BINOCULAR VISION

Latest research on amblyopia treatment

Adele Elliott and **Dr Kathleen Vancleef** offer a review of current thinking in the management of amblyopia

Amblyopia is a visual impairment caused by abnormal early visual experience, which results in a functional imbalance between the two eyes. This disorder is characterised by reduced visual acuity in the 'weak eye', and by perceptual deficits such as in contrast sensitivity and position acuity. Many amblyopes, particularly strabismic amblyopes, suffer from greatly reduced stereoscopic depth perception. This can have a profound impact on everyday life. However, most treatments for amblyopia tend to concentrate on the restoration of visual acuity, and there has been little focus on the recovery of stereopsis. Interest in this has been prompted by a number of case studies of patients in adulthood who have recovered stereopsis, and have seen dramatic improvements in all aspects of their vision. This is especially interesting, as the predominant belief was that treatment for amblyopia was not possible in adulthood. Current research is therefore involved in development of treatments with more focus on recovery of stereopsis, in childhood as well as in adulthood.

MONOCULAR VERSUS BINOCULAR TREATMENT

Previously, amblyopia was thought to be a 'functionally monocular' problem. Traditional treatments reflect this; treatment generally focuses on strengthening of the weak eye. This involves correcting the refractive error to improve visual acuity, and patching or 'penalising' of the strong eye. This can result in improved visual acuity and stereo acuity for both anisometropic and strabismic amblyopes. As can be expected, better baseline stereoacuity relates to better post-treatment stereoacuity, however it still remains impaired. For example, Wallace *et al* noted that even in anisometropic patients with normal/near-normal visual acuity following treatment, their stereoacuity remained impaired compared to normal-sighted children of the same age. Moreover, some patients do not respond to patching at all. It is therefore vital to continue the development of new types of treatment. Recent research has shown treatments that utilise both eyes are often highly effective, especially for those with strabismic amblyopia.[1]

AGE

As mentioned above, it was also previously believed that treatment for amblyopia was only effective in childhood, in a window during which the brain is at peak plasticity – this is known as the 'critical period'. Due to this long-held belief, standard clinical treatment for amblyopia usually takes place in childhood (figure 1). However, recent case studies and clinical trials in adults have refuted this – although treatment may be most effective in childhood, some residual plasticity does remain into adulthood, and treatment can still result in vast improvements. One such example comes from a study by Hess *et al*, which aimed to test a novel treatment for strabismic amblyopia in adulthood.[2] Patients binocularly viewed an artificial stimulus, where images of differing contrasts were presented to each eye. It was found that prolonged periods of viewing resulted in strengthened binocular vision, the effects of which could also be seen under natural viewing conditions. Importantly, stereoscopic function was established in most patients. This study demonstrates the effectiveness of non-monocular treatments in recovery of stereoscopic function, and that treatment of amblyopia outside the critical period is not only possible, but can be highly effective.

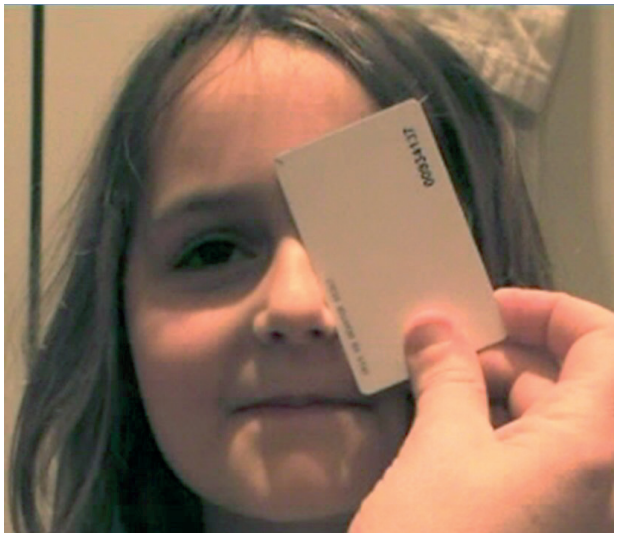

FIGURE 1 Standard clinical treatment for amblyopia usually takes place in childhood

Many new treatments for amblyopia utilise 'perceptual learning', this refers to learning from repetitive practice of a demanding visual task. Originally, this learning was thought to be fairly task-specific; however, recent research has shown that these improvements can be generalised following appropriate training. Perceptual learning paradigms have been used in both monocular and dichoptic treatments, and have produced promising results in improving adult amblyopic vision.

