Effect of induced monocular blur on monocular and binocular visual functions

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Abstract

Background and purpose: *Anisometropia and surgical monovision is likely to have a detrimental impact on binocular visual functions. This study evaluates the effect of induced monocular blur in the form of a refractive defocus on visual functions and binocularity.*
Methods: *An experimental study was conducted on 30 young emmetropic adults. Monocular myopia and hypermetropia was induced using 6 plus and minus spherical lenses in steps of 0.5 Dioptre ranging from +/-0.5DS to +/-3.00DS. Visual Acuity (LogMAR), contrast sensitivity (Pelli Robson), binocularity (Bagolini striated glasses) and stereoacuity (near Randot, distance Randot and Frisby davis Distance) were evaluated at baseline and each level of refractive defocus.*
Results: *Induced monocular myopic shift resulted in reduction of visual acuity to 0.94 log MAR while hyperopic shift reduced visual acuity to 0.1 log MAR. Contrast sensitivity did not show a significant reduction with optical blur. Hyperopic shift did not hamper gross binocular vision unlike myopic shift where distance binocular vision was elicited only till a +2D defocus and near binocular vision till a +3D defocus. Near stereopsis deteriorated with both a hyperopic and myopic blur but was not completely lost and could be elicited even with the maximal blur. Distance randot stereopsis was lost on inducing a +2.5D blur while Frisby Davis distance stereopsis was lost at +3D blur. Induced hyperopic shift did not lead to an absolute loss of distance stereopsis.*
Conclusion: *Binocular visual functions were significantly affected by induced monocular blur through a spherical refractive defocus. Induced myopic shift caused significantly more stereo acuity loss than induced hyperopia. Optical blur impacts distance stereoacuity to a greater extent than near.*

Keywords: *Binocularity, Defocus, Hyperopia, Optical blur, Myopia, Stereopsis, Stereo-acuity*

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INTRODUCTION

Vision encompasses a variety of visual functions including visual acuity, contrast sensitivity and stereo acuity. Binocularity and stereo acuity have been gaining importance due to the increasing demands for three dimensional perception in our daily lives.[1] With the advent of three dimensional entertainment options, and an increasingly competitive world of sports, the precision of appreciating depth is more important than ever before. It is well known that visual functions are affected by various parameters including but not limited to various physiologic and pathologic conditions such as age, optical blur, inter-eye differences, strabismus and amblyopia.[2]

Anisometropia from birth or early childhood is likely to cause a significantly detrimental effect on visual functions, though the same may not be true for anisometropia induced or acquired later in life, as binocularity and other visual functions are expected to have developed by then.[2] An example of the latter scenario is surgically induced mono vision after a cataract surgery.

The concept of an acquired monocular blur and its effects on visual functions has been examined previously in literature though studies either focused on limited visual parameters or used non refractive forms of blur.[3-6] Of these studies, Odell et al induced a blur using Bagerter filters which reduce visual acuity and contrast sensitivity but do not simulate a true optical blur as induced by a refractive anisometropia, while Fawcett et al studied post refractive surgery mono vision cases where multiple factors including optical and higher order aberrations come into play. Thus neither of these truly represents an anisometropic monocular blur such as that induced during mono vision after a cataract surgery. Studies which have experimentally induced optical defocus have only concentrated on near stereoacuity.[5, 6]

This study evaluates the effect of induced anisometropia on various visual functions including contrast sensitivity and near, distance and real depth stereoacuity in order to understand the need for a balanced refractive status after various ophthalmic procedures.

METHODS

The study was conducted at a tertiary care ophthalmology institution after prior approval from the ethics subcommittee. The sample studied consisted of thirty emmetropic and orthotropic subjects of ages18-30 years who had a Snellen visual acuity of 20/20 or better in each eye and a stereo-acuity of at least 30 arc secs on TNO. Subjects who had a history of strabismus or any other eye disease were excluded. All subjects underwent a complete ophthalmological examination and special tests including contrast sensitivity and stereo-acuity measurement.

