Article ▸ Visual Correlates of Static (form) Threshold and Motion Coherence Threshold

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ABSTRACT

Background: In order to characterize visual responses to cortical function, the "ball in the grass" test was used within an optometric practice environment to measure static (form) coherence thresholds and motion coherence thresholds in children presenting for a routine eyesight examination. This testing identified differences in function between children acknowledged as having educational difficulties compared to those without such a label.

Methods: We showed direct relationships of neurological processing, as measured with this test, compared to a number of optometric measures of near visual processing. Analysis was carried out to investigate the effects of using both stress relieving lenses (SRLs) and optometric vision therapy.

Results: These studies indicated significant improvement in cortical processing, associated with improved visual skills, with both SRLs and optometric vision therapy

Keywords: fp/np ratio, motion coherence threshold, standard assessment tasks (SATs), static (form) coherence threshold, stress relieving lenses (SRLs)

This is a follow-up paper to demonstrate the concepts developed in, *"The use of models to help our understanding of vision,"* published in *Optomery and Visual Performance* 2015:3(3) available at http://bit.ly/2exlQl0.

Introduction

Primate visual processing involves distinct mechanisms involved in object recognition and encoding object position and motion. The specific nerve fibre groups referred to as the magnocellular and parvocellular systems in general follow the dorsal and ventral streams, respectively (Figure 1). However, there is some overlap of function.[1] 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.[2] Areas differentially activated by form coherence include regions in the middle occipital gyrus, ventral occipital surface, intraparietal sulcus, and temporal lobe. Motion coherence activated areas are consistent with those previously identified as V5 and V3a, the ventral occipital surface, the intraparietal sulcus, and temporal structures (Figure 2). Neither form nor motion coherence activated area V1 differentially. Form and motion foci in the occipital, parietal, and temporal areas were nearby but showed almost no overlap.

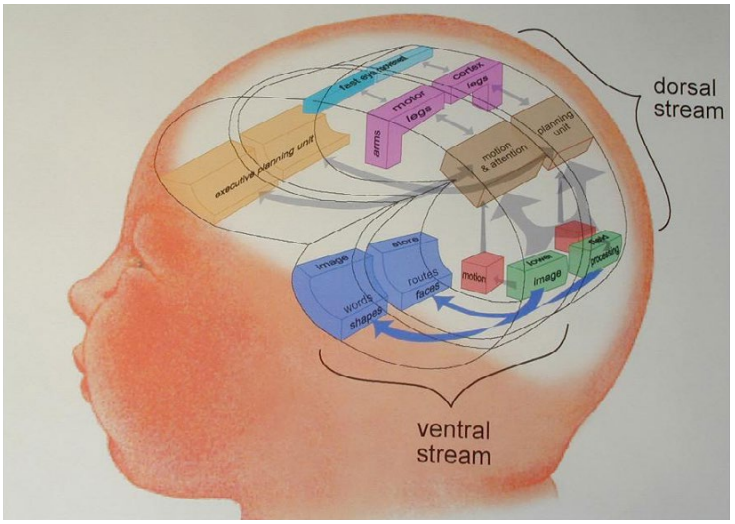


Figure 1. *Diagrammatic representation of the magno/parvo pathways, courtesy of Prof Dutton*

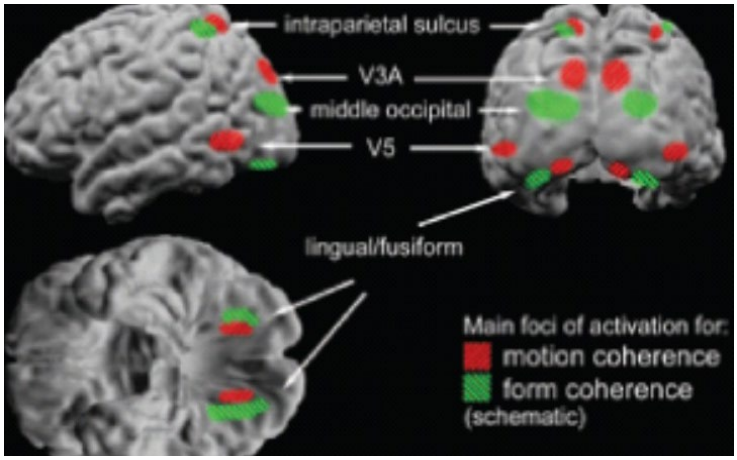


Figure 2. *Diagrammatic representation of the brain areas identified with response to static and motion coherence, reproduced with kind permission of Justin O'Brien, Brunel University.*

