Original Article

Perceptual learning with hand – eye coordination as an effective tool for managing amblyopia: A prospective study

Shreya Shah, Mehul Shah, Anand Purohit, Vaibhav Khanguda

Purpose: Amblyopia is a serious condition resulting in monocular impairment of vision. Although traditional treatment improves vision, we attempted to explore the results of perceptual learning in this study. **Methods:** This prospective cohort study included all patients with amblyopia who were subjected to perceptual learning. The presenting data on vision, stereopsis and contrast sensitivity were documented in a pretested online format, and the pre- and post-treatment information was compared using descriptive, cross-tabulation and comparative methods on SPSS 2.2. The mean values were obtained, and $P < 0.05$ was considered statistically significant. **Results:** The cohort consisted of 47 patients (23 females and 24 males) with a mean age of 14.11 ± 7.13 years. A statistically significant improvement was detected in visual acuity after the perceptual learning session, and the median follow-up period was 17 days. Also, significant improvements were observed in stereopsis but not in the visual outcomes among the age groups. **Conclusion:** Perceptual learning with hand–eye coordination is an effective method for managing amblyopia. This approach can improve vision in all age groups. However, visual improvement is significantly influenced by ocular alignment.

Key words: Amblyopia, amblyopia management in elderly, perceptual learning, visual recovery

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Amblyopia is a cortical development disorder secondary to abnormal visual inputs in each eye early in life (during the cortical plasticity stage), wherein dissimilar action potentials (in amplitude or time or both) generated in the retina reach the cortex. These cortical changes entice the visual cortex to prefer one eye over the other, leading to several functional deficiencies in the eye. These include altered visual functions, such as decreased vernier acuity, impaired contrast sensitivity, especially in detecting high-spatial frequency stimuli, and impaired motor signs, such as hand–eye coordination and spatial localization. These defects can be uni- or bilateral.[1,2] Amblyopia is the most common cause of monocular visual impairment that affects 2%–5% of the general population.

The population-based studies revealed that the prevalence of the disease in 6–71-month-old children was 0.73%–1.9%,[2] whereas school-based studies on older (> 5 years) children reported higher rates (1.0%–5.5%)[2] depending on the population studied and the definition used.[2–14] Bilateral amblyopia is less frequent than unilateral disease; however, the reported proportion varies considerably from 5% to 41% of all cases of amblyopia[4,11–16] and is 2.7–18 times greater in the presence of strabismus.[12,15,17–19]

The risk factors for amblyopia are premature birth, small for gestational age,[20–24] developmental delay[24] and having a first-degree relative with amblyopia.[25,26] Some studies have reported that environmental factors, including maternal substance abuse during pregnancy, are associated with an increased risk of amblyopia or strabismus,[27–32] while other studies have refuted this claim.[12,15,33]

Drashti Netralaya, Dahod, Gujarat, India

Correspondence to: Dr. Mehul Shah, Drashti Netralaya, Chakalia Road, Dahod, Gujarat, India. E-mail: omtrustdahod@gmail.com

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Treatment options for amblyopia in children are optical correction of significant refractive errors, patching, pharmacological treatment, refractive surgery and alternative therapies.

These findings strongly support the need to combine a pharmacological approach with personalized behavioral training aimed at targeting plasticity within specific brain regions or cortical circuits. However, additional studies are essential to further elucidate these approaches.

Polat *et al*.[34] suggested that perceptual learning can augment the visual function in adult amblyopes. Also, pretest to posttest performance and gains in visual acuity (VA) improved in a series of 77 adult amblyopes in a learning trial of Gabor signals. The neural basis for this observation has been postulated to be lateral inhibition within the brain as a result of training.[1] However, the gains in the test outcome in the amblyopic eye could not be transferred to novel situations, and improvement was only observed in the task practiced.

Saccades are short, with rapid eye movements lasting for 30–80 milliseconds working through an internal feedback loop based on the efferent motor commands sent to the ocular motor neurons. Sensory-motor integration occurs in the posterior parietal cortex (PPC), also referred to as an associative cortical

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region, during the generation of the saccade. The lateral occipital vision–mediated cortex activation is present only during the targeted saccadic condition, while internal cognitive saccades are not associated with a lateral occipital cortical activity. The retina between the fovea and the stimulated peripheral retinal point is suppressed during a saccade. The fovea is alerted about the peripheral retinal stimulus a few milliseconds before the onset of the saccade. The top-down impulses originate in the prefrontal cortex and alter the attention mechanism, which in turn affects the striate cortex.

