
Treatment of anisometropic amblyopia in older children using macular stimulation with telescopic magnification

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ABSTRACT • RÉSUMÉ

Background: Brain plasticity exists beyond the critical period in children aged 9–17 years and in adults, and can result in vision restitution following more intense amblyopia treatments. Telescopic magnification provides a clearer image and better visual stimulation and hence promotes brain plasticity. The purpose of this study was to investigate the impact of vision therapy with telescopic magnification on brain plasticity when given after the traditional methods of amblyopia treatment currently in use in older children.

Methods: The study was a prospective, nonrandomized, interventional case series of children aged 7–18 years with a confirmed diagnosis of anisometropic amblyopia not amenable to any further medical or surgical treatments. Strabismic and deprivation amblyopia cases were excluded. The patients wore newly prescribed glasses and were instructed to use a telescopic device in conjunction with the glasses for 30 minutes every day while watching, undisturbed, a favourite television show. Compliance was verified by the parents and investigated at each visit. The outcome measure selected for this study was best corrected visual acuity (BCVA) achieved at the 6-month follow-up visit.

Results: Eighteen study subjects (11 males and 7 females) were recruited aged 7–16 (mean 11.7) years. Before telescopic training sessions the mean BCVA in the amblyopic eye for the entire group was 0.5 (SD 0.3) logMAR units (20/63 equivalent), and this improved following the sessions to 0.24 (SD 0.34) logMAR units (20/35 equivalent) ($p < 0.0001$). A BCVA of 20/25 or better was achieved in the amblyopic eye in 10 (55.6%) of our 18 study subjects and a BCVA of 20/40 or better in 15 (83.3%) of the 18. There were no side effects evident from the intervention, specifically, no diplopia. Compliance with training was complete as per protocol.

Interpretation: The addition of vision rehabilitation therapy in the form of training sessions with telescopic magnification as described in this paper enhanced vision restitution in older children with anisometropic amblyopia.

Contexte : La plasticité cérébrale, qui se maintient au-delà de la période critique chez les enfants de 9 à 17 ans et les adultes, peut conduire au rétablissement de la vue à la suite de traitements plus intenses de l'amblyopie. Le grossissement télescopique produit une image plus nette et un meilleur stimulant visuel et, par conséquent, favorise la plasticité cérébrale. La présente étude a donc pour objet d'investiguer l'impact de la thérapie visuelle avec grossissement télescopique sur la plasticité cérébrale lorsqu'elle est appliquée après les modes traditionnels de traitement de l'amblyopie actuellement utilisés chez les enfants plus âgés.

Méthodes : L'étude, prospective et non randomisée, a porté sur une série d'interventions chez des enfants de 7 à 18 ans qui avaient un diagnostic d'amblyopie anisométrique ne se prêtant pas à d'autres traitements médicaux ou chirurgicaux. Les cas de strabisme et d'amblyopie de privation ont été exclus. Les patients portaient des lunettes nouvellement prescrites et avaient reçu instruction d'utiliser un appareil de télescopie avec leurs lunettes 30 minutes par jour en regardant sans distraction une émission de télévision préférée. La fidélité aux instructions était surveillée par les parents et vérifiée à chaque visite. La meilleure acuité visuelle avec correction (MAVC) obtenue à la visite du 6^e mois de suivi a été retenue pour en mesurer le résultat.

Résultats : Dix-huit sujets (11 masculins et 7 féminins) de 7 à 16 ans (moyenne de 11,7 ans) avaient été retenus pour l'étude. Avant les séances d'entraînement télescopique, la moyenne de la MAVC de l'œil amblyopique pour l'ensemble du groupe était de 0,5 (ÉT 0,3) unités logMAR (équivalence, 20/63). Ce résultat s'est amélioré à la suite des autres séances à 0,24 (ÉT 0,34) unités logMAR (équivalence, 20/35) ($p < 0,0001$). Une MAVC de 20/25 ou supérieure a été obtenue dans l'œil amblyopique chez 10 des 18 sujets de l'étude (55,6 %) et une MAVC de 20/40 ou supérieure a été atteinte chez 15 des 18 sujets (83,3 %). Il n'y a pas eu d'effets secondaires à l'intervention; notamment, pas de diplopie. L'observance du protocole appris pendant la formation a été entière.