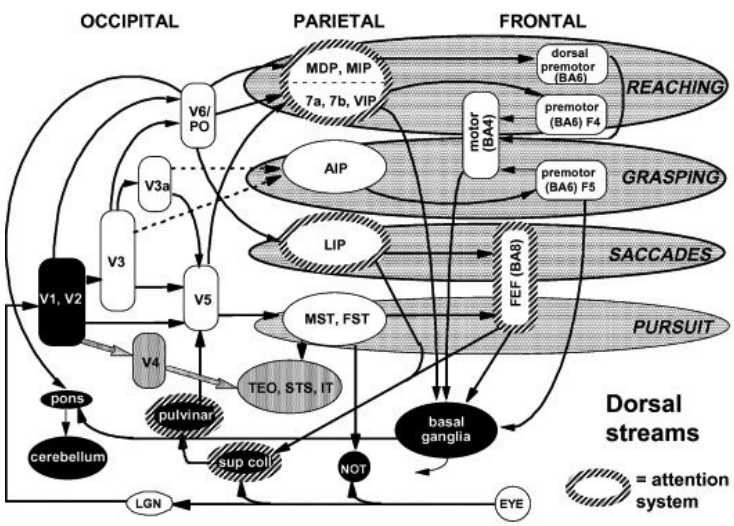


Figure 3. *Dorsal stream pathways*

Motion, ordered via the dorsal stream, linking occipital, parietal, and frontal processing, is associated with attention (Skeffington circles Antigravity and Centering), driving all the visual systems to lock onto the target (Figure 3), whilst static (form) processing within the parvocellular stream provides cognitive knowledge of the object of regard (Skeffington circles Identification and Speech / Auditory).[3]

In summary, static (form) and motion coherence activate independent, but not specifically dorsal/ventral segregated, networks in the human brain. 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.

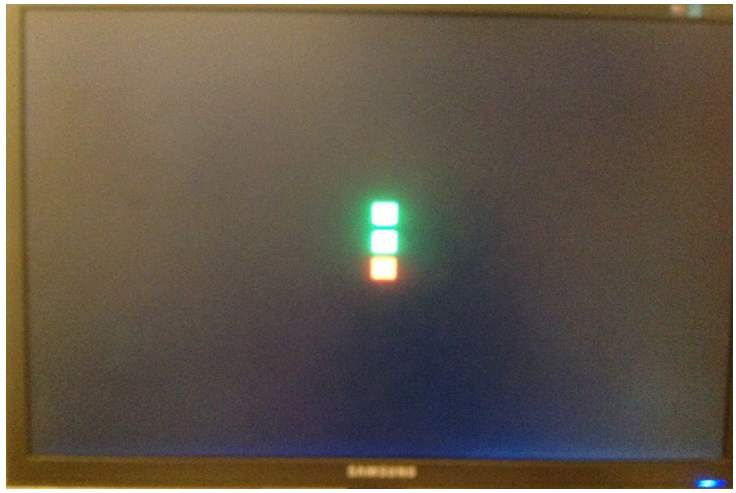


Figure 4. *Ball in the grass test (demo) screen*

Static (form) and motion coherence threshold test program

As part of a number of joint research studies into child development, John Wattam-Bell of University College, in association with Janette Atkinson and Oliver Braddick,[4] developed a computer program to assess these thresholds. I was fortunate to meet these researchers at the Child Vision Research Society (CRVS) conference[5] held in Cardiff, Wales in 2009. At this meeting, I saw the computer program they had developed within the psychology departments at University College, London and Oxford Universities to investigate static (form) coherence threshold and motion coherence threshold testing called the V1.2 "ball in the grass test." After discussing its use and possible uses in optometry with Professor Braddick and Dr. Wattam-Bell, they kindly provided me with a copy of their program for research purposes within my practice.