The dominant eye was determined in each subject. This was done using a card with a hole in the center. The card was held at a one arm distance and a spot light fixed at a distance of 6m viewed through it with both eyes open. Either eye was closed alternately while the other eye continually attempted to focus on the spotlight through the hole in the card. The eye which saw the spotlight unobstructed through the hole was deemed to be the dominant eye.

The next step was to induce an optical blur (refractive defocus) in the dominant and non-dominant eye alternately followed by performing the predetermined visual function testing. Monocular optical blur was induced by six plus and six minus lenses increasing in steps of 0.50D ranging from +/-0.50D to +/-3.00D. Either eye was tested at a time (first with plus lenses then minus lenses).

The first visual function tested was visual acuity using a Log MAR chart at 4 metres. Visual acuity was measured monocularly through the eye with defocus and ranged between 0 to 1.0 log MAR. This was followed by testing contrast sensitivity using the Pelli – Robson chart. Testing was performed monocularly for the eye with blur, in recommended lighting conditions at the standard 1 metre distance. At least 2 of 3 correct responses were required for each threshold before it was deemed achieved. The recording was done in log units, ranging from 0.0 to 2.0 log units. The next step involved assessment of binocular single vision which was done binocularly using the Bagolini striated glasses for distance (6 m) and near (33 cm). The subject was made to wear the Bagolini striated glasses and asked to look at a point source of light at either 6 metres or 33 centimetres. The subject was asked to appreciate the cross response and if present, it was recorded as presence of binocular vision or else noted as suppression of the defocussed eye. This was followed by stereo-acuity testing performed using 3 stereo tests; two for distance (Frisby Davis Distance [FD2] and Distance Randot) and one for near (Near Randot). As was done for the visual acuity and contrast sensitivity, baseline stereo-acuity with all the stereo tests was first assessed without inducing any optical defocus.

The Frisby Davis Distance (FD2) was assessed at 4 metres with testing disparities of 10 to 115 arc sec. The threshold was recorded as the finest disparity at which 4 of 4 shapes were correctly identified after randomly inducing the same disparity between them. The subject's head was kept straight without allowing any movement to avoid monocular clues in the form of parallax. If the subject was unable to appreciate the difference at maximum disparity, the stereo acutiy was recorded as nil and given an arbitrary value of 400 arc seconds for statistical purposes. The Distance Randot stereo acuity was tested at 3 m. The chart possesses fixed stereo values of 400, 200, 100, and 60 arc sec and two correct responses were required to deem each stereo acuity level as achieved, Patients unable to pass the 400 arc sec level were recorded as having nil stereopsis but were given an arbitrary value of 800 arc sec for statistical analysis. The Near Randot Stereo test (NRS) was tested at 33cm, The chart possesses stereo values ranging from 20 to 400 arc secs tested in the format of Wirt's circles. Patients unable to pass the 400 arc sec level were recorded as having nil stereopsis but were given an arbitrary value of 800 arc sec for statistical analysis.

Data was compared graphically using scatter plots with lines and markings. Comparison was done between hyperopic shift and myopic shift for all the parameters taken for the study.

RESULTS

The mean age of the patient population was 23± 4.2 years. The baseline median log MAR visual acuity was 0 (range 0 to 0.09) while contrast sensitivity was noted to be 1.8 (range 1.65-2.0). All patients demonstrated binocularity on the Bagolini striated glasses for near and distance. Prior to inducing the refractive defocus, the Randot steretests revealed a median stereo-acuity of 20 arc secs (range 20-40 arc secs) on the near and 60 arc secs (range 60-100 arc secs) on the distance chart respectively. The median baseline distance stereo-acuity on the FD2 test was 15 arc secs (range 10-20 arc secs).