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Interprétation : L'ajout d'une thérapie de réadaptation visuelle sous forme de séances d'entraînement télescopique comme le décrit cette étude a amélioré le rétablissement de la vision chez les enfants plus âgés atteint d'amblyopie anisométrique.

Amblyopia is the most common cause of monocular visual impairment in children and affects about 1%–4% of the population.^{1,2} Amblyopia may result from visual deprivation, anisometropia, or strabismus in infants and young children. There is consensus in the ophthalmic literature that, in patients afflicted by this impairment, treatment of amblyopia at an earlier age works best.^{3–5} Traditionally, the best time for treatment of amblyopia is before the age of 9 years, with less successful results thereafter.

In anisometric amblyopia, occlusion therapy is the treatment of choice once glasses have been prescribed. However, the success rate following treatment may be limited by poor compliance or late diagnosis. Compliance with patching might be better in younger children and poorer in the older ones, as reflected in the nonsatisfactory treatment results reported in the past for the older age groups.⁵

Studies and case reports have shown that visual improvement after the age of 9 years is possible,^{6,7} even in adults with amblyopia.^{8,9} Given that neural plasticity is recognized as a factor capable of improving visual function,¹⁰ it seems that in such cases there is potential for visual improvement with more intense therapy than just patching and glasses. The main reason recognized for failure of amblyopia treatments is noncompliance as a result of frustration from a blurred image supplied to the brain by an amblyopic eye, and frustration is not tolerated easily by an older child.^{11,12}

We hypothesized that provision of a clearer image would be tolerated more willingly by older children, leading to better compliance and better vision outcome. We felt this could be achieved using a telescopic magnifier to optimize macular vision. We measured the impact of this intervention on anisometric amblyopia following the use of traditional methods for amblyopia treatment, such as corrective glasses, patching, and (or) use of pharmacological agents.

METHODS

The study was designed as a prospective, nonrandomized, interventional case series. Patients were recruited from the community through advertisements of the study and from the ophthalmology clinical offices of one of the authors (Samuel N. Markowitz). The amblyopic eye was included in this study. Inclusion criteria were a confirmed diagnosis of anisometric amblyopia not amenable to any further medical or surgical treatments, and refractive error corrected and patching therapy attempted in the past. Included in the study were subjects with an age in the range of 7 to 18 years, a best corrected visual acuity (BCVA) worse than 20/50, and patient availability for follow-up visits for the duration of the study. We excluded patients

with strabismus over 8 prism diopters, myopia of more than 6 diopters, a history of previous muscle surgery, and a history of neurological disease or cognitive impairment.

Data were collected on demographic characteristics, most responsible diagnosis for amblyopia, past ocular and past medical history, and past vision rehabilitation interventions for amblyopia. The study protocol included assessment of the refractive error and prescription of glasses for obtaining BCVA. The BCVA was assessed by recording the line seen at 6 m using the Snellen chart and at 1 m using ETDRS (Early Treatment Diabetic Retinopathy Study¹³) charts. For more accurate assessment of visual acuity we used potential visual acuity measurements, which are based on assessment of resolution acuity present at preferred retinal loci. Potential visual acuity was measured at 0.5 m using the tumbling multiple E test.¹⁴ Contrast sensitivity was assessed with the Vistech VCTS 6500 Chart (Vistech Consultants, Inc, Dayton, Ohio)¹⁵ with monocular testing of the amblyopic eye in all subjects at a distance of 1 m. An adjustable Galilean telescope with $\times 2.2$ magnification, of nondistinct origin and commonly available, was attached with a wire clamp to the new spectacle glasses prescribed and positioned in front of the amblyopic eye (Fig. 1).

