Marc B. Taub OD

Binocular vision anomalies

What every optometrist should know

In the field of eyecare, to put it simply, we help people to see. Whether dispensing spectacles or contact lenses, co-managing LASIK, or cataract surgery, treating diseases such as glaucoma or fitting a low vision device, the ultimate goal is improved vision. Rarely do we get the opportunity to alter the outcome of patients' lives. Behavioral optometry, or binocular vision, allows you to take a child's or an adult's life and put them on a better path.

Imagine a child who is failing school; the parents and the child have done everything, including hiring tutors, without success. Your testing indicates an underlying binocular vision (BV) problem which, once treated, will allow the child to succeed in school and in life. You have not only changed the child's educational future, but their social and emotional make-up as well. In the practice of optometry, you must be alert to the signs and symptoms associated with BV problems.

Classification

The most widely accepted system for classifying BV dysfunctions in the field of behavioral optometry is based on Duane's classification[1]. It has evolved from four categories into a nine-category system developed by Wick[2], and is based on both the distance phoria and AC/A ratio. The accommodative classification system in use was developed by Donders[3] and modified by Duke-Elder and Abrams[4]. Ocular motor dysfunction is an entity unto itself which includes fixation, pursuit and saccadic anomalies[5]. **Table 1** is a summary of the classification system for binocular, accommodative and ocular motor anomalies.

Table 1
Summary of classification system for binocular, accommodative and ocular motor dysfunctions

A. Low AC/A ratio
1. Convergence insufficiency
2. Divergence insufficiency

B. Normal AC/A ratio
1. Fusional vergence dysfunction
2. Basic esophoria
3. Basic exophoria

C. High AC/A ratio
1. Convergence excess
2. Divergence excess

D. Accommodative anomalies
1. Accommodative insufficiency
2. Ill-sustained accommodation
3. Accommodative excess
4. Accommodative infacility

E. Ocular motor anomalies
1. Ocular motor dysfunction

Prevalence

You might be wondering how common some of these problems are in your patients. The most frequently encountered condition in optometry after refractive error is a binocular, accommodative or ocular motor anomaly. Two recent studies, by Scheiman *et al*[6] and Lara *et al*[7], indicated similar findings. The study conducted by Scheiman included 2,023 paediatric patients and found 19.7% to have a binocular or accommodative dysfunction. This was further categorised into convergence excess (7.1%), convergence insufficiency (4.6%), accommodative insufficiency (2%) and accommodative excess (1.8%)[6]. Similarly, Lara *et al*, found the overall prevalence of binocular and accommodative dysfunctions at 22.3% in a study size of 265. This was further categorised into accommodative insufficiency (3%), accommodative excess (6.4%), convergence excess (4.5%), convergence insufficiency (0.8%) and multiple diagnoses (7.2%)[7].

Symptoms

In any examination, the first signal that a problem exists lies in the patient's complaints. What the patient says to you, combined with your follow-up questions, will direct the flow of the examination. As with any disease process, there are specific complaints which should immediately indicate that a patient has a binocular vision problem. **Table 2** is an example of an intake form which simplifies the history process. There are questions

Table 2
Sample supplementary history form

Birth/developmental history
1. Was the child born prematurely?
2. Was the birth natural? C-section?
3. Was oxygen used post-delivery?
4. What was the child's Apgar score?
5. At what age did the child:
   crawl_____ walk_____ speak (one word)_____ (two words)_____?

School history
1. Is the child at the age appropriate grade level?
2. Has the child had to repeat a grade?
3. What is the child's best subject?_____ and worst_____?
4. Does the child receive extra help in any subject?

Please tick all that apply?
1. Reversals when reading/writing
2. Reading below grade level
3. Poor reading comprehension
4. Letter/number transposition
5. Poor/sloppy handwriting
6. Work takes longer than expected
7. Uses finger or marker when reading
8. Often loses place, skips or rereads words/letters when reading
9. Blurred vision when reading or when looking from near to far
10. Headaches associated with near tasks
11. Print moves around, or runs together
12. Double vision at near
13. Closes or covers an eye when performing near tasks
14. Eye strain or pulling sensation with near work
15. Fatigue or sleepiness with near tasks
16. Burning or tearing while reading
17. Excessive rubbing or blinking of eyes
18. Tilts or turns head with visual tasks
19. Avoids reading, writing or other near tasks
20. Short attention span, easily distracted, extensive daydreaming

relating to the patient's complaints, birth and developmental history and school performance. While this does not replace routine history, it does focus in on problems which the patient or parents might not realise are connected to vision.