On inducing a myopic shift with the use of plus lenses, the visual acuity reduced to a low of 0.94 log MAR (+3D blur) while on inducing a hyperopic shift with the use of minus lenses, the visual acuity dropped to 0.1 log MAR. Contrast sensitivity did not show a significant reduction with both the myopic or hyperopic shift. With a maximal myopic shift (+3.00 D lens), the contrast sensitivity fell just below 1.50 but all other amounts of blur kept contrast sensitivity in the range of 1.65 to 1.8. (Figure 1)

Binocular vision (positive cross response on Bagolini striated glasses) was maintained for both distance and near even with the maximal hyperopic shift. However, on inducing a myopic shift, distance binocular vision could only be elicited till a defocus of +2.00 D corresponding to a visual acuity of 0.67 log MAR and near binocular vision was lost with a blur of +3.00 D corresponding to a visual acuity of 0.94 log MAR.

Both myopic and hyperopic shift resulted in deterioration of near and distance stereo-acuity. (Figure 2) Distance Randot stereo-acuity became nil with a +2.50D blur corresponding with log MAR visual acuity of 0.83 units. Subjects continued to respond to the FD2 stereo test at +2.50D blur and real depth stereopsis became nil only with a +3.00D defocus corresponding to a log MAR visual acuity of 0.94 units. Despite maximum optical blur, subjects continued to respond to near stereo acuity and significant deterioration was noted only after inducing a +2.00 D blur. In contrast to a myopic shift, even maximal hyperopic shift did not result in total loss of stereopsis though some reduction was observed.

No significant difference was noted on comparing data from blurring of either the dominant or the non-dominant eyes.

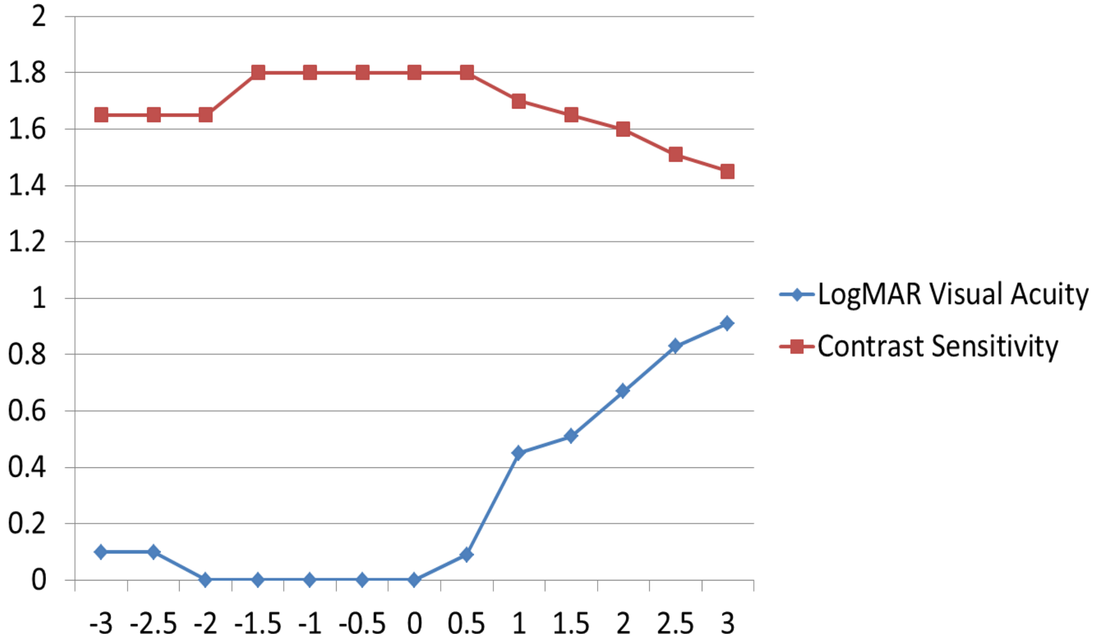

Fig. 1: This is a line graph depicting the change of Log MAR visual acuity and contrast sensitivity with various levels of induced monocular blur. The x-axis represents the varying power of lenses used to induce an optical blur (-3 to +3). The y-axis represents the units of visual acuity and contrast sensitivity.