The study protocol called for full-time wearing of the newly prescribed glasses. The patient was instructed to use the telescopic device in conjunction with the glasses for 30 minutes uninterrupted every day while watching a favourite television show. The focus calibration of the telescope was done with the nonamblyopic eye on a clear and stable television picture. After this, the better eye was patched, and the telescopic training session was performed with the telescopic device positioned in front of the amblyopic eye and attached to the glasses with the clamp provided. Repeat assessments, as already described, were performed at 3- and 6-month intervals. Compliance with the study protocol was assessed at each visit by specifically questioning the study subject and the parent on whether the protocol was being followed at home. The need to follow the protocol accurately was reinforced at each visit. Adjustments to changes in the refractive error were prescribed, and the



Fig. 1—Telescopic training device for children with anisometric amblyopia.

patient was instructed to purchase new lenses for the glasses as indicated. The outcome measure selected for this study was BCVA achieved at the 6-month follow-up visit.

The data collected were organized to match the format used in a recent study sponsored by the National Eye Institute,⁶ which served also as the control group in the design of our study. The study was performed in adherence to the guidelines of the Declaration of Helsinki. The study protocol was approved by the Research Ethics Committee of the University Health Network of Toronto. Informed consent was obtained from all participants. Data were analyzed using a 2-tailed paired Student's *t* test of the mean values of the measured parameters, including visual acuity, compared before and after the intervention. A *p* value < 0.05 was considered statistically significant. Data analysis was performed using Statistical Package for the Social Sciences v. 10.1 for Windows (SPSS Inc, Chicago, Ill.).

RESULTS

Over a span of about 24 months, 18 study subjects (11 males and 7 females) aged 7–16 (mean 11.7) years were recruited. There were 8 subjects aged 7–12 years and 10 subjects aged 13–16 years. In 14 cases the left eye was amblyopic. Glasses prescribed just before the start of the study were minimally different from prescription glasses worn before. In 15 out of 18 cases the calculated spherical equivalent of the measured refractive error in the amblyopic eye did not differ before or after the intervention (*p* < 0.52). In 14 out of 18 cases astigmatism was present in the amblyopic eye, ranging between 0.5 and 4.5 (mean 1.85) diopters.

Potential visual acuity in the amblyopic eye for the entire group was found to be 0.25 (SD 0.3) logMAR units (20/35). Contrast sensitivity was present at all spatial frequencies, in most cases within the normal range in the lower spatial frequencies and slightly below normal in the higher spatial frequencies, and was not significantly different before and after the telescopic training session (*p* < 0.37) (Fig. 2).

There was an improvement of 2 lines in BCVA for the entire group: before the intervention BCVA was 0.5 (SD 0.3) logMAR units (20/63 equivalent) and follow-

ing the intervention it was 0.24 (SD 0.34) logMAR units (20/35 equivalent) (*p* < 0.0001). There was an improvement of 2 lines in the subgroup of 8 younger study subjects (7–12 years old): BCVA measured before the training sessions was 0.42 (SD 0.13) logMAR units (20/53 equivalent), and afterward it had improved to 0.16 (SD 0.13) logMAR units (20/29 equivalent) (*p* < 0.0001). A similar trend was observed for the subgroup of 10 older study subjects (13–16 years old): mean BCVA before the sessions was 0.57 (SD 0.4) logMAR units (20/74), which improved to 0.27 (SD 0.47) logMAR units (20/37 equivalent) (*p* < 0.006).

A benefit of the training protocol resulted in 3 lines of improvement on the visual acuity charts and was seen for both moderate (BCVA < 20/80) and severe (BCVA > 20/100) amblyopia. Nine (69%) of the 13 study subjects with moderate amblyopia achieved BCVA of 20/25, and 2 (40%) of the 5 with severe amblyopia achieved BCVA of 20/40 (Table 1).

Overall, a BCVA of 20/25 or better was achieved in 10 (55.6%) of our 18 study subjects (Table 2). In the subgroup of younger study subjects (7–12 years) BCVA of 20/25 or better was achieved in 4 (50%) of 8 cases, and in the subgroup of older study subjects (13–16 years) BCVA of 20/25 or better was achieved in 6 (60%) of 10 cases.

