explanation of the consequences of low vision in the future, minimal patching and that too in privacy was the key factors for better compliance during our studies. Yet, good compliance does not directly result in improved outcomes as seen in literature reports including the PEDIG studies. We would like to attribute the better results in our participants to the specific nature of the video games which stimulated the exact defocussed amblyopic meridian. We also found good adherence to the therapy over the study period.

Video games have been used to improve vision in patients with amblyopia in the past. Three distinct approaches have been described: (1) Monocular approach: Video games with the good eye patched with the aim of improving aspects of vision related to the crowding phenomenon, (2) Dichoptic stimulation: where the game presents the same background to both eyes, but an enriched foreground is presented to the amblyopic eye, the purpose being anti-suppression and (3) Video games that improve stereopsis. Our strategy is similar to the first approach and has been utilized in the past as well although dichoptic stimulation has been more widely used in previous studies. The PEDIG[10] conducted a randomized controlled trial to determine whether near or distance activities are more beneficial while patching for amblyopia in children 3 to <7 years old. The strategies used for near vision stimulation included the use of video games among other activities. Authors concluded that performing common near activities does not improve VA outcome when treating anisometropic, strabismic, or combined amblyopia with 2 h of daily patching. Although this study failed to show a beneficial effect of using video games for amblyopia therapy, it did not exclusively involve children with MA, and importantly, near vision tasks including video games, were based on spatial detail rather than contrast based, contrary to our contrast-based perceptual learning video games.

Contrary to this, Li *et al*. showed significant visual benefit when adults with amblyopia were treated using the fast-paced

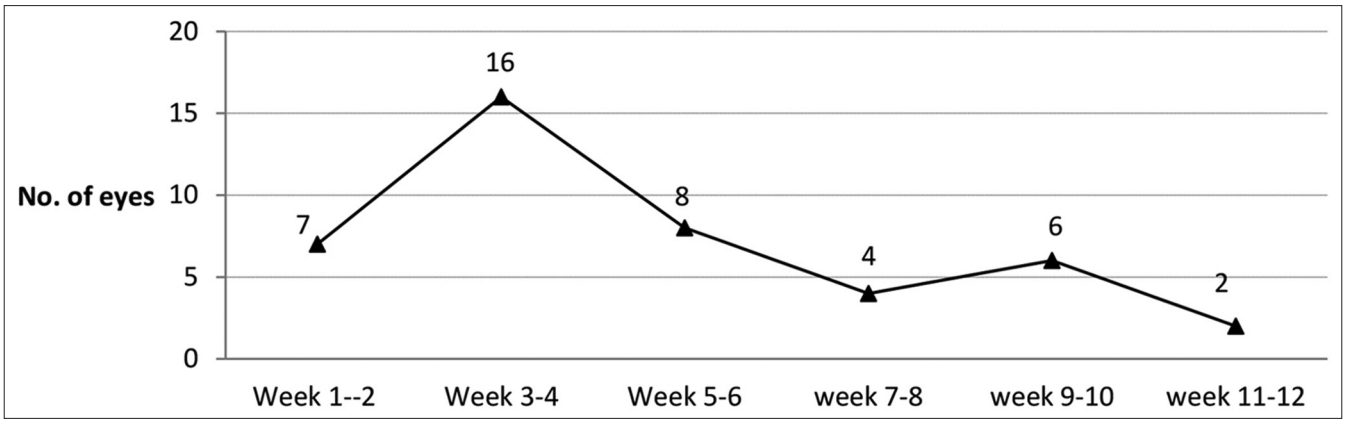

Figure 2: Full or partial improvement of visual acuity

Table 2: Number of fully or partially improved eyes with respect to astigmatism type

	Full improvement (*n*=43), *n* (%)	Partial improvement (*n*=7), *n* (%)	No Improvement (*n*=7), *n* (%)	Total eyes (*n*=50), *n* (%)	*P*
Nonoblique astigmatism	7 (100)	0	0	7 (100)	<0.001
Oblique astigmatism	29 (67)	7 (16)	7 (16)	43 (100)	

Table 3: Comparison of best corrected visual acuity at various time points during the study

	Mean (LogMAR VA)	SD	*P* value versus baseline	*P* value versus previous
Baseline	0.428	0.106		
At 1 week	0.356	0.136	0.023	
At 2 weeks	0.260	0.133	<0.001	0.017
At 4 weeks	0.138	0.134	<0.001	<0.001
At 12 weeks	0.077	0.083	<0.001	0.04