Convergence insufficiency

Convergence insufficiency (CI) is among the most common binocular vision condition which will be encountered. It is characterised by a reduced near point of convergence (NPC), a low AC/A ratio, a high exophoria or intermittent exotropia at near, and a reduced positive fusional vergence[8-15]. Expected results (**Table 3**) on a standard cover test are orthophoria at distance and orthophoria to six exophoria at near[5,12,13,16]. The following direct measures of positive fusional vergence (PFV) will be reduced in a convergent insufficient: smooth vergence in the phoropter, step vergences with the prism bar and fusional facility. Several indirect measures of PFV will also be decreased, including negative relative accommodation (NRA), monocular estimated method (MEM), and plus lenses on the binocular accommodative facility (BAF)[5].

The importance of repeating the NPC (**Figure 1**) several times with varied targets, including both an accommodative and non-accommodative target, such as a penlight with red/green spectacles, cannot be understated. Because the NPC is most likely performed at the beginning of the examination, it may be wise to repeat the test several times towards the end, simulating the normal fatigue the patient experiences throughout the day. If the patient has a fragile system, the NPC will become increasingly reduced with repeated testing. The expected values for this procedure vary based on the target used. With an accommodative target, such as a 6/9 letter on a fixation stick, the blur should occur at 2.5-5cm and the break at 4.5-7.5cm. With a pen-light and red/green spectacles, the expected values will be slightly different with the blur occurring at 3-7cm and the break at 5-10cm[5,7]. An important point to remember is that you should not estimate the numbers – get out your ruler or tape measure and get the exact results.

There are several common complaints associated with a CI. Patients may complain of eyestrain, headaches, blurry vision at near, diplopia[5,10,13,15], moving or jumbling print and a pulling sensation around the eyes[5,10,13]. Several other complaints might not obviously signal a visual problem. These include nausea or dizziness with reading[11,13], difficulty with reading comprehension, sleepiness or closing an eye while reading and avoidance of near work should all be considered red flags[5]. Most complaints do not begin before the age of 10, and the symptoms seem to occur increasingly towards the end of the day[13]. Adults may have their first symptoms later in life due to a job change, which requires increased reading or computer work, or they can simply be decompensating as they lose their accommodation due to presbyopia.

Test	Expected	Standard deviation
Cover Test		
– Distance	1 exophoria	±2
– Near	3 exophoria	±3
Distance lateral phoria	1 exophoria	±2
Near lateral phoria	3 exophoria	±3
AC/A ratio	4/1	±2
Vergence testing		
1) Distance		
– Base-out	Blur: 9	±4
	Break: 19	±8
	Recovery: 10	±4
– Base-in	Break: 7	±3
	Recovery: 4	±2
2) Near		
– Base-out	Blur: 17	±5
	Break: 21	±6
	Recovery: 11	±7
– Base-in	Blur: 13	±4
	Break: 21	±4
	Recovery: 13	±5
Near point of convergence		
– Accommodative target	Break: 5cm	±2.5
	Recovery: 7cm	±3.0
Penlight/red-green specs	Break: 7cm	±4.0
	Recovery: 10cm	±5.0
Accommodative amplitude		
– Push-up/pull away	18-1/3 age	±2D
– Minus-lens-to-blur	2D < push-up/pull away	
Monocular acc. facility		
1) Children		
– Six-year old	5.5cpm	±2.5
– Seven-year old	6.5cpm	±2.0
– Eight to 12-year old	7.0cpm	±2.5
2) Adults		
– 13-30-year old	11.0cpm	±5.0
– 30-40-year old	Not quantified	
Binocular acc. facility		
1) Children		
– Six-year old	3.0cpm	±2.5
– Seven-year old	3.5cpm	±2.5
– Eight-year old	5.0cpm	±2.5
2) Adults	10.0cpm	±5.0
MEM	+0.50 D	±0.25
Fused X-cylinder	+0.50 D	±0.50
Negative relative acc.	+2.00D	±0.50
Positive relative acc.	-2.37D	±1.00