Overall a BCVA of 20/40 or better was achieved in 15 (83.3%) of our 18 study subjects (Table 3). In the subgroup of younger study subjects a BCVA of 20/40 or better was achieved in all 8 cases, whereas in the subgroup of older study subjects a BCVA of 20/40 or better was achieved in 7 cases (70%). Cooperation and compliance with the train-

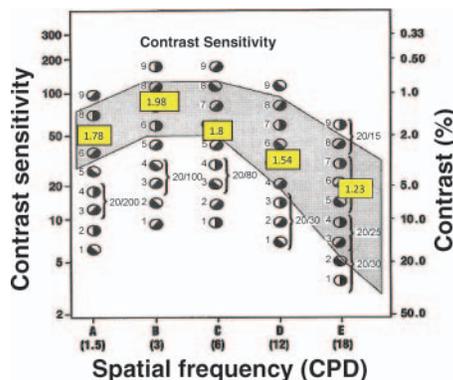


Fig. 2—Contrast sensitivity (mean logMAR units). (CPD, cycles per degree.)

Table 1—Visual acuity restitution in amblyopia

Visual Acuity	Glasses + "therapy"* (%)	Glasses* (%)	Our study (glasses + TTS) (%)
20/25 achieved in those with moderate loss (<20/80)	36	14	69
20/40 achieved in those with severe loss (>20/100)	23	5	40

*Results from the Pediatric Eye Disease Investigator Group.⁶
Note: TTS, telescopic training sessions.

Table 2—Visual acuity restitution of 20/25 in amblyopia

Age group	Glasses + "therapy"* (%)	Glasses* (%)	Our study (glasses + TTS) (%)
7–12 years	28.1	9.5	50
13–16 years	10	6.4	60
All	24.5	9.5	55.6

*Results from the Pediatric Eye Disease Investigator Group.⁶
Note: TTS, telescopic training sessions.

Table 3—Visual acuity restitution of 20/40 in amblyopia

Age group	Glasses + "therapy"* (%)	Glasses* (%)	Our study (glasses + TTS) (%)
7–12 years	63.7	37	100
13–16 years	44	23.5	70
All	59.5	34.6	83.3

*Results from the Pediatric Eye Disease Investigator Group.⁶
Note: TTS, telescopic training sessions.

ing protocol were excellent in all patients. No side effects were reported, including diplopia.

INTERPRETATION

The recent multicentre, randomized controlled trials carried out by the Pediatric Eye Disease Investigator Group (PEDIG)⁶ reopened the long-standing debate over the efficiency of amblyopia treatments in individuals 9 years of age and older. The exciting conclusions of the study, that vision restitution is possible in older children aged 9–17 years, confirmed observations in previously reported small series.^{6,7}

The period of time during which abnormal visual inputs can result in anisometropic amblyopia is considered the critical period of visual development, but it is also viewed as the time during which amblyopia can be reversed by restoration of normal visual inputs, usually by prescription glasses supplemented when needed by occlusion vision therapy. In the past it was a commonly held view that amblyopia reversal is impossible past the critical period. Emerging new evidence is changing this perception of brain plasticity, and the recently published study by the PEDIG showed that vision can be improved in at least one-third of amblyopes in the 7–17-year age group, which had been considered to be beyond the “plastic period”.

Recent evidence shows that neural plasticity produced by repetitive visual stimulation is possible in adults and can improve vision-related skills.¹⁶ Similar findings have emerged in animal models with proof of structural changes in the visual cortex. A 6-fold increase in cells in the visual cortex responding to stimuli to an amblyopic eye was demonstrated after enucleation of the nonamblyopic eye in cats.¹⁷ Since there is no hard evidence as to the length of the critical period in humans, the late childhood period is a prime target for testing the validity of the brain plasticity theory with the use of meaningful repetitive visual stimuli, which constitute a strong influence in restoring visual pathways.^{16–18}