SD: Standard deviation, LogMAR: Logarithm of minimum angle of resolution, VA: Visual acuity

action game "Medal of Honor" with their amblyopic eye.[22] They used a crossover study design of patching and video game playing and showed that playing video games (both action and nonaction games) for a short period of time (2 h/day) using the amblyopic eye resulted in a substantial improvement in a wide range of fundamental visual functions, from low level to high level, including VA (33%), positional acuity (16%), spatial attention (37%), and stereopsis (54%). Authors also claim that the recovery in VA that they observed could be at least five-fold faster than would be expected from occlusion therapy in childhood amblyopia and attribute this to plasticity in the visual system induced by video game playing. Although we did not have a control group, and our patients had MA, we also found that our video game assisted amblyopia therapy lead to improvement in VA in the majority of participants. In another study, very similar to ours, Hussain *et al*. designed a video game to improve contrast sensitivity called the Pan's remarkable adventures. Like our AAVG, this game also had an embedded perceptual learning task in which moving targets with varying degrees of contrast formed an integral part of the game. This was tested on 10 adults and 10 children and both groups showed equal visual improvement, similar to our cohort.

We found that younger children (<12 years) benefitted more than older children (>12 years) with 90% eyes in the former group showing full improvement. This is in sync with previously reported that younger the child, the better the response to amblyopia therapy.[15] We also found that maximum number of eyes showed improvement between 2 and 4 weeks of initiation of video games. This is similar to that reported by Li *et al*. who also found optimal benefit with their video games between 40 and 80 h of use.[22] It is possible that neural recalibration that potentially occurs with video game stimulation peaks at this time point in most patients, showing the desired response and visual improvement. Interestingly, we found that all eyes with nonoblique astigmatism had full improvement compared to only 67% on the oblique astigmatism group. However, there were only 7 eyes in the former group, making comparisons difficult. It is possible that with more number of eyes in the nonoblique group, we may have seen treatment failures. However, this concept requires further study in the future. We also found good adherence to the AAVG use on a daily basis and good follow-up rates. This may be because the games were engaging and were changed on a weekly basis based on the performance of the child in the previous week.

Limitations

The limitations of our study were the lack of a true control group, nonrecording of stereo-acuity and other measures of visual quality such as contrast sensitivity. However, we wanted to understand whether the AAVG shows any benefit in children and adolescents with residual MA and hence this was designed as a proof of concept study. The advantages of the study are a good adherence rate, good follow-up from patients and recording of data at various time points during the 12 weeks follow-up, giving us insight into when most children start responding to the treatment. To the best of our knowledge, this is the first study evaluating the visual benefits of specifically designed video games on eyes with MA.

Conclusion

The AAVG described in this paper, lead to visual recovery in the majority of moderate grade residual MA patients especially in eyes with oblique astigmatism. Most of them experienced speedy visual improvement between 2 and 4 weeks after onset of playing the games. However, some regression following abrupt cessation of the games must be kept in mind. The astigmatic axis stimulation games may be considered supplemental to patching therapy for the improvement of VA in MA yet we realize that further research is warranted.

Acknowledgement

We are thankful for the guidance and encouragement from time to time. (1) Dr.Surendran (V.Chairman Shankar Netralaya Chennai ,India). (2) Prof : Kamalesh (Maulana Azad M.C,Delhi. India). (3) Dr. Subhash Dediya (Maulana Azad M.C,Delhi. India).

Financial support and sponsorship

Nil.

Conflicts of interest

The Author has a commercial interest.

