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The science of behavioural optometry

Last year, the British Association of Behavioural Optometrists celebrated its 10th anniversary. Its founder, Keith Holland, reviews some of the research behind the behavioural model of vision.

What is vision?

Those who say vision is about seeing – about neurological processes – are right. Those who say it is about imagination are also right. Those who say it is about aspirations, about dreams, about reaching out for some erstwhile inaccessible goal, are right as well.

Vision means many things to many people. But what does it mean to us, as eyecare professionals? Sadly, I would suggest that we have often lost touch with the meaning of vision, replacing it with the working actions of "sight" in our deliberations and our practice.

We look at eyes as simply another structure which functions within the body – healthy or otherwise. We correct errors of refraction, we patch amblyopes, we straighten squints, we lower IOPs, we remove cloudy lenses – all in order to maintain the function of sight. But do we look beyond the mechanics to see how sight becomes vision?

Behavioural optometry is about exploring the relationship between the neurobiological and mechanical processes of seeing and the functional requirements of living and surviving in a dynamic environment – in other words, about vision.

Vision is the dominant component of all human behaviour, it is in part innate – we can all see at birth, but it is also learned. From the infant's first explorations of the world about them, right through life, we are learning to see, enhancing our visual processes.

Figure 1 shows a familiar object, seen throughout the land, and presented in a form that is perfectly clear. Isn't it? **Figure 2** (overleaf) shows the same picture, but with some features emphasised to aid recognition. Now can you see what it is? Looking again at **Figure 1**, it should be quite clear that it is a cow.

We never stop learning to see. Our biomechanical visual processes may be formed in early life, but our neurological control and analysis processes – our visual software – is continually developing and adapting to cope with the ever-changing demands and novel experiences of life. As we gain more information about the world, the biomechanical processes themselves can change and adapt to match the demands placed on us. In short, function alters structure.

Multiple inputs and influences

To better illustrate this and to demonstrate the multiple inputs and influences on vision, Dr A.M. Skeffington, who was one of the early pioneers of behavioural optometry, introduced the four circles concept in which vision, as the dominant mode for information processing, is viewed as the emergent of four underlying sub-processes – anti-gravity, centring, identification and speech auditory **(Figure 3).**

Anti-gravity

The first circle, anti-gravity, encompasses all the processes which tell us "where we are in the world". This includes the ability of the body to respond to gravity through the vestibular mechanisms, and the use of proprioceptive processes to tell us where our body parts are in relation to the gravitational forces acting on us. Carl Pribram has shown that vision is both a bottom-up and a top-down process, with multiple connections between other sensory systems and the retina. The eyeball is thus far more than a simple sensing device.

Consider also that more nerve fibres leave the optic nerve at the lateral geniculate nucleus and pass to the superior colliculus than exist in the auditory nerve itself. It would seem that this branch is heavily implicated in the integration of visual information with vestibular/balance and proprioceptive information.

Centring

The second circle, centring, is about locking onto a target, or image of a target, and involves all those range-finding systems so that we can direct action to the target. In effect, the centring system tells us "where it is". Included within this is the vergence system, which allows us to "range find", utilising the 12 extraocular muscles. Also of importance are the body movements that allow us to "square up" to the object of interest in order to minimise the effort of ocular control, and optimise efficiency of seeing. We cannot see everything in our visual world all the time, and we must make constant decisions as to what we are going to "look at", and it is the role of centring to make this happen.

Identification

The third circle, identification, includes everything that helps us answer the question, "What is it?". Interpretation of peripheral visual information, enabling accurate positioning of foveal vision in order to facilitate accurate identification requires efficient figure ground relationships. Current work on magno and parvo cellular pathways of visual control, reviewed by Tychsen[1], has confirmed this concept. Only

Figure 1: What is this? This picture is not an illusion but a photograph of a familiar subject. Can you see what it is? Figure 2 overleaf should help you