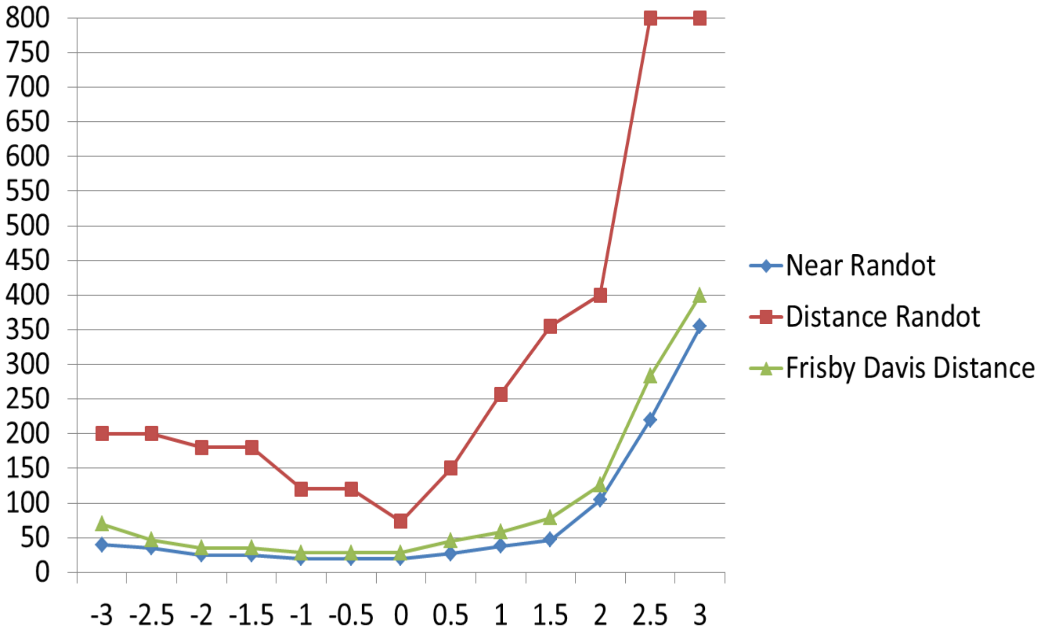

Fig. 2: This is a line graph depicting the change of Near Randot stereo acuity, Distance Randot stereo acuity and Frisby Davis Distance stereo acuity with various levels of induced monocular blur. The x-axis represents the varying power of lenses used to induce an optical blur (-3 to +3). The y-axis represents the units of stereo acuity in arc secs

DISCUSSION

Stereo acuity is an important visual function which is significantly impacted by optical blur. It has been previously demonstrated that presence of anisometropia hampers the development of stereo-acuity either by virtue of amblyopia or by inducing a relative monocular blur.[2] Since all subjects had a normal binocular development, the concept of an acquired monocular blur is explored on the lines of some previous studies.[3-6]

The effect of optical blur on visual acuity is clearly demonstrated in this study. Visual acuity reduced significantly on inducing myopia while it was relatively resistant to hypermetropic blur. This is due to the ability to accommodate and overcome an induced hypermetropia particularly in the lower minus lenses.[7]

Contrast sensitivity was found to be resistant to optical blur. Previously the effect of optical blur on contrast sensitivity has been evaluated but in contrast to our study, that study found a significant deterioration of contrast sensitivity with every diopter of optical blur.[8] The difference between the study protocols was the use of sine wave/grating based contrast function as against the optotype based Pelli-Robson chart in the current study which may explain the differing results. These results show that refractive defocus tends to spare the lower spatial frequencies as represented in the letter optotype chart though previpus literature has shown an affect across the range of spatial frequencies.[9]

Gross binocularity as observed through the Bagolini glasses was lost completely with a large myopic anisometropia but not with a hyperopic anisometropia. This result is almost aligned to that seen in a previous study though the effect by +2 and +3 D lenses was more pronounced and that by -2 and -3 D lenses was less pronounced in our study.[6]