The V1.2 "ball in the grass" test program – Static (form) coherence threshold test

Using the program

Between each test screen, the screen goes black with a vertical series of 3 changing coloured squares (Figure 4). To clear this screen, the subject presses the down arrow on the keyboard; the screen is covered with an array of short white lines with random orientation (Figure 5). Either on the left or right of the

Figure 5. *Ball in the grass test using static threshold test*

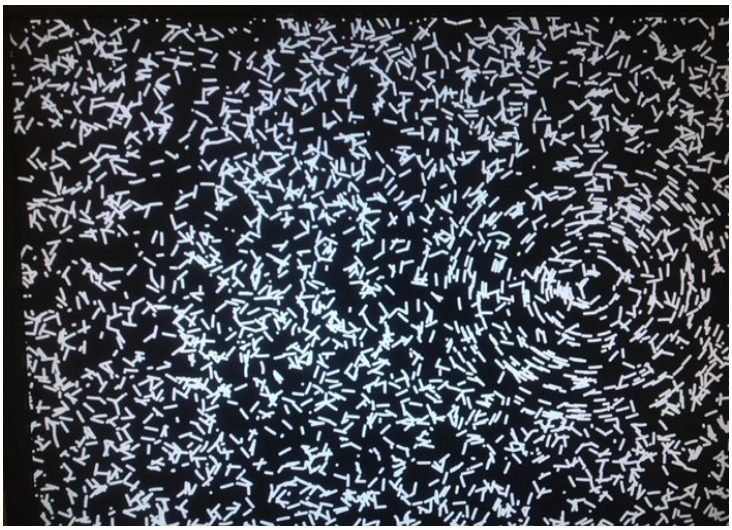


Figure 6. *Ball in the grass test using static threshold test screen*

screen, the lines are orientated in a circular "ball" pattern.

Following a demonstration where all (100%) of the lines within this ball are in a circular orientation, the subject indicates whether they see the ball to the left of the screen by pressing the left arrow key, or to the right by pressing the right arrow key. Once the subject has shown that they understand the concept of the test, the space bar is pressed, and the program continues by reducing the percentage of lines that conform to the circular pattern (Figure 6). The subject continues to identify, or guess (forced choice), as the program goes through a series of up and down steps to identify the 50% error over 30 attempts. Every seven screens, a 100% line orientation is shown to maintain their attention. At the end of the test, the program

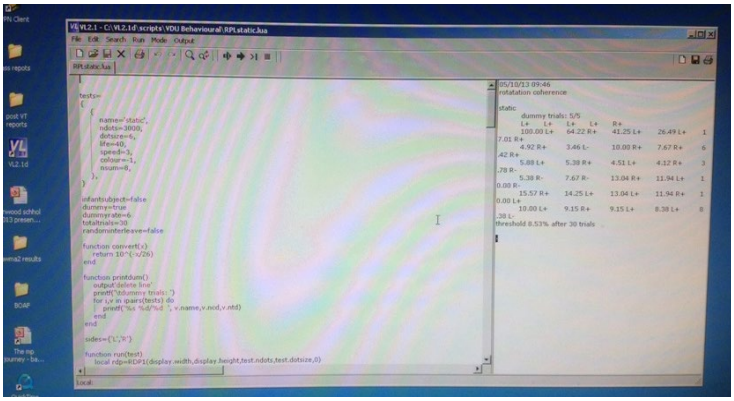
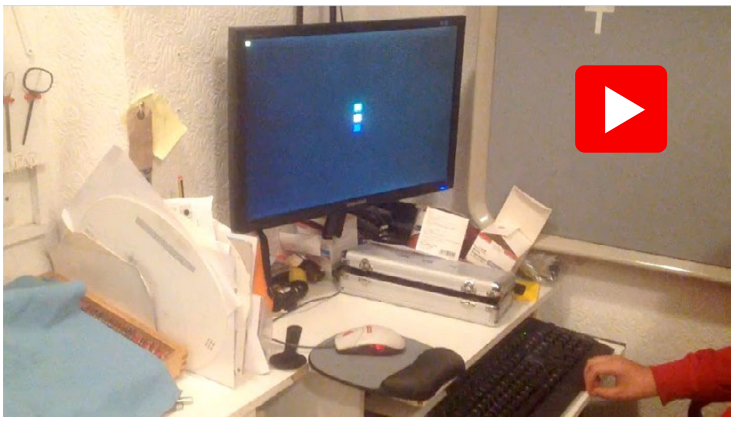


Figure 7. *Ball in the grass test result print out*

displays the result of all the tests (Figure 7) and the calculated 50% error rate, which is their measure of static (form) coherence threshold. The lower the percentage coherence threshold figure, the better and more efficient the neurological processing. This can be thought of in a similar manner that 20/20 is better than 20/60.