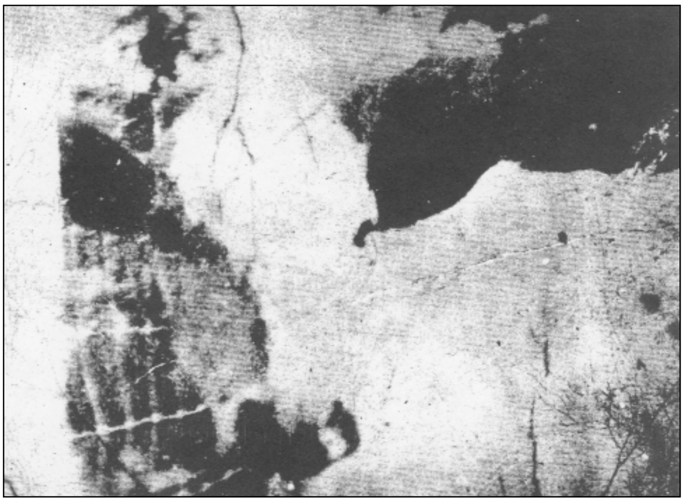

Figure 3: Skeffington's four circles concept of vision

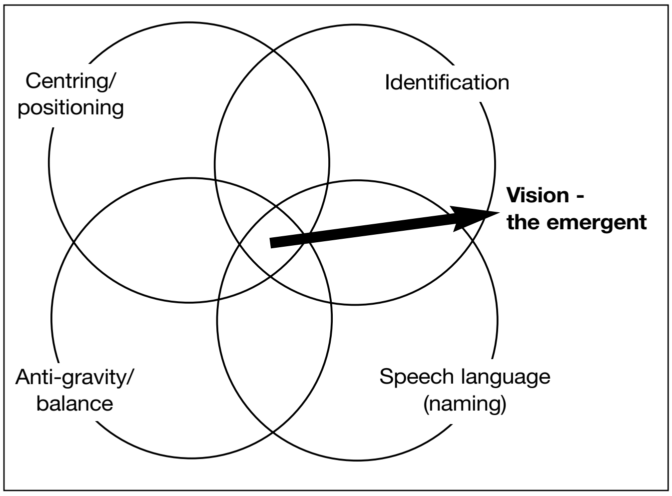

Figure 2: The same as Figure 1 but with enhancement

when the object of regard is centred effectively can the accommodative processes ensure that it is the clearest object in our space world, and the one that is given maximal attention. The perceptual processes that allow interpretation to occur complete the "Ah-ha!" process of cognition.

Speech-auditory

The fourth circle speech-auditory (or communication), encompasses the processes that allow us to communicate our ideas and thoughts. It is both internal and external. Internal recognition of an object must involve some form of labelling – whether verbalised or not. Where we do not "label" the object or event, then it has passed us by. With this model of vision as the background, Skeffington proposed an alternative approach to the development and treatment of visual anomalies.

Influencing factors

Classical theory holds that refractive and binocular deviations are due to biological variation, heredity and growth. The so-called near-point stress model, however, suggests that visual development is shaped by our environment – and by our reaction to it, and in particular, how we react to near objects. There is ample evidence in the literature that sustained close work causes stress in the visual system. For example, Greene[2] found an increase in myopia amongst air force personnel working in underground mission control bunkers for extended periods. Pickwell[3] noted that there was a close relation between increasing fixation disparity under stressful conditions and visual symptoms. Ehrlich[4] found a myopic shift in otherwise normal subjects after an intense two-hour visual task requiring detailed visual search.

In animal studies, Young[5] found that in a group of monkeys confined in an illuminated but restricted visual space, a significant degree of myopia developed, relative to a control population.

Young[6] also showed in a review article that heredity appears to play a relatively minor role in the amount of myopia that will be found in human children or monkeys.

Visual attention itself leads to heightened arousal of the sympathetic nervous system[7,8,9]. Activity in the sympathetic nervous system normally affects all structures, as opposed to the parasympathetic system, where innervation of discrete structures tends to occur. Ocularly, dilation of the pupils is the most well known sympathetic activity, and this is widely used as an index of autonomic arousal.

