Article ▸ The Use of Models to Help Our Understanding of Vision

Geoff Shayler, BSc, FCOptom, Dorset, England

ABSTRACT

In the mid-20th century, Dr A.M. Skeffington developed his four circle concept of vision. Present knowledge of brain neurology permits a greater understanding of the complex visual process. This presentation utilises this knowledge to expand on the Skeffington concept and draws on both school- and practice-based studies to provide a practical evidence base indicating the integration of visual performance with both cortical brain function and educational performance.

Keywords: autonomic nervous system, fp/np ratio, motion coherence, A.M. Skeffington, Standard Assessment Task (SAT), static (form) coherence

History

Ancient Greek philosophers attempted to understand the world around them by a process of observation and logical thought. Modern science uses observation to develop models and scientific analysis to evaluate the reality of those models until new knowledge is gained, at which point these models have to be adapted further. Models do not necessarily have to be scientifically correct, but they need to be adequate to explain or to demonstrate an understanding of the problem. For example, Newton's laws of motion[1] break down against Einstein's theories of relativity[2] but are still adequate to put men on the moon!

Introduction

As an optometrist, I have had continually to change and to adapt my personal model of vision as my professional education has progressed into the concepts behind behavioural and syntonic optometry. This article addresses how models of vision can help us, as optometrists, better understand our patients and their needs, as well as the effect and efficacy of lenses, prisms, and optometric vision therapy. Developing my personal models of the visual process, I have used both school- and practice-based research to provide evidence. In a separate article, I will demonstrate how these concepts can be directly linked to brain function by measuring an individual's ability to process both static (form) coherence and motion coherence utilising a computer program developed at University College London and Oxford universities by Atkinson, Braddick, and Wattam-Bell.[3,4]

As school children, we were taught that the eye is like a camera; light passes through the lens to produce an inverted image on the retina, the light-sensitive film at the back of the eye. The retina is connected to the brain, which somehow turns the image the right way up, and through some magical process, we see! At optometry school, this model of vision is developed to provide an explanation for myopia, hypermetropia, astigmatism, and presbyopia. This model, though very basic, is sufficiently adequate for the typical optometrist to carry out refraction and to provide a prescription for spectacles if needed. When an optometrist extends his knowledge into developmental, behavioural, and syntonic optometry, there has to be a change in the models of vision that are used on a daily basis. These models have to provide the optometrist with an understanding of the patients' difficulties and allow the planning and provision of appropriate therapy.

In the mid-twentieth century, Dr A.M. Skeffington realised that "vision" played a much larger part in individuals' lives than simply being able to read a letter chart, and he developed his four circle concept.[5] With our present knowledge of the various neurological systems, we can enhance and develop his concept.

Model 1: The Autonomic Balance Board

The autonomic nervous system (ANS),[6] part of the peripheral nervous system, acts as a control system and functions largely below the level of consciousness. The ANS affects heart rate, digestion, respiratory rate, salivation, perspiration, pupillary dilation, micturition (urination), and sexual arousal. Whereas most of its actions are involuntary, some, such as breathing, work in tandem with the conscious mind. The ANS is classically divided into two subsystems: the parasympathetic nervous system and the sympathetic nervous system. Functionally, the ANS is usually divided into sensory (afferent) and motor (efferent) subsystems. Within these systems, however, there are inhibitory and excitatory synapses between neurons.

Sympathetic and parasympathetic divisions typically function in opposition to each other, which can be considered complementary in nature rather than antagonistic. Consider sympathetic as "fight or flight" and parasympathetic as "rest and digest" or "feed and breed." Generally, these two systems should be seen as permanently modulating vital functions, in usually antagonistic fashion, to achieve homeostasis.

Pupillary function

The iris receives both sympathetic and parasympathetic innervation. The sympathetic nerves innervate the pupillary dilator muscles and inhibit accommodation.[7] The parasympathetic nerve fibers (from Cranial Nerve III) innervate the pupillary constrictor (sphincter) muscles, as well as the ciliary apparatus for lens accommodation. During the

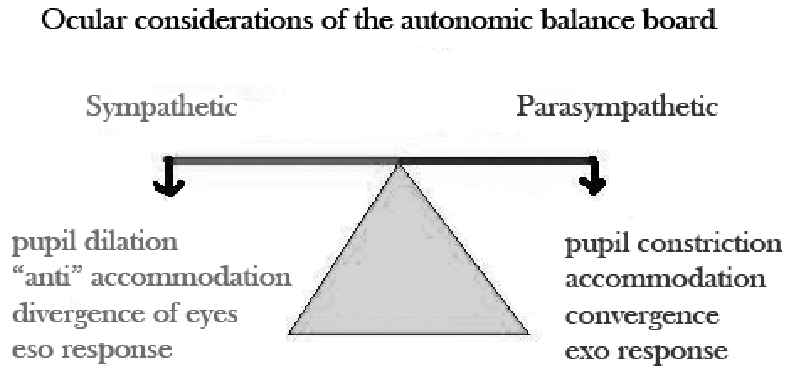

Figure 1: *Efferent visual functions of the autonomic nervous system*

Figure 2: *Observing alpha omega pupil (photo by Stefan Collier reproduced with his permission)*

normal waking state, the sympathetics and parasympathetics are tonically active. They also mediate reflexes dependent on both emotion and ambient lighting. Increased light produces increased parasympathetic tone and therefore pupilloconstriction (this also accompanies accommodation for near vision; Figure 1).

With age, the average size of the pupil decreases. Approximately 25% of individuals have asymmetric pupils (anisocoria), with a difference of usually less than 0.5 mm in diameter, something to be considered when attributing asymmetry to disease, unless there are other signs of neurologic dysfunction.[8]

The Alpha Omega pupil reaction

The late Dale A. Fast, OD identified that pupil examination is an important part of the evaluation of a patient who is to be considered for syntonics. One of the most useful tests is for an alpha omega (αω) pupil. This term was suggested by Dr. Paul Johnson after hearing Dr. Dutton Brewer's paper on pupillary asthenia in 1934.[9] This test gives the practitioner a good indication of how the autonomic nervous system is functioning at that particular time (Figure 2). It indicates whether the sympathetic or parasympathetic is dominating the individual, and specifically, it is indicative of inadequate adrenal function.

To administer the test, a penlight is pointed directly at, and maintained on, the pupil of an eye while the patient fixates a distant non-accommodative target. Normally, when the sympathetic and parasympathetic systems are in balance, the pupil will constrict and maintain that initial constricted size for about 15 seconds if the light is not varied. With an alpha omega pupil, the pupil will constrict and then start to dilate back again. The quickness and amount of dilation will depend on how dominant the sympathetic system is over the parasympathetic.[9,10]

Photophobia

Let's consider how the visual system reacts to (excessive) bright light. The fast magnocellular loop to the Edinger-Westphal nucleus will stimulate the parasympathetic system to constrict the pupil to reduce light input. The slower parvocellular system, activating the sympathetic system, reacting to the stress of the bright light staying on the eye, has the opposite effect, dilating the pupil and exacerbating the problem. Thus, we see the pupil re-dilate, the alpha omega pupil.

So how can else the body deal with the situation?

1) Squinting is a natural reaction to reduce discomfort in bright light but causes significant strain to the orbicularis muscles and cannot be maintained for long without eye strain and headache.
2) Covering one eye reduces glare and is a much more comfortable way to cut this glare problem.

This simple experiment demonstrates that photophobia occurs primarily as a binocular symptom rather than a monocular symptom. The reactions of an individual to that photophobia, i.e. squinting, tearing, etc., come from cortical involvement, indicating that the stress that the excessive light is producing must occur at a cortical layer within the brain rather than in the eye. Thus, photophobia is actually an inability to react to, and adequately to control, "excessive neurological input from the visual system" to the cortex rather than an ocular problem (unless there is a pathological ocular problem such as cataract or corneal scarring causing monocular glare).