Overt attention is defined as the moment when the peripheral stimulus draws the attention of the eye and ensures foveal fixation. On the other hand, covert attention is when the patient is fixating on the central light and still can see the peripheral lights. Both covert and overt attention stimulate the lateral occipital cortex via the top-down impulses. The above motor and sensory aspects of vision are the principles used for developing the Orthoptek Magnocellular Stimulator (OMS), an advanced treatment modality for amblyopia. The stimulation of magnocellular cells also activates the fovea a few milliseconds before the saccadic movements begin and last after the completion of the saccade. The further away from the fovea the image is located on the retina, the greater the eye movement to bring the peripheral retinal image onto the fovea and the greater is the retinomotor value of the receptor. Hence, the fovea has zero retinomotor value,[1] which is a crucial principle for instrument design [Fig. 1].

Perceptual learning is yet to gain widespread support. Most studies were conducted on only a small number of participants. The effects of perceptual learning have been demonstrated to last from hours to months without continued practice, albeit long-term follow-up is lacking. Additionally, binocular/dichoptic therapy and a comparison of various treatment modalities are essential. Currently, no studies have compared the conventional modalities of amblyopia management, such as patching and penalization, with the newer modalities, such as dichoptic therapy and liquid crystal glasses.

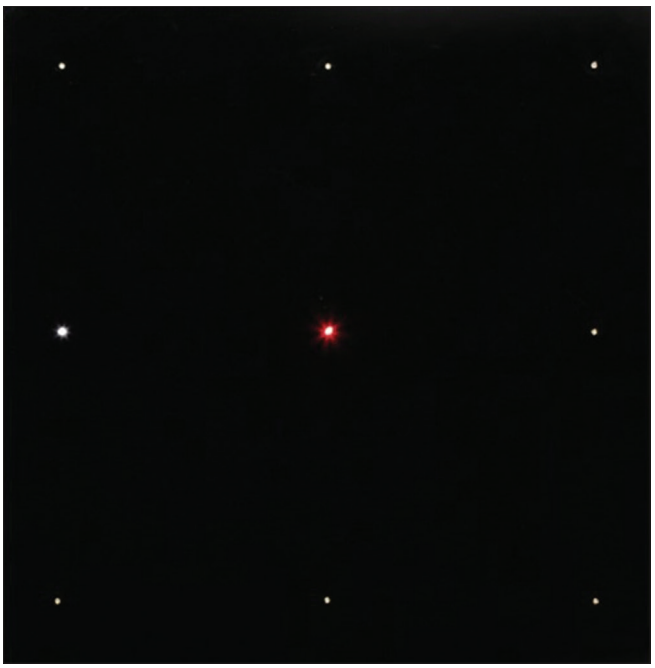

Figure 1: Electronic panel for hand eye coordination with laser pointer

Methods

This prospective cohort study was approved by the Ethics Committee of DxxxHospital (xx 21/22). All patients in the ocular motility clinic diagnosed with amblyopia of any cause (strabismic and anisometropic) were enrolled in this study. All eyes with organic lesions were excluded. All enrolled patients underwent complete cycloplegic refraction and anterior and posterior segment examination. Also, distance as well near stereopsis, contrast sensitivity and handwriting were examined, after which they were subjected to hand–eye coordination training for a designated period (20 sessions of 30 minutes each). All patients were followed up at the end of one month, and the information was documented in a pretested online format before and after the treatment.

Pre- and post-treatment VA, distance and near stereopsis, angle of deviation and contrast sensitivity were compared using the Statistical Package for the Social Sciences (SPSS) version 22, descriptive analysis, cross-tabulation and analysis of variance.

Results

This method was applied to 47 patients (23 [48.9%] women and 24 [51.1%] men) with a mean age of 14.11 ± 7.13 23 years [Table 1].

The mean follow-up period was 17 days.