Additionally, however, a number of studies, reviewed by Gilmartin[10], now show there is a sympathetic innervation to the ciliary muscle in humans that causes an attenuation of the accommodative response. In effect, the sympathetic system facilitates a rapid shifting of accommodation from near out to far – as one would expect in a "fight or flight" situation.

A number of studies have confirmed this. Randle et al[11] and Malstrom[12] have both reported that mental activity is accompanied by a shifting in accommodation towards far. In another study, they identified a similar shift in commercial pilots during stressful decision making situations. The effect increased with increasing importance in the decision-making process. It is normally small – less than 0.50 DS, but significant.

Birnbaum[13] suggests that a parasympathetic-induced increase in innervation to accommodate occurs to override the sympathetic shift of accommodation to far, that accompanies mental effort. In turn, this increasing parasympathetic innervation to achieve conjugate focus generates increased convergence. Hence, in situations of near point stress, convergence tends to localise closer than accommodation.

This then is the crux of the behavioural theory of vision, first described by Skeffington, purely on the basis of clinical observations, but subsequently amply borne out through clinical and theoretical research – "That... near point stress results from the biologically unacceptable, socially compulsive, visually near-centred task... that becomes a drive to centre nearer in visual space".

Visual processing

So far then, I have argued that close work causes stress on the visual system which can affect the accommodative/convergence relationship. So why then are we not a nation of myopic esophores – or of neurotic, stressed out non-readers, experiencing double vision every time we read? The answer, of course, is that we have developed responses to the situation.

Skeffington argued that the normal visual system should not be orthophoric and emmetropic, but should be mildly hyperopic and exophoric, thus providing a buffer that could be used to counter stress-induced over-convergence. Once this buffer has been absorbed, then symptoms are likely to occur.

Haines[14], Shepard[15] and Morgan[16] have demonstrated the existence of a small 5° degree of exophoria at near in a normal population, whilst Manas[17] has described the absorption of these buffers during stress. Schor[18] and McCormack[19] have both shown that exophores, whose exophoria was neutralised by base-in prism during a sustained reading task, reverted back to the original exophoric state, demonstrating that "vergence adaptation maintains exophoria, rather than orthophoria, suggesting that the exophoria is not a defect, but a valuable attribute" (from Birnbaum[20]).

The adaptatory pathways which an individual can take appear to be dual, as reported by Skeffington and, latterly, by Howell[21]. Firstly, there is the convergence insufficiency/accommodative excess group and secondly, the convergence excess/accommodative insufficiency group. There would appear to be fundamental differences in visual processing between the two groups, possibly linked to differences in focal/ambient (or parvo/magno cellular) interactions, and to basic responses to stress. The former group tends to take the path of avoidance of close work, refusing to give up distance acuity for near work efficiency, whilst the latter group tends to take the path of increasing effort to resolve any mismatch, accompanied by reducing working distance, apparently driven by the verbal information processing demands of the near task (i.e. reading). This latter group typically develops into myopia, apparently driven by their response to blur[22].

A recent paper by Jiang & Morse[23] includes the following: "Near work causes changes in the oculomotor characteristics of susceptible individuals which begin even before the development of refractive error. This series of changes in oculomotor function apparently results in optical defocus, which has the potential to induce ocular compensatory changes resulting in myopia".

Another recent paper by Ciuffreda[22] confirms the differing responses to near work seen, with one group showing rapid recovery from close work, and no apparent long-term changes. A second group showed a near point stress response with rapid recovery after cessation of the task, while a third group showed a very long recovery time after removal of the near task. This same paper also advocates the use of plus lenses as a means of breaking the cycle of stress, and reports on positive long-term responses to this approach.

Optometric input

So where does that leave us? I hope that I have shown how a truly behavioural model of vision can, and should, encompass a range of sensory inputs and processes. I have briefly explored the effects of stress on vision, and in particular on the relationship between accommodation and convergence, resulting in a change in function as a result of the imposed near vision task. I have also touched briefly on the responses that can occur to the system in an attempt to resolve this.

But where does optometry fit in? Firstly, in the identification and assessment of these near-point disorders and, secondly, in the treatment and management of them to improve visual function and ameliorate symptoms.

We have three main tools at our disposal – lenses, advice and vision training.