Monocular perceptual learning tasks involve training of the amblyopic eye while the strong eye is patched. Most studies have reported improved visual acuity, however, few specifically

focused on recovery of stereopsis. One exception is a study by Zhang *et al* which reported significant improvements in stereoacuity in amblyopes. Nineteen adult patients with anisometropic and/or strabismic amblyopia participated in the study.[3] During the task, the amblyopic eyes practiced various visual discrimination tasks at one orientation for six to eight sessions. Results showed that perceptual learning of these tasks could be transferred to a previously untrained orientation. This resulted in improved visual acuity, and contrast sensitivity at both low and high spatial frequencies. Most remarkably, there was a 53% improvement in stereoacuity. The study concludes that monocular perceptual learning can substantially improve amblyopic vision, and further demonstrates the recovery of stereopsis is possible in adulthood. The authors account this improvement to high-level cognitive compensation, rather than early plasticity in the amblyopic visual brain. Overall, the study provides evidence, and a possible mechanism, for improvements in amblyopic vision outside of the critical period.

Some of the treatments which have produced the most promising results utilise direct stereo-training, ie binocular visual training or perceptual learning of stereopsis specifically. One study which demonstrated the effectiveness of this comes from Xi *et al*.[4] During this study, 11 patients with amblyopia were trained to judge depth of textured stimuli over 10 to 13 sessions. Results showed long-lasting, significant improvements in stereoacuity, and visual acuity of the amblyopic eye. The study demonstrated improvements in amblyopic vision following stereo-perceptual learning. Furthermore, Astle *et al* demonstrated that a learning-based therapy which utilised experience-dependent plastic mechanisms, could be used to recover stereoscopic visual function in adult amblyopes.[5] In this study, two patients with anisometropic amblyopia underwent both monocular perceptual learning (to reduce the difference in acuity between the two eyes), and stereoscopic learning (to improve stereoacuity). After treatment, both patients showed significant improvement in letter-based visual acuity, as well as improvement of stereoacuity to 'near-normal' levels. The effects of the treatment were still evident in a follow-up seven months after the study. Overall, it was concluded monocular improvements in visual performance promoted the independent recovery of stereopsis in adults with amblyopia. Again, this shows promising recovery of stereopsis outside of the critical period. More recently, stereopsis training in a virtual reality game has shown to improve stereoacuity in adults with strabismic and anisometropic amblyopia.[6]

SUMMARY

Across all studies, recovery of stereopsis following direct stereo-training was greater than recovery following either monocular or dichoptic treatments (see table 1). Overall, treatments generally resulted in greater chance of improvement of depth perception in anisometropia than strabismus. Results showed those with strabismic amblyopia had a low chance of improvement with monocular treatments, a better chance with dichoptic treatments, and the best chance of improvement following direct stereo-training. The difference in results between the types of amblyopia could be related to how suppression of the amblyopic eye occurs. In anisometropic amblyopia it is thought that the suppression by the strong eye is passive (ie the amblyopic eye's vision is blurred). However, in strabismic amblyopia, the suppression of the weak eye is thought to be active in order to avoid diplopia. Therefore it is suggested that in order to overcome this, recovery of stereopsis may require more active treatment in strabismic amblyopia than in anisometropia.

TABLE 1 Summary table

Treatment	Extend of recovery of stereopsis	Age group	Type of amblyopia
Monocular training	Small improvements to full recovery	In 50% of adults and children	With anisometropic amblyopia
Dichoptic training	Small improvements	In 50% of adults and children	With anisometropic or strabismic amblyopia
Stereo training	Small improvements to full recovery	In 75% of adults	With anisometropic or strabismic amblyopia

Up to now, there is no unified consensus as to the mechanisms of stereopsis recovery. Generally, it is believed that changing the balance of excitation and inhibition may have a key role. As such, new treatments seek to retrain the amblyopic eye by either increasing signal to it, reducing noise or modulating its attention.

To conclude, it has been shown that newer treatments, such as perceptual learning and direct stereo-training, can be highly effective in improving amblyopic vision, especially in patients that have not responded to traditional monocular treatments. Most importantly, the above studies have demonstrated that improvement of amblyopic vision, and recovery of stereopsis to some extent, are possible outside of the critical period. This research calls into question the plasticity of the visual system in adulthood, and provides a strong foundation on which to continue to develop treatments for adults with amblyopia.

Adele Elliott and Dr Kathleen Vancleef are researchers in perception and neuroscience at the University of Newcastle.[7]

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