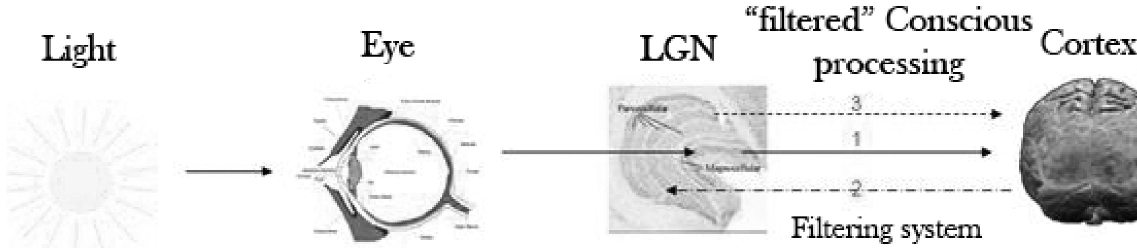

Figure 3: *Schematic "model" demonstrating feedback activation at the LGN to reduce cortical overload*

Is there another way an individual can filter visual input to the cortex?

Despite the great influence that innervation from the retina has on the function of the lateral geniculate nucleus (LGN), about 80% of the excitatory inputs to the LGN come not from the retina but from the primary visual cortex.[11] The primary visual cortex therefore exerts a significant feedback effect on the LGN, modifying the LGN's own visual responses. Some activity of the LGN may also be stimulated by brain stem neurons whose activity is associated with vigilance and with processes related to attentiveness.

This modulation of the response of the LGN neurons tends to confirm that the LGN may be one of the first locations within the visual pathway where particular mental states can influence our visual perception. A schematic model of a visual filtering system (Figure 3) demonstrates feedback activation at the LGN to reduce cortical overload. The use of a lens, prism, or tint may result in reducing stress within the visual process, permitting less "filtering" needed at the LGN. This in turn allows greater functional processing to take place.

Continuing with this principle, the parasympathetic system also stimulates convergence and accommodation. When an individual finds close work stressful, the reaction of the sympathetic will attempt to negate other parasympathetic actions, i.e. dilating the pupils (αω pupil), diverging the eyes, and reducing accommodation (an exo flight response), However, as it is necessary for an individual to succeed in school by reading and writing, additional effort is forced into the situation to attempt to enable the individual to perform at near (at a reduced performance level) and at the expense of mental and physical energy, leading to convergence insufficiency (or adaptive convergence excess, an eso fight response), a restricted range of clear near reading (needs to hold book close), reduced accommodative facility, poor pursuit and saccadic eye movements, reduced fusional reserves, etc.

Model 2: Understanding the Neurology Behind Skeffington's Four Circle Concept[12]

The magnocellular system combines a number of fast-acting neural processes to support the body against gravity, to alert us to potential danger, and to direct the visual system to the object of interest. Some nerves leaving the eye do not synapse in the LGN but travel on to the superior colliclus and pretectal nuclei. This pathway impacts pupil function, as well as sending fibres to the pulvinar (posterior thalamus), where it is relayed to the parietal cortex, bypassing the occipital cortex. This is a subconscious reflex that is closely associated with the vestibular and proprioceptive/kinesthetic systems. This ambient system can also be considered as Skeffington's first circle, antigravity.

The fibres that go to the superior colliculus are magnocellular but do not follow the pathway via the LGN and optic radiation to the visual cortex. This is why in some animal studies, when the superior colliculus is destroyed, the animal can still see but cannot negotiate a learned maze. This system therefore clearly plays a role in answering the question of "where am I?"

The magnocellular dorsal stream eventually ends in the parietal cortex later than the superior colliculus/pulvinar pathway to answer the question "where is it?" This helps the individual to identify where an object is in space (i.e. integration of all the body's attention and range-finding systems, aligning the eyes, head, and body with convergence and accommodation accurately to fixate the object of regard). This can be considered to be a reflex arc pathway, which Skeffington labelled as the centering system.

The conscious parvocellular stream, the focal system, which eventually ends up in the temporal cortex, helps us to identify the object (what is it) by integrating static form, colour, and contrast information with the brain's memory databases. This is considered by Skeffington to be associated with identification.

The fourth circle of Skeffington, termed speech/auditory, helps us put our thoughts into words: "I can see an object and describe it to you" (efferent speech) or "you can look at an object and describe it to me" (afferent auditory), allowing the other party to visualise the object. This occurs through coordination of the temporal and frontal cortices to integrate audition and vision in order to label the object of regard. The fourth circle can also be considered in a slightly different way as "what do I have to do to get to it" (i.e. how we organize ourselves through our visualization processes). Note that this is a simplified explanation, as there is a great deal of interlinking of the various visual systems, as demonstrated by the overlapping circles.

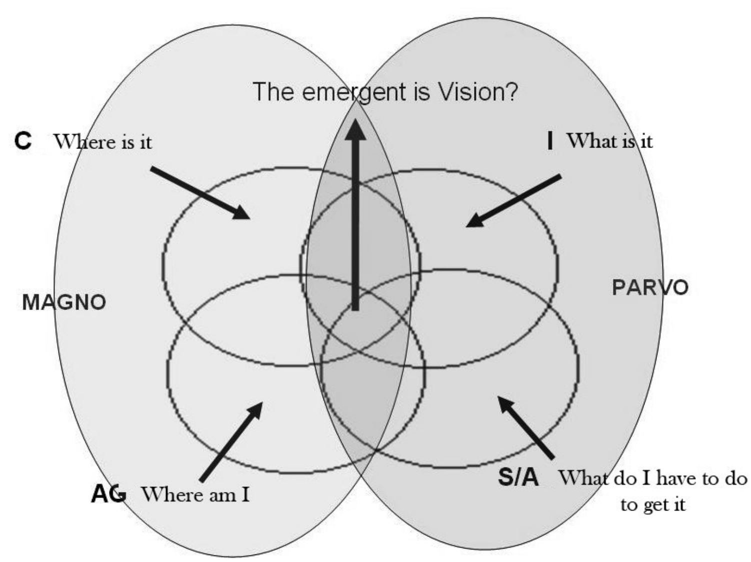

Figure 4: *The relationship of the magno/parvo systems with Skeffington's 4 circles*

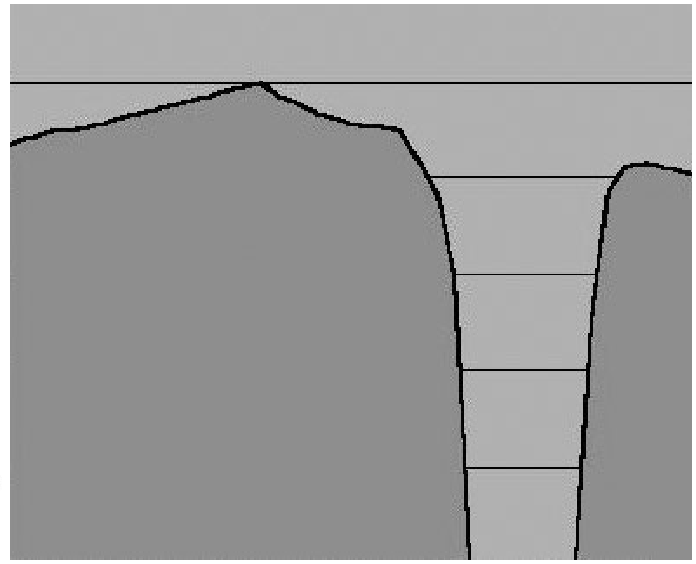

Figure 6: *Demonstrating the blind spot size in relation to threshold value (Syntonic Theory and the Visual Process, Journal of Optometric Phototherapy 2013, Used with Permission)*