References

1. Mitchell DE, Freeman RD, Millodot M, Haegerstrom G. Meridional amblyopia: Evidence for modification of the human visual system by early visual experience. Vision Res 1973;13:535-58.
2. Freeman RD, Mitchell DE, Millodot M. A neural effect of partial visual deprivation in humans. Science 1972;175:1384-6.
3. Gwiazda J, Bauer J, Thorn F, Held R. Meridional amblyopia does result from astigmatism in early childhood. Clin Vis Sci 1986;1:145-452.
4. Abrahamsson M, Sjöstrand J. Astigmatic axis and amblyopia in childhood. Acta Ophthalmol Scand 2003;81:33-7.
5. Harvey EM, Dobson V, Clifford-Donaldson CE, MillerJM. Optical treatment of amblyopia in astigmatic children: The sensitive period for successful treatment. Ophthalmology 2007;114:2293-301.
6. Simons K. Amblyopia characterization, treatment, and prophylaxis. Surv Ophthalmol 2005;50:123-66. 7. Harvey EM. Development and treatment of astigmatism-related amblyopia. Optom Vis Sci 2009;86:634-9.
7. Harvey EM, Development and treatment of astigmatism related amblyopia, Optom. Vis. Sci. 2009; 86: 634–639.
8. Wallace DK; Pediatric Eye Disease Investigator Group, EdwardsAR, Cotter SA, Beck RW, Arnold RW, *et al*. A randomized trial to evaluate 2 hours of daily patching for strabismic and anisometropic amblyopia in children. Ophthalmology 2006;113:904-12.
9. Sala NA, Hodde RM. Pediatric Eye Disease Investigator Group. A randomized trial of near versus distance activities while patching for amblyopia in children aged 3 to less than 7 years. Ophthalmology 2008;115:2071-8.
10. Holmes JM, Beck RW, Kraker RT, Astle WF, Birch EE, Cole SR, *et al*. Risk of amblyopia recurrence after cessation of treatment. J AAPOS 2004;8:420-8.
11. Suttle CM. Active treatments for amblyopia: A review of the methods and evidence base. Clin Exp Optom 2010;93:287-99.
12. Levi DM, Li RW. Perceptual learning as a potential treatment for amblyopia: A mini-review. Vision Res 2009;49:2535-49.
13. Chen PL, Chen JT, Fu JJ, Chien KH, Lu DW. A pilot study of anisometropic amblyopia improved in adults and children by perceptual learning: An alternative treatment to patching. Ophthalmic Physiol Opt 2008;28:422-8.
14. Zhou Y, Huang C, Xu P, Tao L, Qiu Z, Li X, *et al*. Perceptual learning improves contrast sensitivity and visual acuity in adults with anisometropic amblyopia. Vision Res 2006;46:739-50.
15. To L, Thompson B, Blum JR, Maehara G, Hess RF, Cooperstock JR, *et al*. A game platform for treatment of amblyopia. IEEE Trans Neural Syst Rehabil Eng 2011;19:280-9.
16. Kämpf U, Shamshinova A, Kaschtschenko T, Mascolus W, Pillunat L, HaaseW, et al. Long-term application of computer-based pleoptics in home therapy: Selected results of a prospective multicenter study. Strabismus 2008;16:149-58.
17. Cleary M, Moody AD, Buchanan A, Stewart H, Dutton GN. Assessment of a computer-based treatment for older amblyopes: The Glasgow pilot study. Eye (Lond) 2009;23:124-31.
18. Rastegarpour A. A computer-based anaglyphic system for the treatment of amblyopia. Clin Ophthalmol 2011;5:1319-23.
19. Foss AJ. Use of video games for the treatment of amblyopia. Curr Opin Ophthalmol 2017;28:276-81.
20. Achtman RL, Green CS, Bavelier D. Video games as a tool to train visual skills. Restor Neurol Neurosci 2008;26:435-46.
21. Green CS, Bavelier D. Action video game modifies visual selective attention. Nature 2003;423:534-7.
22. Li RW, Ngo C, Nguyen J, Levi DM. Video-game play induces plasticity in the visual system of adults with amblyopia. PLoS Biol 2011;9:e1001135.
23. Knox PJ, Simmers AJ, Gray LS, Cleary M. An exploratory study: Prolonged periods of binocular stimulation can provide an effective treatment for childhood amblyopia. Invest Ophthalmol Vis Sci 2012;53:817-24.
24. LiSL, JostRM, MoraleSE, StagerDR, DaoL, StagerD, *et al*. A binocular iPad treatment for amblyopic children. Eye (Lond) 2014;28:1246-53.
25. Birch EE, Li SL, Jost RM, Morale SE, De La Cruz A, Stager D Jr., *et al*. Binocular iPad treatment for amblyopia in preschool children. J AAPOS 2015;19:6-11.
26. Hess RF, Mansouri B, Thompson B. A new binocular approach to the treatment of amblyopia in adults well beyond the critical period of visual development. Restor Neurol Neurosci 2010;28:793-802.
27. Hess RF, Mansouri B, Thompson B. A binocular approach to treating amblyopia: Antisuppression therapy. Optom Vis Sci 2010;87:697-704.
28. Li R, Polat U, Makous W, Bavelier D. Enhancing the contrast sensitivity function through action video game training. Nat Neurosci 2009;12:549-51.
29. Hussain Z, Astle AT, Webb BS, McGraw PV. The challenges of developing a contrast-based video game for treatment of amblyopia. Front Psychol 2014;5:1210.
30. Griffiths MD, Kuss MJ, King DL. Video game addiction, past, present and future. Curr Psychiatry Rev 2012;8:1-11.