Vision training

The use of programmed procedures to improve flexibility and control of vergence and accommodation functions is nothing new, and many hundreds of papers have been published on the efficacy of vision training in treating disorders of accommodation, vergence and oculomotor systems. Vision training has been described as: "The art of arranging conditions so that the patient becomes aware of new relationships in his visual world, and through these new relationships learns to utilise processes that allow him to extract a greater amount of information in a more efficient manner"[24].

Earlier thinking on the existence of a critical period, beyond which no changes in the visual system are possible, has been shown to be incorrect. Separate studies by vonNoorden[25], Van Sluyters[26] and Pettigrew[27] have all shown that complete reversals of experiential deprivation could be overcome well after established critical periods had been and gone. These studies suggest that the reticular activating system is in some way responsible for "gating" these changes. Thus visual development can be guided and enhanced well on in years.

Lenses

The use of low powered lenses has been controversial in the past, but increasingly, studies are showing that the influence of lenses upon the convergence/accommodation systems can be significant. A +0.50 D lens appears of negligible value when related to a typical child accommodative reserves of 15.00 D , but when related to a mismatch in the accommodative/vergence system of +0.75 D, then the effect suddenly becomes significant.

This use of low powered lenses has perhaps more than any other area provoked comment and criticism of "behavioural optometrists", who have been accused of over-prescribing. There are, however, numerous studies in the literature to support the use of lenses in the improvement of visual control. Typically, lens power is based on the "mismatch" between the expected near accommodative lag of +0.62 DS (as described by Skeffington) and the findings of near point testing, using tests such as MEM retinoscopy. The behavioural assertion is that such lenses will improve performance, and could affect study skills, reading abilities and visual comfort.

Much writing within the field of behavioural optometry has focused on the application of lenses, and prescribing methods. Sadly, and here I must be very critical of those clinicians who carried out this work, relatively little has been published in appropriate scientific journals, although there is an increasing move to "rediscover" some of the early work and have it republished.

Work by Pierce[28] and Greenspan[29] has often been quoted in support of low plus, but their methodology is open to some criticism. Nonetheless, they do show a clear and unequivocal link between the application of low powers of lenses and improvements in visual performance. In other studies, Pirman and Lamb[30] and Caden[31] have shown improved performance on pattern copying tasks with the use of lenses prescribed on the basis of accommodative lag determination. The following case history demonstrates the effects it is possible to achieve with suitable low powered lenses, in clinical conditions.

The eye track **(Figure 4)** of this patient is shown whilst reading a text of N12 material, matched to reading ability. It is quite clear at which point lenses were introduced into the proceedings, based on the measured mismatch between convergence and accommodation. Reading speed improved, quality of reading improved, and comprehension also improved.

Advice

The final area to mention is of improvements in visual hygiene. Given the links between vision, and working distance, it behoves us all to give carefully structured advice about working position and posture, duration of task and relevant use of spectacles. This is easily glossed over in a busy practice situation, but should always be provided in writing, to ensure optimal compliance. The review paper described earlier by Ciuffreda[22] strongly advocates this, and notes the impact this may have on future visual development.

This article has provided a brief overview of the scientific basis for behavioural optometry, which evolved first out of clinicians seeking to describe and understand their findings "at the coal face" in the context of a meaningful model of vision, without the benefit of extensive research. It has since been validated by the scientific community – and is increasingly being shown to be an appropriate and truly holistic approach to the provision of eyecare.

Practitioners who are interested in discovering more about the behavioural approach to prescribing, to the use of lenses, and to vision therapy should contact the British Association of Behavioural Optometrists (BABO), or view the websites of the College of Optometrists in Vision Development (www.covd.org), the Optometric Extension Programme (www.oep.org), and of course, BABO (www.babo.co.uk).

References

References are available upon request. Please fax 01252-816176.

Figure 4:
The power of a lens. An infra-red eye track of a ten year old poor reader reading from a reading age appropriate passage. The impact of the introduction of low-plus lenses at 'A' can clearly be seen with increased reading speed, improved saccadic control, and better comprehension.