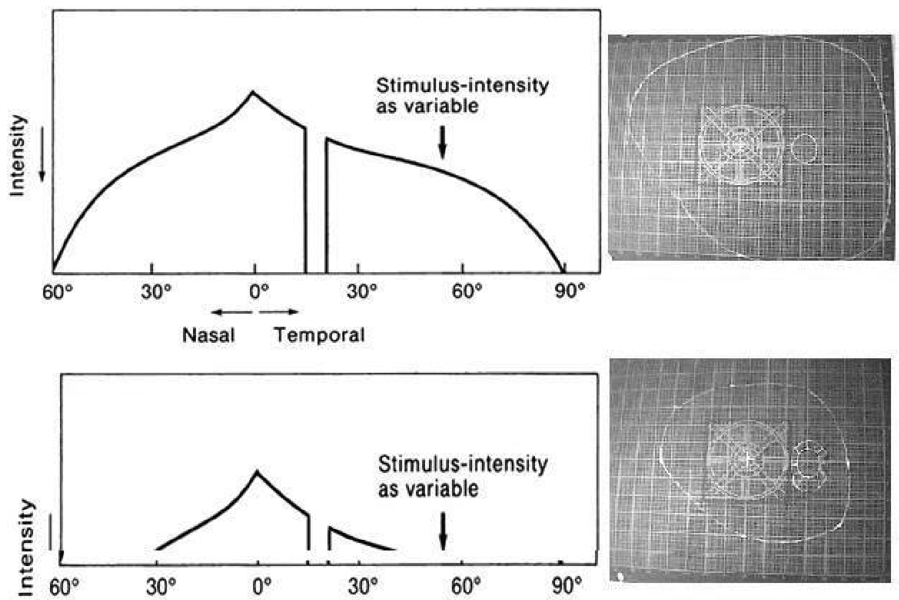

Figure 5: *The effect of change in peripheral threshold on island of vision (Syntonic Theory and the Visual Process, Journal of Optometric Phototherapy 2012, Used with Permission)*

In summary (Figure 4), we can consider that input from the eye via the magnocellular system leads to (primarily unconcious) output interaction with vestibular/auditory/tactile and proprioception, thereby directing body physiology and structure (Skeffington "A/G"). This includes intraocular and extraocular muscles (Skeffington "C"). Input from the eye via the parvocellular system leads to output for the individual to derive (conscious) meaning from the external world by interaction and identification (Skeffington "I"), leading to consequent visualisation (visual planning) and communication (Skeffington "S/A").

Pathological and Functional Visual Fields

The relevance of Skeffington's model of visual neurology and processing now becomes evident when we consider the routine assessment of visual fields in our patients. Threshold visual fields are those measured by automated perimeters using light threshold measures such as Henson, Friedman, Humphrey, and Dicon. This type of visual field screener is particularly good for identifying pathological disorders such as those found in glaucoma or typical neurological damage from brain trauma or stroke.

However, functional (dynamic or kinetic) visual field assessments are a measure of the ability to process specific visual information within the periphery, typically through the detection of a moving target. For example, the use of a Bjerrum (tangent) screen or campimeter is a measure of when a moving target appears within the perceptual field of the individual. This motion detection is mediated by magnocellular processing. It is this visual processing stream that also forms the basis of

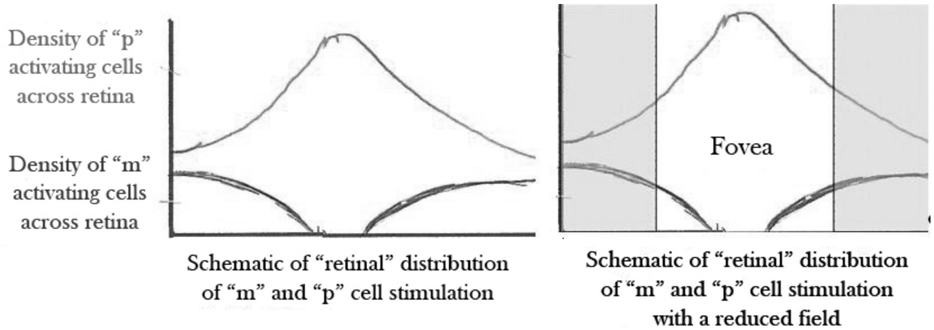

Figure 7: *Schematic to demonstrate effect of reduced field on magno and parvo stimulation*

frequency doubling technology (FDT) since it is believed that damage to the magnocellular system in early glaucomatous changes can be detected before threshold testing methods. It is this knowledge that can be utilised in the detection of Alzheimer's and Parkinson's diseases also, as functional visual field constriction is a common finding in both of these diseases.[13]

Model 3: Traquair's Island of Vision

If we consider Traquair's model of vision[14] as a measure of sensitivity across the visual field, then changing the threshold at which a stimulus elicits a reaction will affect the size the field (Figure 5). When an individual is suffering from an overload of cortical input, there is consequent stress. The action of the sympathetic "flight" system adapts to this stress by changing the threshold at which a response is activated, perhaps, as already discussed, at the LGN, which in turn results in a reduction in the size of the functional visual field. In Traquair's Island of Vision, the blindspot is not a straight sided "well" but enlarges towards the top of the "well," so reduced sensitivity across the field will lead to an enlarged blind spot (Figure 6). As a result, whenever these functional visual fields are reduced, the physiological blind spot is always enlarged. This serves as a useful back check that your subjective measures are correct.[15]

How does this reduced field affect visual function?

If we consider the schematic in Figure 7, the distribution of M and P activating cells across the retina, it can be observed that the effect of reduced peripheral function will have a greater effect as a percentage of the total population of M cells than P cells. It will also reduce visual stimulus at the cortex, which, as demonstrated earlier, is a necessary demand in order to reduce neurological stress.

In summary, the inappropriate effect of neurological stress on the visual system causes it to shut down peripheral function in order to reduce cortical overload. This causes more impact on dorsal (motion) processing functions than on ventral (static) processing functions, but both are affected. According to Eric Hussey, OD, the parvocellular system needs magnocellular input to function adequately.[16]

The primary magnocellular pathway functions include:

- Integration of visual, vestibular, and proprioceptive inputs to maintain stable and upright posture and balance against gravity (Skeffington A/G)
- To attend to an object of interest by the integrated control of eye movements, convergence, accommodation, etc. (Skeffington C)
- Involvement in the processing of motion, via the dorsal stream

Effects of dorsal stream dysfunction will primarily include magnocellular driven functions:

- Convergence insufficiency
- Reduced accommodation
- Reduced range of clear near vision (accommodative flexibility)
- Reduced speed of focus change (accommodative facility)
- Poor eye movement control – pursuits and saccades
- Poor motion coherence measures
- Reduced fusional reserves
- Related to a reduced functional field of vision

The parvocellular pathway primarily deals with:

- Detail, colour, and identification of the object of attention and the utilisation of visual memory (Skeffington I)
- As a result of being able to name, describe, and understand the object of attention (or have that object described to you), it leads the individual to a state of cognition (Skeffington S/A)
- The processing of static objects, form and colour, via the ventral stream

Effects of ventral stream dysfunction will primarily include parvocellular driven functions:

- Poor language and comprehension skills, leading to reduced performance in school as measured by school exam in reading, writing, and maths (SATs)
- Reduced speed of reading (Wilkins Rate of Reading Test)