Previous literature has documented that there is a significant reduction of near stereo acuity with inducing even 1 Dioptre of anisometropia (either myopic or hypermetropic) and values of 3 Dioptre cause a marked reduction.[6] Our study differs slightly from these results and notes a significant reduction of near stereo acuity with a 1 Dioptre induced myopia but not a 1 Dioptre induced hypermetropic anisometropia where a 2.5 Dioptre blur was required to cause a similar loss. On the contrary, distance stereo-acuity fell more significantly with induction of both a monocular myopic and hyperopic shift starting from as little as 1 Dioptre. In long standing cases, the authors have previously demonstrated that 1 Dioptre of anisometropia caused a significant deterioration of distance stereo-acuity but not near stereopsis and other studies have highlighted the need for at least 2.5 Dioptre of anisometropia to affect near stereoacuity.[10,11]

The myopic shift had a greater impact as compared to a hyperopic shift and part of this may be related to the ability of the eye to achieve a better visual acuity by accommodating for minus lenses and anisoaccomodation may have a role to play.

The real depth stereo test was more resistant to induced anisometropia than the simulated Randot tests. polaroid dissociation based tests. More degradation in stereoacuity on distance Randot than FD2 also suggests that the Randot, being a more dissociative test, is a more sensitive method to measure any changes in distance stereo-acuity.

There is evidence to suggest that anisometropia as generated by a monocular defocus hampers stereo-acuity to a greater extent than a binocular optical blur.[12] This explains the significant drop in stereo-acuity in our subjects even with low optical changes. The higher adverse impact seen due to a monocular myopia versus a hypermetropia may be explained by the fact that a subject may be able to accommodate to a certain extent and balance the anisometropia to achieve a low hypermetropia in one eye and low myopia in the other. This is further supported by the relatively better visual acuity in all steps of induced hyperopia in comparison to myopia. Considering this explanation, in pseudophakic patients where a monovision has been induced, there would be no difference between an induced myopia and hyperopia as accommodation would not play a role. Keeping this in view, it is not recommended to induce an anisometropia greater than 1 D to avoid hampering binocular visual functions. The other reason which has been hypothesized for the difference between an induced myopia and an induced hypermetropia is the change in image sizes. It has been postulated that the presence of aniseikonia is an important factor which impacts fine stereopsis.[13]This however is offset by the inability to clear blur while seeing through a plus lens which may magnify image sizes but induce greater blur.

An important aspect that comes to the fore when examining the figures is the presence of a clear floor and ceiling effect which is generated by virtue of the charts used for testing the visual acuity and stereopsis. Since the visual acuity was limited to a best of 0.0 on the Log MAR, it was not recorded to levels better than this and therefore the deterioration in visual acuity on inducing the blur was noted at higher refractive defocus than it actually maybe. Similarly by virtue of design of the stereopsis charts, there were only fixed discrete valies that could be determined and the minimal stereopsis was given an arbitrary value of 800 arc secs. This too contrinuted to a ceiling and floor effect which gave a non-linear curve as seen in the figure 2.

It is also evident from our study that there is no difference in the deterioration of visual functions with optical blurring of either the dominant or non-dominant eye. This implication is that there is no specific functional significance to selecting either of the eyes for inducing a myopia or hyperopia when planning mono vision.

An important observation from the study is the fact that near Randot stereo-acuity and distance FD2 stereo-acuity remains fairly stable between the -2.5 D anisometropia and +1.5 D anisometropia, while distance Randot stereo acuity remains stable over a smaller range of -1.5D to +0.5 D anisometropia.

There are certain limitations of this study which merit mention. Firstly, there is a certain optical aberration induced by introduction of lenses in front of one eye which may hamper stereo-acuity testing to a variable and unpredictable extent. This is more evident when polaroid glasses are being used over such lenses. However these aberrations would be small since only low powered lenses were used for inducing blur. Secondly, there is a learning curve for each of the stereo tests and as subjects perform them repeatedly with different degrees of blur induced, they may improve in their responses. Finally, there is a limited adaptation time for subjects as compared to patients with long standing mono vision causing slight discrepancies in the direct application of the study results to such cases.

To conclude, the study demonstrates the significantly detrimental impact of monocular blur or refractive defocus on binocular functions and highlights the greater effect of induced myopia as compared to induced hypermetropia. Surgical mono vision is likely to significantly impact bimocular visual functions.

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