Table 3
Expecteds for binocular and accommodative testing
(adapted from Scheiman and Wick, 2002)[5]

Convergence excess

The contrasting problem to a visual system which does not converge enough, is one which converges too much. Convergence excess is associated with an esophoria greater at near than distance, reduced negative fusional vergence (NFV) and a high AC/A ratio[5,12,18]. Direct measures of NFV which will be reduced are smooth vergence in the phoropter and jump vergence with a prism bar at near. The indirect tests of negative fusional vergence affected are a low PRA, high MEM and a failure of minus lenses on the BAF[5].

Figure 1
The near point of convergence (NPC) is performed with a 6/9 target on a fixation stick

Figure 2
The negative/positive relative accommodation (NVA/PRA) is done in the phoropter with a 6/9 target at 40cm

Figure 3
The monocular/binocular accommodative flippers (MAF/BAF) is performed with ±2D flippers and a 6/9 target on a fixation stick held at 40cm

There are two methods used to determine the AC/A ratio – the gradient and calculated. The results of the gradient method have been found to be lower than the calculated method due to the normal lag of accommodation. The gradient AC/A is obtained by measuring the phoria at near, adding +1.00 or -1.00 lenses and measuring a second time. The difference found in the phorias is the AC/A ratio.

The calculated ratio requires some mathematics and memorising a formula, but it is not difficult to perform. It is:

AC/A = IPD (cm) + NFD (m) (Hn-Hf)

IPD = interpupillary distance, NFD = near fixation distance, Hn = near phoria (eso is + and exo is -), and Hf = distance phoria.

An example with this formula is a patient with 60mm IPD, two eso at distance and 10 exo at near:

AC/A = 6 + 0.4 (-10-2) = 9/1

The expected AC/A ratio is 4/1 with a standard deviation of ±2[5,16]. The patient's symptoms with a convergence excess are not dissimilar from a convergent insufficient. The CE will complain of headaches, blur, diplopia, and asthenopia associated with reading[5,12,16,18]. Lack of concentration, reading comprehension issues and avoidance of near work will again be a problem with these patients[5]. Tearing, loss of place, distance blur after reading and fatigue or sleepiness are the associated symptoms[18].

Accommodation dysfunction

There are several types of accommodative or focusing problems including insufficiency, excess, and infacility which are well documented in the optometric literature. Many of the complaints which patients have are common among the different maladies. Eyestrain[19-21], blurred vision at near, headaches, fatigue or sleepiness, movement of print, avoidance of near work, diplopia and reduced reading comprehension are the most common symptoms. Difficulty focusing from far to near and from near to far, photophobia[5,11,12,20,21] and a pulling sensation around the eyes[5] can also be associated with accommodative problems.

Accommodative insufficiency is the most prevalent of this group. It is characterised by a reduced amplitude of accommodation[5,12,20-24], a high MEM (>+0.75), low PRA, failure or difficulty with minus lenses on both monocular and binocular accommodative facility[5,20], and low base-out to blur finding at near[5].

There are several methods used to attain the amplitude including minus lens-to-blur and push up/pull away. The minimum amplitude, is based on Hofstetter's equation 15-0.25 x age[20]. The measurement of accommodation is a simple process and is a technique to add to your repertoire. The push up/pull away method is performed using a 6/9 target. With the push-up test, the target is slowly moved closer to the monocular patient until they can no longer keep the image clear. The pull-away test is the opposite because the target starts close to the patient and the end-point is when they can first clear the image. The pull-away may be preferable to the push-up system due to the "Aha!" factor when the patient first recognises the letter or shape. The end-point with either method is then converted from inches into dioptres. This conversion is done by taking 40 and dividing it by the result in inches. For example, the pull away end-point is two inches. The amplitude in would be 20. One downside to this method is the overestimation of amplitude by about 2D due the relative magnification distance. This must be taken into account when utilising this method[5].