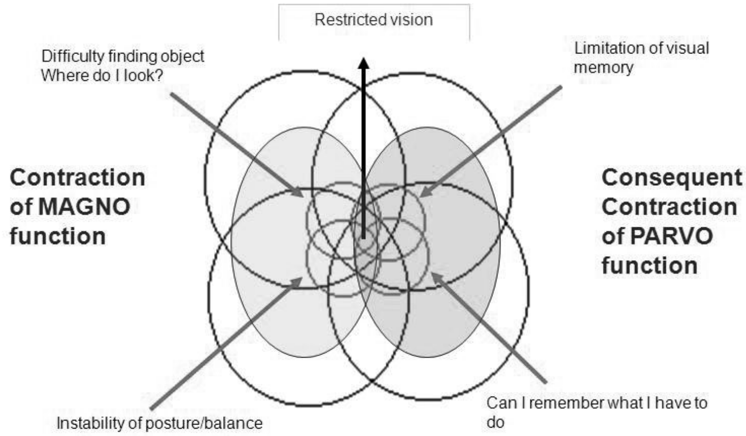

Figure 8: *Effect of a reduced field on magno/parvo functions*

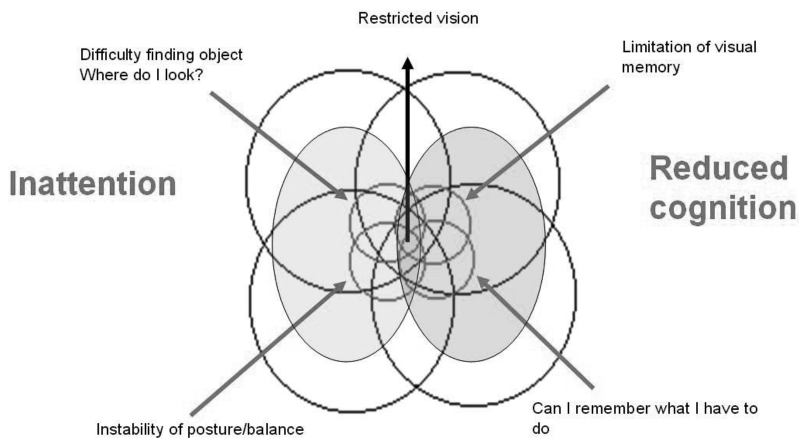

Figure 9: *Effect of a reduced field on attention/cognition*

Table 1: Parvo/Magno Functions (source, Stefan Collier; reproduced with permission)

Parvocellular	Magnocellular
1. Most sensitive to high spatial frequencies, fine details	1. Most sensitive to low and middle spatial frequencies, large shapes
2. Low sensitivity to contrast	2. High sensitivity to contrast
3. Central (foveal) vision dominant	3. Peripheral vision dominant
4. Responds during and after stimulus presentation. Longer response persistence	4. Responds to onset and offset stimulus. Short response persistence
5. Most sensitive to low temporal frequencies	5. Most sensitive to high temporal frequencies
6. Sensitive to stationary or slow moving targets	6. Responds quickly to moving targets (early waning)
7. Sensitive to longer wavelengths (e.g., red)	7. Sensitive to shorter wavelengths (e.g., blue)
8. Identification of shapes and patterns	8. Global analysis of incoming visual information
9. Involved in processing color	9. Involved in perception of depth, flicker, motion, brightness, and discrimination
10. Responds subsequent to transient output and is dependent upon transient output	10. Prepares visual system for the input of slower detailed information that follows

- Poor fluency of reading, lack of intonation, boring to listen to
- Behavioural problems, unable to sit still, unable to maintain concentration, disrupts other students
- Poor static coherence measures
- Related to a reduced functional field of vision
- Disorganisation of Van Orden star

Parallel visual input processing is detailed in Table 1.[17]

Figure 8 demonstrates how a reduced functional field of vision affects all aspects of the Skeffington concept. We can consider that contraction of the visual field relates to contraction (or imbalance) of magno/parvo, leading to corresponding visual (and auditory) limitations, as shown in this modification of the Skeffington four circle concept. This figure also demonstrates the typical problems experienced by many of the children who are diagnosed with educational difficulties.

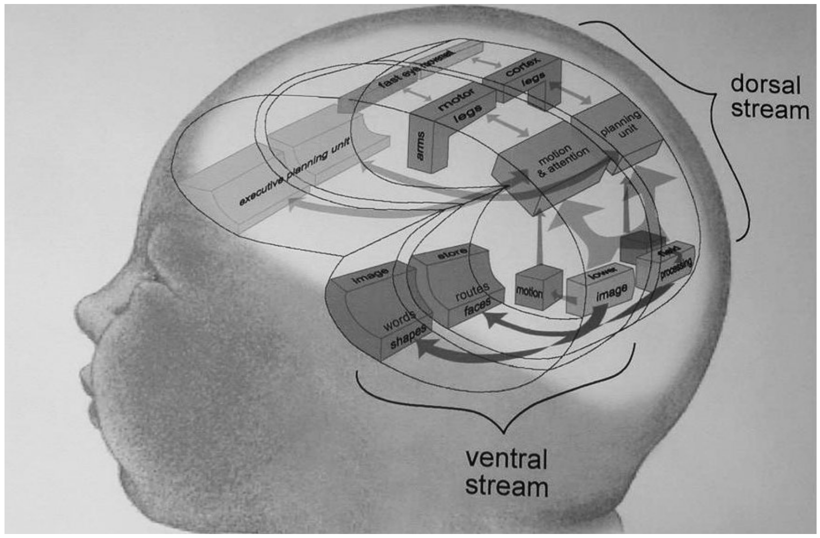

Figure 10: Dorsal/ventral stream processing (Ageing vision, Part 3: Visual dysfunction in Alzheimer's disease. Optometry Today 11/2/11 p 37-40, Used with Permission of Prof Dutton, Glasgow Caledonian University and Optometry Today)

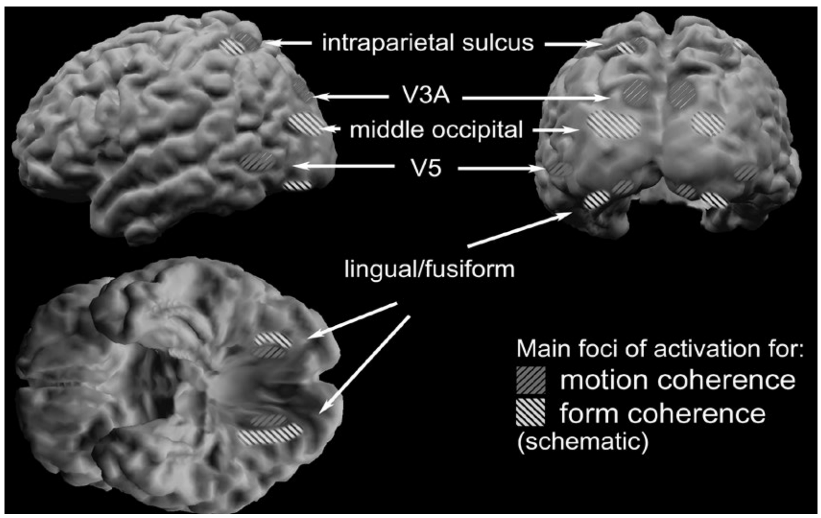

Figure 11: Areas of the brain associated with form and motion processing, identified with MRI (Ageing vision, Part 3: Visual dysfunction in Alzheimer's disease. Optometry Today 11/2/11 p 37-40, Used with Permission of Justin O'Brien, Brunel University and Optometry Today)

Attention and Cognition

We can consider that the magnocellular aspects of the four circle concept are associated with attention and the parvocellular aspects are associated with cognition. A collapsed field of vision will be associated with reduced function of the visual pathways and lead to both reduced attention and consequent loss of cognition (Figure 9).