Prior to the procedure, 28 (59.6%) patients were orthophoric, whereas after the procedure, 30 (63.8%) had orthophoria. A significant difference was detected for distance and near in the deviation by Prism bar cover test [Table 2].

Nonetheless, no significant difference was observed between the two age groups for distance as well as near ($P = 0.449, 0.271$). Visual improvement was also observed in the older age group.

Table 1: Age and sex distribution

	Sex		Total
	F	M	
6-10	4	13	17
>10	19	11	30
Total	23	24	47

Table 2: Comparative study of pre- and post-study values

Variable	*P*
Pre post vision OD#	0.000
Pre post vision OS$	0.000
Pre post stereopsis for near	0.000
Pre post stereopsis distance	0.001
Strabismus	0.001
Type of strabismus	0.503
PBCT* OD# vs post procedure	0.007
PBCT* OS$ vs post procedure	0.016
PBCT* near deviation OD# vs post procedure	0.045
PBCT* near deviation OS$ vs post procedure	0.028
Contrast sensitivity	0.000

*PBCT, Prism bar cover test. #OD, Right eye. $OS, Left eye

Interestingly, strabismic amblyopia was detected in 48.9% of patients, and refractive amblyopia was noted in 46.8% of patients. However, no significant difference was observed in the visual outcome (P = 0.178) following training, but the pre- and post-treatment vision, near and distance stereopsis and contrast sensitivity differed significantly in the two subgroups [Tables 2 and 3].

Discussion

No significant difference was observed among the various age groups. Marianne *et al*. reported several changes in the perspective of the recovery period for amblyopia. Previous studies and clinical practice demonstrated that conventional treatment improved VA in the amblyopic eye in children aged >7 years. These media-described cases within the community eye care domain suggested that the literature on amblyopia treatment in older children (aged >7 years) should be screened to address the misconceptions and focus on the current issues faced by clinicians while treating newly diagnosed amblyopia in this age group.[34,35]

Notably, VA improved significantly after the treatment [Table 2]. Grant *et al*.[36] reported that a combined therapy of perceptual learning-based visual training and patching was effective in improving VA in children with amblyopia who did not regain their vision with patching alone or had poor patching compliance. This preliminary outcome should be confirmed in future clinical trials.

Similar findings have been reported by Bonaccorsi *et al*.[37] on the impact of visual perceptual learning on amblyopia, with a focus on a new experimental model of perceptual learning in amblyopic rats.

Non-human animal models have demonstrated that selective serotonin re-uptake inhibitors (SSRIs) enhance the plasticity within the mature visual cortex and enable recovery from amblyopia.[38,39]

The strategies employed by children with amblyopia and abnormal binocularity to attain precision grasping alter with age. The visual feedback during the "inflight" approach was pronounced during the age of 5–6 years, which increased the reliance on tactile/kinaesthetic feedback from object contact at an age of 7–9 years. However, regaining binocularity improved the hand–eye coordination speed and accuracy in an age-dependent manner, which is a better predictor of these fundamental performance measures than the degree of VA loss.[36]

Antonio *et al*. Rodan A *et al*. reported that several treatments differing in design (for example, type of stimulus, context used and duration of the training) and with a wide age group, including adults, have been applied. Most of the studies showed an improvement in some monocular and binocular visual functions, such as VA, contrast sensitivity and stereopsis. Currently, it is recommended to use these processes as an alternative or as a complement to the traditional passive therapy.[40]

The strength of our study is its prospective nature, while the small sample size and the short follow-up period are some limitations. Thus, we may try a combination of therapies, such as patching and perceptual learning or randomized, controlled trial for alternative therapies.[40]

Table 3: Mean of variables

Variable	Mean	St deviation
Pre distance stereopsis	474.38	426.21
Pre near stereopsis	347.89	367.27
Post distance stereopsis	343.83	256.92
Post near stereopsis	299.56	256.21
Pre contrast	0.82	0.126
Post contrast	0.80	0.000

Conclusion

Perceptual learning with hand–eye coordination is an effective method for managing amblyopia in older children. The technique is utilised, irrespective of age, and the visual outcome has improved in patients with orthophoria.

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Conflicts of interest

There are no conflicts of interest.

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