The PEDIG study confirmed the existence of brain plasticity beyond the critical period in children aged 9–17 years, expressed as vision restitution following traditional amblyopia treatments. However, the same study did not address the benefits of meaningful, repetitive visual stimuli in relation to the brain plasticity theory. In an attempt to further enhance the inducement of brain plasticity, the PEDIG study patients were instructed to perform near visual activities with the amblyopic eye for 1 hour a day with a Game Boy (Nintendo of America, Inc, Redmond, Wash.) or activities such as reading, computer work, workbooks with mazes, word finds, and other eye–hand activities. The use of activities requiring near visual acuity did not fulfill the requirement for meaningful, repetitive, useful stimuli, which are a stronger influence on brain plasticity.¹⁰ Such activities, referred to in the PEDIG study as “treatment”, were performed by the study participants probably while they were experiencing blurred images not sufficiently enhanced by the exercise of accommodation.

Furthermore, the requirement to induce accommodation under such circumstances further strengthens and enhances the vicious circle of blurred vision → accommodation → ciliary muscle spasm → lenticular capsule distortions → blurred vision.

In an attempt to further enhance the inducement of brain plasticity in a group of patients in a similar situation to that of the PEDIG participants, for our study we selected meaningful, repetitive visual stimuli requiring only the use of distance visual acuity. Low-grade magnification was used to enhance the quality and clarity of images viewed, making the vision therapy session more appealing and engaging. This approach, referred to in our study as telescopic training sessions, was used with prescribed structure and rigid instructions for implementation in conjunction with a popular activity such as watching television shows. This gave the patients a better chance for compliance during the vision therapy session. Contrast sensitivity measurements were observed to be close to normal in the study subjects, with no significant differences between values before and after treatment. This observation supports the brain plasticity assumption and suggests that anisometropic amblyopia is a form of functional vision loss and, as is commonly the case for all lost skills, training can restore function.

The multiple modalities (patching, glasses, and vision therapy) used in the treatment regimen to maximize the therapeutic response seem to work well in amblyopia. We specifically designed our study as a continuation of the PEDIG study beyond the stage where that study stopped. Therefore, the use of the PEDIG study groups as controls for our study seems appropriate and was also helpful for assessing and comparing results.

The addition of vision rehabilitation therapy in the form of telescopic training sessions described in this paper enhanced further the restitution of vision in such cases. The use of the training resulted, according to the results of this study, in double the possibility of restitution of BCVA in cases with moderate amblyopia (69% vs. 36%) as well as in cases with severe amblyopia (40% vs. 23%) when compared with the results of the PEDIG study (Table 1). The same applies to restitution of BCVA of 20/25 (Table 2) and of 20/40 (Table 3).

We acknowledge that our study is based on clinical observations, which require validation by a prospective, randomized trial based on larger numbers. As such, this is a pilot study with inherent limitations in design: it is based on a small number of cases, specifically looking for validation of a core concept (telescopic magnification as a method for enhancement of brain plasticity in children aged 9–17 years), and a limited study group (anisometropic amblyopia cases), possibly including some patients with combined mechanisms for amblyopia.

However, the improvement “across the board” of BCVA with the use of the training, a relatively simple and inexpensive technique, confirmed in our experience that vision

restitution is possible to a larger extent in amblyopia than previously thought. The results of our study confirm and support the theory of noncompliance as a cause of failure of amblyopia therapy, and confirm the theory that brain plasticity offers a legitimate option in the treatment of amblyopia. This is also in line with another area of vision rehabilitation, in which brain plasticity is thought to be responsible for observed improvements in vision following vision rehabilitation therapy. Specifically, eccentric view training and prisms for image relocation to preferred retinal loci on the retina¹⁸ produce positive results by reducing oculomotor instability, and thus enable the process of brain plasticity to restore vision to previous levels.

We conclude, therefore, that the addition of the training sessions with telescopic magnification in the treatment protocols for amblyopia can help with restitution of vision in anisometric amblyopia in a clinically simple and readily available format, with no detrimental aspects identified.

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