Static Form and Motion Coherence Testing

The specific nerve fibres referred to as the magno and parvo systems in general follow the dorsal and ventral streams, respectively (Figure 10); however, there is some overlap of function. It has been identified by Atkinson et al. that the cortical regions activated by form coherence do not overlap with those activated by motion coherence in the same individuals. Areas differentially activated by form coherence include regions in the middle occipital gyrus, the ventral occipital surface, the intraparietal sulcus, and the temporal lobe. Motion coherence activated areas that were consistent with those previously identified as V5 and V3a, the ventral occipital surface, the intraparietal sulcus, and temporal structures (Figure 11). Neither form nor motion coherence activated area V1 differentially. Form and motion foci in occipital, parietal, and temporal areas were nearby but showed almost no overlap. Testing these specifics of visual function allows a greater understanding of which parts of the brain are responding to the test and can further our understanding of their relationship to various measures of visual function.[4,18]

Is there evidence to validate these model concepts?

The late Wayne Pharr, OD introduced me to the elements associated with campimetry and syntonic (optometric) phototherapy. He showed me that many of the children that I was examining who were experiencing educational

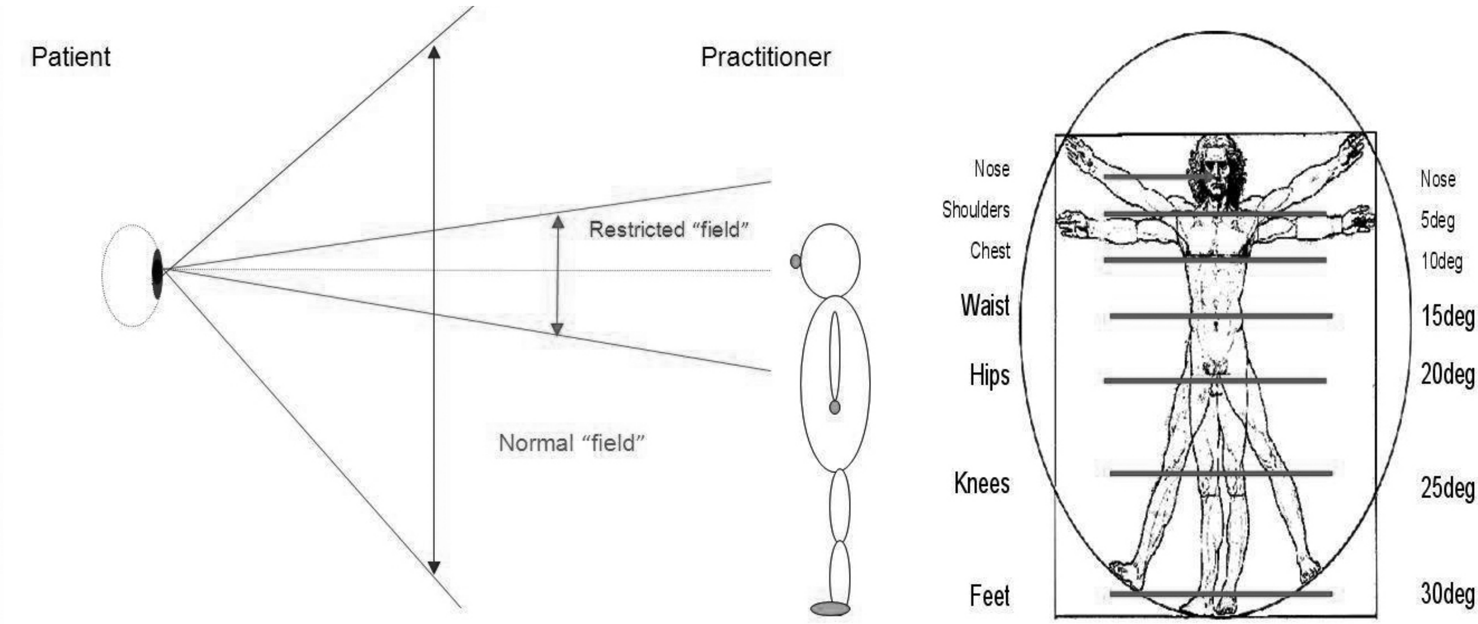

Figure 12: *The AOP test (Ageing Vision, Part 4: The role of optometrists in identifying visual problems in patients with Alzheimer's or Parkinson's Diseases. Optometry Today 25/2/11, Used with Permission)*

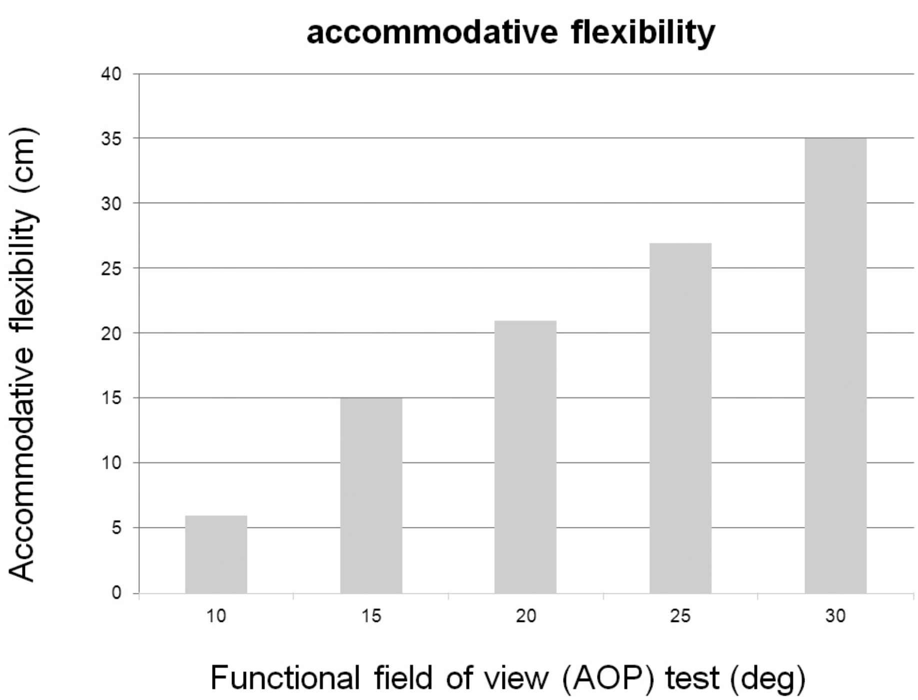

Figure 13: *The relationship between AOP test and accommodative flexibility (Ageing Vision, Part 4: The role of optometrists in identifying visual problems in patients with Alzheimer's or Parkinson's Diseases. Optometry Today 25/2/11, Used with Permission)*

difficulties had a reduction in their ability to process peripheral information.

Two Interesting (Antigravity) Practical Tests

Ask someone to stand on one leg and close one eye, and then observe their balance.

Repeat the activity, but this time, have them look through a tube with their open eye. Unless they are trained in Yoga or martial arts (when they tend to bend their knee to lower their centre of gravity), there is reduced stability. This is a useful demonstration when giving talks to teachers as it demonstrates something they are particularly aware of in children with dyspraxia. In addition, children with a retained moro reflex frequently exhibit a head-down posture.

We commonly see head down posture in the elderly, especially those with Parkinson's disease. In this demonstration, simply look at someone's stability when they stand on one leg with head upright and looking straight ahead with both eyes open, then repeat the test with the person adopting a typical head-down posture, looking about one meter in front of their feet. Stability is severely compromised in this position. This is not surprising, since patients with this posture are more likely to suffer from falls with consequent risk of hip and pelvic injury and resultant cost to health services and possible reduction in life span and quality of life.