The opposite can be said about the minus-lens-to-blur or minus lens amplitude. The result tends to be an under-estimation of the amplitude secondary to minification of the target. This test is once again performed monocularly and the 6/9 target is placed at 13 inches. Minus lenses in 0.25D steps are added until the patient can no longer sustain a clear image. A working distance adjustment of 2.50D is used once the result is attained[5]. For example, the patient has a prescription of -2.00D and the phoropter reads -10.00D when the test is completed. The amplitude would be the difference from beginning to end, which is eight and then adjusting for the working distance would bring the final answer to 10.50D.

The opposite end of the spectrum is known as an accommodative excess or spasm. It has been attributed to an overaction of the ciliary muscle or excessive flexibility of the lens[25]. The spasm or excess occurs when accommodative response is greater than what is required for a given demand. Simply put, the patient has trouble relaxing their accommodation. There are several symptoms which are specifically associated with AE, including a history of frequently changed or ineffective spectacles and gastric disturbances or vomiting[12]. The findings for an AE will be the exact opposite in comparison to an AI. The MEM will be low (+0.25 or less), NRA and fused cross-cylinder reduced and difficulty clearing plus lenses on both BAF and MAF[5,20].

The measurement of relative accommodation is essential in determining if a patient is an accommodative insufficient or excess (**Figure 2**). This direct measure of accommodation allows us to assess the flexibility of the system. In contrast to amplitude, this test is performed binocularly. A 6/9 target is placed at 40cm and 0.25D steps are made until the patient can no longer sustain a clear image. One trick to remember is that for positive relative accommodation, minus lenses are added, while plus lenses are increased with the negative relative accommodation[5,16,23]. You must evaluate not only the value of the end-point but the quality of the response. You are looking for the first sustained blur to give the patient a few seconds to stabilise the image before making the next change. Morgan reported an average PRA of -2.37 (±1.12) D and an NRA of +2.00 (±0.50)D[16], which has been supported by many recent studies.

A third category within the accommodative realm of dysfunctions is a deficiency in both stimulating and relaxing the focusing system. This is known as an accommodative infacility. The patient will have trouble adjusting their accommodative response to the appropriate stimulus. Apart from the common symptoms associated with general accommodative problems, these patients often complain of intermittent blur when they look up from near work[16]. Whereas with an insufficient or excess, where the minus and plus lenses respectively will cause trouble, an infacility will have difficulty with both. The BAF and MAF will indicate an inability to clear both plus and minus lenses. The PRA, NRA, and both the base-out and base-in to blur findings will be reduced at near[5].

The binocular and monocular accommodative facility is a tool which you should be able to use to determine the flexibility of the focusing system (**Figure 3**). While the preferred target is the #9 Bernell vectogram, which allows for suppression control, a 6/9 target on a fixation stick may also be used. The patient is asked to clear an image through alternating ±2.00D lenses as many times as possible in a one minute time span. If the target has several letters or words, you can request that the patient calls out letters as they clear the image. This serves as a check that the image is indeed clear and that the patient (usually a child) is not making it up. One obstacle to this test is the confusion surrounding the expected results. There are two general rules of thumb in this matter. The expected BAF will be less than the MAF for any given age group, and this result increases as the age increases. The range for MAF results range from 5.5cpm in a six-year old to 11cpm in a 13 to 30-year old. The BAF will be slightly lower with a range of 3cpm for a six-year old to 9cpm for a 30 to 40-year old[5,13].

Ocular motor dysfunction

If a patient presents with all testing within a normal range, but continues to struggle in school, you must consider ocular motor dysfunction (OMD) as a possible culprit. If a system has difficulty with saccades, it may also have deficient pursuits and fixations. Imagine how difficult reading would be if you could hardly find the right spot on the page, follow along the line and then find the beginning of the next line.

Patients who suffer from saccadic or pursuit dysfunctions will have general complaints which can be overlooked or explained by being a poor student. Poor reading comprehension, skipping lines or omitting words, loss of place, and excessive head movements are common signs. These patients will also have difficulty copying from the blackboard, with maths work with columns, a short attention spans, slow reading and poor sports performance[5,13].

Pursuits and saccades are easily tested in the preliminary battery. Saccades can be examined by holding two targets, about 10cm apart, and having the patient look back and forth 10 times. Pursuit testing can be done by asking the patient to follow a target as it is moved left, right, up and down and then in a circle. The range of the target should be restricted centrally, and the movement must be smooth and choppy. Both procedures are performed monocularly and are graded on a one to four scale, with four representing smooth and accurate movements and one indicating a severe deficiency[5].

Another time-tested and quick check of saccades is the developmental eye movement (DEM) test. This includes the reading of vertical and horizontal letters to assess speed and accuracy. Technology has recently provided an electronic method to assess ocular motility – the Visagraph. Eye movement recordings are made with special goggles and the number of saccades, fixations and regressions are measured. The use of the Visagraph prior to the initiation of therapy can be used to monitor improvement as the treatment progresses.

Treatment

With any type of binocular dysfunction, treatment comes down to one thing – will the use of plus lenses alleviate the problem or not? (**Table 4**) Other options include the use of prisms, vision therapy or a combination of treatments. This article does not cover the concept and efficacy of vision therapy; the treatment is accepted by the American Optometric Association and the American Academy of Optometry and its effectiveness has been documented countless times in the optometric literature.

Both convergence excess and accommodative insufficiency are generally accepting of plus[5,12,13,16]. Once the problem has been investigated, documented and the prescription which includes plus lenses given, the patient should be followed up six to eight weeks later to evaluate progress. The patient may require vision therapy as well to fully alleviate the symptoms and reduce complaints.

Vision therapy is the treatment of choice for convergence insufficiency, OMD, accommodative spasm and infacility, as well as several other problems not discussed here[5,12,13,16]. There are many variations of vision therapy used by practitioners around the world. The therapy can be performed in the practice or at home, and can include the use of computer programs or only tactile activities. It is probably the case that no two practitioners, who regularly perform vision therapy, will have the same treatment regimen or philosophy. If you are not ready to start your own vision therapy practice, speak to a colleague who has experience in co-managing. Not only will you be truly practising full scope optometry, but your patients will appreciate the time and energy you have spent on solving their problem.

Conclusion

'Riley' was your typical child. He was in second grade and was very vocal and rambunctious. He was not the "sharpest tool in the shed", but he was not stupid. He seemed to have trouble with reading and concentrating on his schoolwork. After a while, his mother became accustomed to the phone calls from the principal's office that Riley was in trouble.

Not long after Riley entered the second grade, his teacher began to notice a trend in his work. He was a 'visual learner' but after a short period of time, both in the morning and after lunch, he turned himself off to schoolwork and began to misbehave. The teacher knew that he could learn the material, but something was stopping him from attaining true success. It was suggested that his vision should be checked.

A full examination revealed that not only was Riley myopic, but he also suffered from a learning related vision problem. Specifically, he was diagnosed with a convergence excess, accommodative insufficiency and an ocular motor deficiency. His brain and visual system were battling against each other and neither was winning. His first pair of spectacles had bifocal lenses, and he started vision therapy immediately. Changes occurred within a few weeks. Riley's grades began to rise and school was no longer such hard work for him. He completed the vision therapy course and was able to parlay his success in vision therapy into success in the classroom and life. He went on to graduate from college and even went to graduate school. You might be wondering what he studied. The answer is obvious if I let you in on a little secret – Riley was actually me.

I consider the behavioral optometrists that I worked with two of the most important people in my life. Their hard work and dedication to my wellbeing were critical in my educational and social development. It is this ability to change a child's life that attracted me to this field of optometry. If I can help one child in the same manner that my optometrists helped me, then my career will be a success. I challenge you all to do the same.

About the author

Dr Marc Taub is a graduate of the Pennsylvania College of Optometry and is currently completing a residency in paediatrics at Nova Southeastern University in Ft. Lauderdale, Florida.

References

For a full set of references, email nicky@optometry.co.uk.

Table 4

Treatment options for binocular and accommodative anomalies

Condition	First treatment	Second treatment
Convergence insufficiency	Vision therapy	
Convergence excess	Plus lenses	Vision therapy
Accommodative insufficiency	Plus lenses	Vision therapy
Accommodative excess	Vision therapy	
Accommodative infacility	Vision therapy	
Ocular motor dysfunction	Vision therapy	