These demonstrations indicate the importance of peripheral vision and posture and their utilisation by the brain to maintain structural stability. Reduction of that field, either as a result of postural pose or functional dysfunction, affects the stability of the individual. Professor Ed Howell postulated that balance was 1/3 auditory, 1/3 proprioception, and 1/3 visual, but of all the senses, vision is "the governor."[19]

The Awareness of Practitioner (AOP) Test (Fig. 12)

When examining mature adults, I observed a great variation in their accommodative flexibility (af) measures; those with smaller measures also had reduced functional visual fields.[20] As a result of these observations, I developed this simple test. Stand facing your patient at a distance of 3 m (10 feet), ask them to concentrate on your nose, and invite them to report how far down your body they are aware of (without moving their eyes). There appears to be a close relationship between the found reading (af) range and the AOP test. (All the patients in this study had 6/6 (20/20) Snellen and wore a +2.25 D add for reading; Figure 13). The smaller the range available for reading, the smaller the awareness of peripheral vision.[13] This test is also very useful to identify and to demonstrate change in peripheral function to parents and children when low plus/yoked prism lenses are found to benefit reading function and expand peripheral awareness.

From this relationship, it can be seen that the awareness field of a typical elderly patient with Parkinson's disease that reaches "down to the waist" corresponds to a clear range of reading (af) of only 15 cm. Elderly patients with these problems are more likely to be clumsy and to suffer from falls, with increased risk of hip fractures. Simply adding these quick (accommodative flexibility and AOP) tests can alert the optometrist to potential visual processing problems that may require further investigation or spectacle lens consideration.

The Relationship Between the Fp/Np Ratio and Functional Visual Fields

The diameter of a simple measurement of the first awareness of a 5 mm white target using the campimeter built by Rex Cross being brought in from non-seeing to seeing was compared to the far point (fp)/near point (np) ratio. Subjects with small fields showed a low fp/np ratio, while large fields demonstrated a large fp/np ratio.[21]

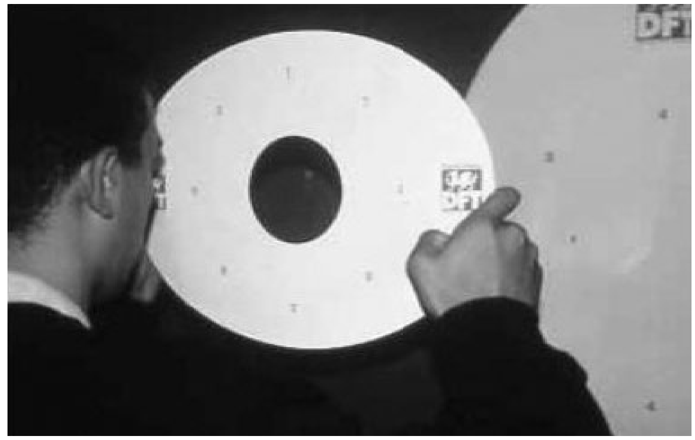

Figure 14: *The DFT Test (developed by Geraint Griffiths)*

Balance and Body Stability (Skeffington A/G)

Many children, when asked to stand upright, have stability problems, with frequent proprioceptive corrections taking place in the body's muscles to maintain an upright posture. It will be frequently noted that there is hand and arm twitching and general motor overflow. These effects are often exaggerated during eye tracking tests when the eyes are looking away from their primary position.

Centering

A number of studies have indicated a link between learning difficulties and delinquency with eye movements. Within my practice, I used the Dynamic Fixation test (DFT; Figure 14), developed by sports vision optometrist Geraint Griffiths,[22,23] to investigate eye movement speed, and I compared the results to the fp/np ratio. This study identified that children with a good fp/np ratio took less time to complete the test than those with a low fp/np ratio.[20]

Identification

Up to 20% of children have restricted functional fields, with some studies quoting an 85% correlation with failure in at least one subject in school.[23-28] When examining the visual status of children with learning difficulty, I became aware that those with reduced functional visual fields had:

- Poor eye movements frequently compensated by head turning and/or head tilts
- Reduced fusional reserves
- Poor accommodation and/or accommodative facility
- Reduced ability to converge to a near point
- An inability or slowness in reading letter charts and small print
- A reduction in stereopsis
- Reduced range of clear, near vision
- Difficulty identifying the numbers on the Ishihara colour vision test (e.g., reading "3" as an "8" by filling in the gaps)

The result of this in education is related to slow reading, poor comprehension, difficulty copying from the blackboard, difficulty with ball games, etc.

School-Based Research

On the basis that restricted functional visual fields appeared to be linked to a restricted range of clear near vision and accommodation, I wondered if it would be possible to:

- Identify children with visual processing difficulties by the simple idea of measuring their near and far points whilst reading small print
- Determine whether there was a measurable link between the limitation of this range and scholastic achievement/ability
- Explore any relationship between these ranges and behaviour

Mrs. Julie Barsby, the head teacher of Elmrise School in Bournemouth, Dorset, England, 20 miles from my practice, offered to help with this research.

Educational Testing

In the UK, children are periodically assessed by means of Standard Assessment Tasks (SATs) tests. The SATs tests are carried out by examination in Maths, Reading, and Writing, marked by the school but evaluated by external examiner. SATs scores at this age are w, 1, 2c, 2b, 2a, 3, with w (working towards grade1) being the lowest and 3 the best grade. SATs data was produced from the information provided by the school of sixty-seven 6- to 7-year-old children in Year 2.

Assessing Vision in the Classroom

A reading chart was designed which included the instructions for use in Times New Roman font, size 8. Classroom assistants used this chart to measure the near and far points of clear vision on each child. Exclusion criteria included those that had left the school or had not had a SATs target set. In a supplementary study, the children were subjectively graded by their regular teacher on their behaviour on a scale of 1-5.

This provided a well-balanced, independent study in order to identify any links between vision and learning with:

- No optometric intervention in obtaining the results
- Subjective on-going pre-assessment of the children by their teacher
- Objective assessment by written examination with results reviewed by an external examiner
- A vision test design simple enough to be used on young children
- Results simple enough to be obtained by a classroom assistant with no optometric training
- Subjective assessment of behaviour by the teacher

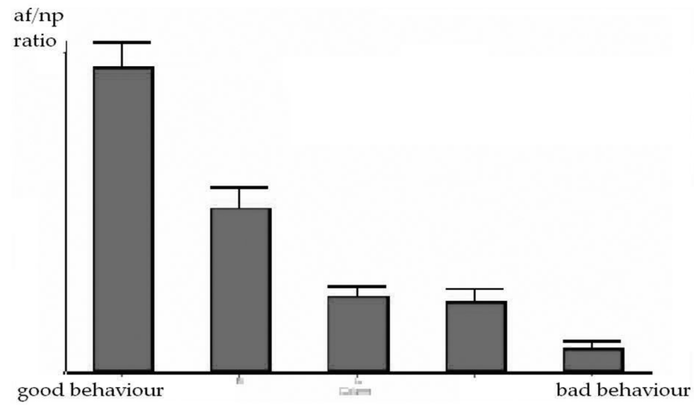

Figure 15: *Relationship of fp/np ratio with scholastic behavior (Deux tests simples, pour reconnaitre l'enfant qui echole a l'ecole, du fait de difficultes de traitment visual, LRO La Revue, No 36, January 2011, 36-42, Used with Permission)*

Results[29-31]

The study identified that poor educational performance was linked to a:

- Reduced ability to focus in to a near point (np)
- Reduced ability to read print towards arms-length (fp)
- Reduced range of clear, near vision – accommodative flexibility (af=fp-np)
- Reduced fp/np ratio, a criterion developed to incorporate the fp and np measures, which provides a better statistical significance and an easy measure that can be used for teacher referral

Statistical analysis showed that an fp/np ratio <3.5 indicated deficient near processing.

To see if this concept works as a screening tool, this ratio was used in another study carried out by optometrist Smita Trividi at Raglan School in London using the same criteria, vision test, and measurements. That study demonstrated that a high percentage of children in the lower SAT grades had an fp/np ratio <3.5, with only a low percentage of children in the upper SAT grades. In both school studies, statistical significance of the test was greatest with reading (most visually demanding) and least in writing (least visually demanding).[32,33]

Vision and Behaviour

The Elmrise study also investigated behaviour with the teacher using a simple 1-5 scale of good to poor behaviour for each child in the study. The average fp/np ratio for each behaviour grade was calculated and plotted. A significant relationship (ANOVA p=0.0001) was identified, with those children with good visual performance (fp/np ratio >10) having good behaviour and those with reduced visual performance (fp/np ratio <4) typically having behavioural problems. If we consider that these children find sitting still and having to carry out a task (for example, reading or writing) difficult, then these children will do anything to avoid these stressful activities, potentially leading to disruptive behaviour, as indicated in this study (Figure 15).[32]

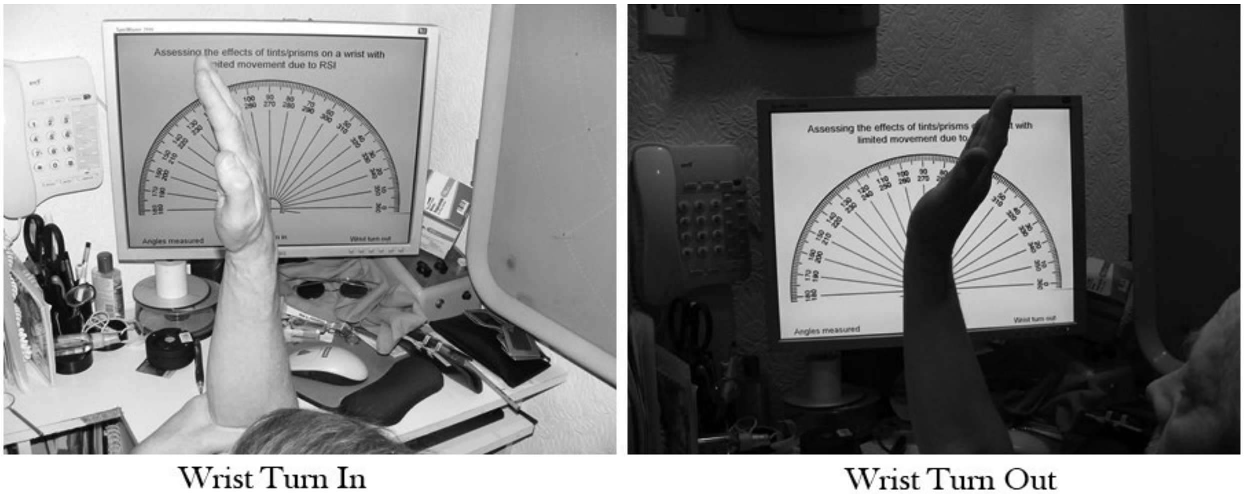

Figure 16: *Measurement of arthritic wrist angle*

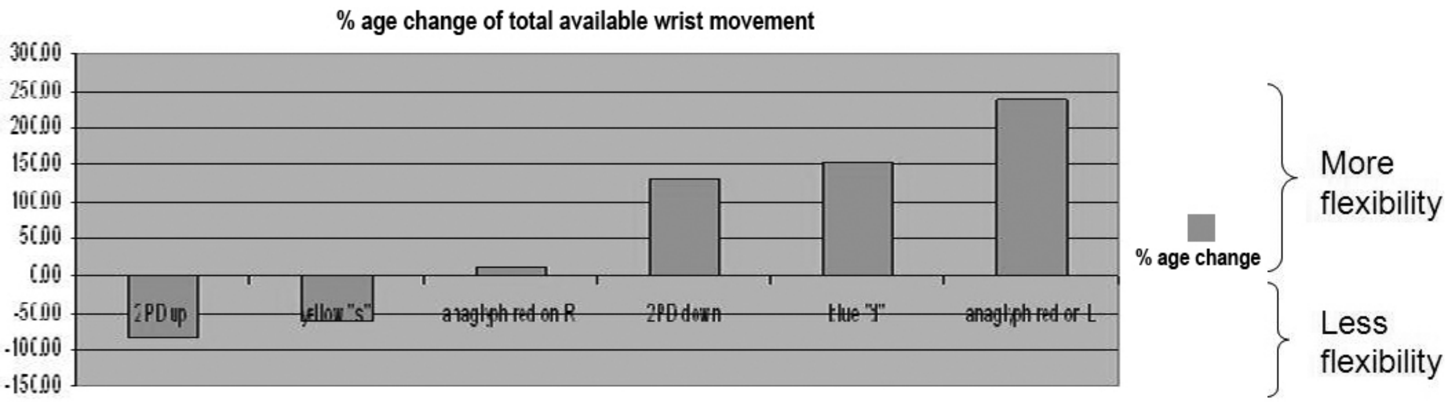

Figure 17: *Effects of various lenses, prisms, and tints on wrist flexibility*

Speech/Auditory

One of the most obvious differences we see when children are reading is their fluency and intonation. When suitable low plus/yoked prism is provided to a child with reading difficulty, an improvement in reading speed, fluency, and intonation is frequently observed.

Stress and the Body

Stefan Collier, during his curriculum 1 course in Syntonic Optometry,[9] identified that different coloured filters can affect body stiffness. Personally, I have a Repetitive Strain Injury (RSI) arthritic problem affecting my right wrist. Experimenting with some of his filters, I identified that the "D" (blue depressant) goggle increased wrist flexibility and the "S" (yellow stimulant) goggle reduced flexibility. Similar effects were identified with plus/minus lenses and vertical yoked prisms. In view of these observations, I set up a simple study to look at the various lens/prism/tint options, measuring my wrist flexibility (Figure 16).

The "D" filter, low plus, and base down yoked prism increased movement, while the "S" filter, minus, and base up yoked prism decreased movement. From this we can theorise that those lens options which reduce wrist movement stimulate the sympathetic nervous system, and those which improve wrist movement inhibit the sympathetic nervous system (Figure 17).

Near Vision and the Autonomic Nervous System

Let us consider that in order to read we need to have accurate and linked convergence, accommodation, and miosis. All are connected with parasympathetic stimulation in association with pursuit tracking, saccadic tracking, and comprehension. If someone is under stress, there is stimulation of the sympathetic nervous system, leading to enlarged pupils, reduced accommodation, and divergence of the eyes (exo reflex).

The individual in school has to keep carrying out close work, however, resulting in a demand to increase convergence stimulation, esophoria, and an effort to constrict the pupil, which causes even more stress, a vicious circle. To compensate, the parasympathetic has to go into overload to force the visual system to enable the individual to perform at near (at a reduced level), at the expense of mental and physical energy. This can lead to convergence insufficiency (or adaptive convergence excess, eso response), restricted range of clear near reading, reduced accommodative facility, and poor pursuit and saccadic eye movements.

Dr. Geoff Getzell[34] introduced me to the benefits of low plus and yoked prisms. If we consider these lenses from a conventional optometric view, plus lenses should increase exophoria, and yoked prisms should do nothing but shift the image. Exploring the use of these lenses in children who had visual processing limitations produced improvements in convergence, accommodation, accommodative flexibility, pursuit and saccadic tracking, and visual field expansion. No change was noted with these lenses in children with normal visual processing. Logically then, we can suggest that the effects observed with these lenses can only occur as a result of inhibition of the (over active) sympathetic system, allowing the parasympathetic system to carry out its actions in a more efficient way.

This theory may also explain why Stein[36] found that a higher percentage of dyslexic children diagnosed with Meares/Irlen syndrome found simple blue or yellow tints beneficial for reading as opposed to the very specific tints identified using colorimetry recommended by Wilkins and Evans.[36] Stein also found that only the children with reduced near-point convergence and accommodation (CA) improved their reading with these tints. He showed that those who had the greatest improvements in reading were those who also showed the largest gains in CA. Those who showed no CA improvement did not significantly improve their reading. Just as found in my studies, Stein indicates that the possibility that the resultant improved convergence and accommodation contributed to improved reading.[35] Unstable convergence might be the cause of apparent movement of letters, whilst inaccurate accommodation would cause blurring of the text. These are precisely the symptoms of which these poor readers so often complain.

Conclusion

Skeffington's concepts of the visual process stand up to scrutiny with our modern understanding of the neurological processes of the magnocellular and parvocellular systems. We can consider that the antigravity and centering circles relate to primarily magnocellular processing and are associated with attention. The identification and speech/auditory circles are primarily parvocellular in origin and are associated with cognition. In addition, we can consider the size of each circle, within his model, to be related to the size of the visual field; a large field being associated with good processing, while a small field is associated with deficient function. An individual suffering from neurological stress, with which the individual is unable to cope, may result in over-action of the sympathetic, leading to collapse of the visual process, impacting all areas of Skeffington's circles.

The second article in this series will introduce the readers to a computer-based program developed by Dr. Wattam-Bell in association with Professors Atkinson and Braddick which permits measurement of both static (form) and motion coherence threshold testing. Within my practice, I have now used this program on several hundred children. I will share the results of these tests with a number of optometric measures of the visual system which in addition can indicate how brain function is affected by appropriate lens prescribing and optometric vision therapy.

References

1. Newton I. Principia Mathematica, 1687.
2. Einstein A. Relativity: The Special and General Theory. New York: H. Holt and Company, 1916 (translation 1920).
3. Wattam-Bell J, Atkinson J, Braddick OJ. Normal and anomalous development of visual motion processing: Motion coherence and 'dorsal-stream vulnerability.' Neuropsychol of Motion Percept 2003;41:1769-84.
4. Braddick OJ, O'Brien JMD, Wattam-Bell J, Atkinson J, et al. Brain areas sensitive to coherent visual motion. Perception 2001;30:61-72.
5. Schmitt EP. The Skeffington Perspective of the Behavioral Model of Optometric Data. Bloomington, Indiana: Author House, 2006:545.
6. Williams PL. Grays Anatomy, 38th edition. London: Churchill Livingston, 1995:1292-301.
7. Mallen EA, Gilmartin B, Wolffsohn JS. Sympathetic innervation of ciliary muscle and oculomotor function in emmetropic and myopic young adults. Vis Res 2005;45:1641-51.
8. Reeves AG. Disorders of the Nervous System, 3rd edition. Imperial Company Printers, 1995. Online version developed at Dartmouth Medical School: available at http://www.dartmouth.edu/~dons/
9. Collier S. In Syntony, 2011, Hersetllung and Versag, BoD – Books on Demand, 2011, Nortestedr.
10. Suter PS, Harvey LH. Vision Rehabilitation: Multidisciplinary Care of the Patient Following Brain Injury. Boca Raton, Florida: CRC Press, 2011.
11. Bear MF, Connors BW, et al. Neuroscience: Exploring the Brain. Philadelphia: Lippincott, Williams & Wilkins, 2008:318.
12. Shayler GR. Ageing vision, part 1, Neurology of vision: A new model? Optometry Today 2011;51(1):47-50.
13. Shayler GR, Ageing vision, part 4, optometric management of Alzheimer's and Parkinson's diseases. Optometry Today 2011;51(4):41-4.
14. Traquair HM. An Introduction to Clinical Perimetry. London: Henry Kimpton, 1948.
15. Shayler GR. Identifying functional visual field problems in adults. J Optom Phototherapy 2002;22(5).
16. Hussey E. Binocular visual sensation in reading, a unified theory. J Behav Optom 2001;12:119-26.
17. Collier S. Syntonics Curriculum 1 course content, 2011 (for College of Syntonic Optometry).
18. Braddick OJ, O'Brien JM, Wattam-Bell J, Atkinson J, Turner R. Form and motion coherence activate independent, but not dorsal/ventral segregated, networks in the human brain. Curr Biol 2000;10:731-4.
19. Howell E. BABO lecture, Bristol 2000.
20. Shayler GR. The effects of Reduced near visual Function (AF/NP ratio). J Optom Phototherapy 2008:7-16.
21. SShayler GR. Identifying functional field problems in adults and their relationship with reading range. Proceedings of 4th ICBO, Societe d'Optometrie d'Europe 2003;179:1-8.
22. Griffiths G. Eye speed, motility and athletic potential. Optom Today 2002. http://bit.ly/1FwKKjS
23. Griffiths G. Visual performance in yachting: SVA testing for the olympics Optom Today 2004. http://bit.ly/1GTElfc.

24. Eames TH. The speed of picture recognition and the speed of word recognition in cases of reading difficulty. Am J Opthalmol 1938;21:1370-5.

25. Searfoss J, Garzia R. Tunnel vision, a loss of visual sensitivity in school age children. J Optom Vis Dev 2000;21:117-30.

26. Ingersoll S. Syntonics as reading enhancement techniques at the Livingston Developmental Academy. Presented at 66th Annual Conference Light and Vision, Vancouver, CN, 1998. J Optom Photother 1999.

27. Kaplan RM. Changes in form visual fields in reading disabled children, produced by syntonic stimulation. College of Syntonic Optometry, 1983.

28. Lieberman J. The effects of syntonic colored light stimulation on certain visual and cognitive functions. J Optom Vis Dev 1986;17:4-14.

29. Shayler GR. Childhood visual problems and education Part 1 Near point and educational performance. Optom Today 2003:43-5. http://bit.ly/1F46x2e.

30. Shayler GR. Childhood visual problems and education Part 2 Educational performance and accomodative flexibility. Optom Today 2003:41-3. http://bit.ly/1AKXvle

31. Shayler GR. Childhood visual problems and education Part 3 Educational and visual performance links. Optom Today 2003:41-3.

32. Shayler GR. Deux tests simples, pour reconnaitre l'enfant qui echole a l'ecole, du fait de difficultes de traitment visual. LRO La Revue 2011;36:36-42.

33. Shayler GR. Stress and Reading, A neurological approach. J Optom Phototherapy 2007:1-8.

34. Getzell J. Prescribing in eighth dioptre steps and microprisms. Great Lakes optometric Congress, 2012.

35. Stein J. Blue or yellow filters can improve reading in dyslexic children, Report of the Enterprise and Learning Committee, Interim Report of the Dyslexia Rapporteur Group, EL(3) 09-07: Paper 4: Evidence to the Committee on Dyslexia Support in Wales – Prof John Stein, National Assembly for Wales Enterprise and Learning Committee Oral and Written Evidence EL(3) 14-07 – Wednesday, 12 December.

36. Wilkins A, Sihra N, Smith IN. How precise do precision tints have to be and how many are necessary? Ophthal Physiol Optics 2002;25:269-76.

Correspondence regarding this article should be emailed to Geoff Shayler, Bsc, FCOptom at kinoptom@lineone.net.

Shayler G. The use of models to help our understanding of vision. Optom Vis Perf 2015;3(3):138-50.

The online version of this article contains digital enhancements.