Ball in the grass test

The V1.2 ball in the grass test program – Motion coherence threshold test

The motion program is basically using the same concept as the static test, but in this case, instead of lines, the test uses randomly moving white dots.

In-Practice Studies

I have now been using this program on a regular basis within optometric practice for 5 years, and it has become an indispensable tool within my vision assessments. In particular, it has helped not only with my understanding of the visual process, but it also answers some questions about the provision of lenses and optometric vision therapy.

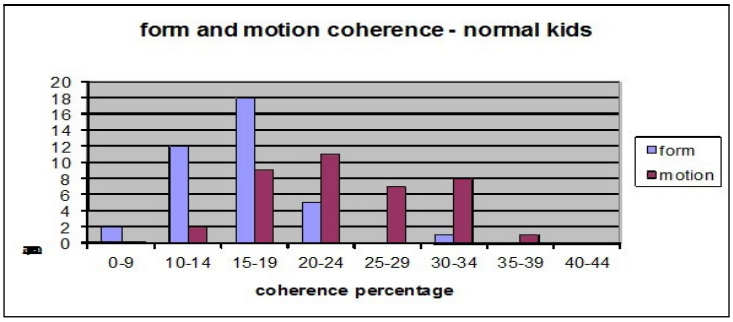


Figure 8. *Form and motion coherence—normal children*

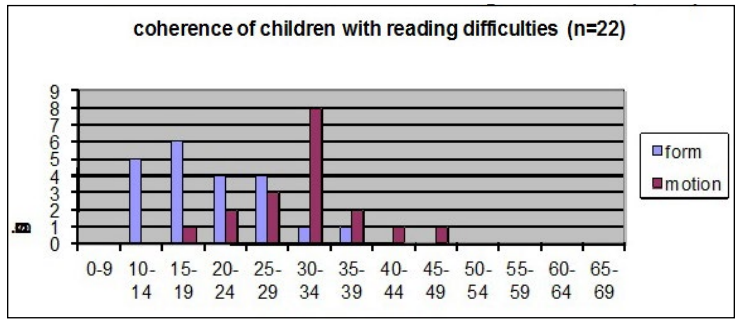


Figure 9. *Coherence of children with reading diffculties (n=22)*

I am unaware of any previous optometric investigations with this concept, so I was starting with no knowledge of what results to expect. As I gained a greater understanding of these tests and their correspondence with various visual measures, I was able to investigate increasingly complex relationships, including:

1. Normal v. children identified, by school or parent, as experiencing educational difficulties
2. The relationship of various measures of visual processing with static and motion coherence threshold testing
3. The evidence of neurological change when prescribing low plus/yoked prism (SRL) lenses
4. The evidence of neurological change both during and following optometric vision therapy

Study 1: Normal v children with educational difficulties

My initial study was to determine whether the program results would identify children from my practice who were thought by their parent or school to be experiencing academic difficulties. Consecutive children were split into two groups, those whose parents had not identified any educational difficulties, and those whose parents or school felt that their child was underachieving.

Establishing the norms (1)

This study involved 38 consecutive children attending the practice for routine eye examination without educational difficulties and exhibiting normal reading ranges (Figure 8).

Results

Average static (form): 16.73 +/-4.22, 95% confidence interval for mean 15.34 to 18.11

Average motion: 24.51 +/-6.73, 95% confidence interval for mean 22.30 to 26.72

Establishing the norms (2)

This study involved 22 consecutive children attending the practice for routine eye examination experiencing educational difficulties and exhibiting reduced reading ranges (accommodative flexibility, Figure 9).

Results

Average static (form): 21.40 +/-7.21

Average motion: 31.90 +/-7.62

Combining this information shows the visual processing differences of both static (form) coherence threshold and motion coherence threshold between normal children and those already identified as experiencing educational difficulties, with the average figures identified indicated by the arrows (blue equals av. static, brown equals av. motion, Figure 10). This study shows a significant difference in visual processing of both static and motion coherence threshold as measured in children who are struggling in a school environment compared to those without educational difficulties.

Study 2: The relationship of various measures of near visual processing with static (form) coherence threshold and motion coherence threshold testing

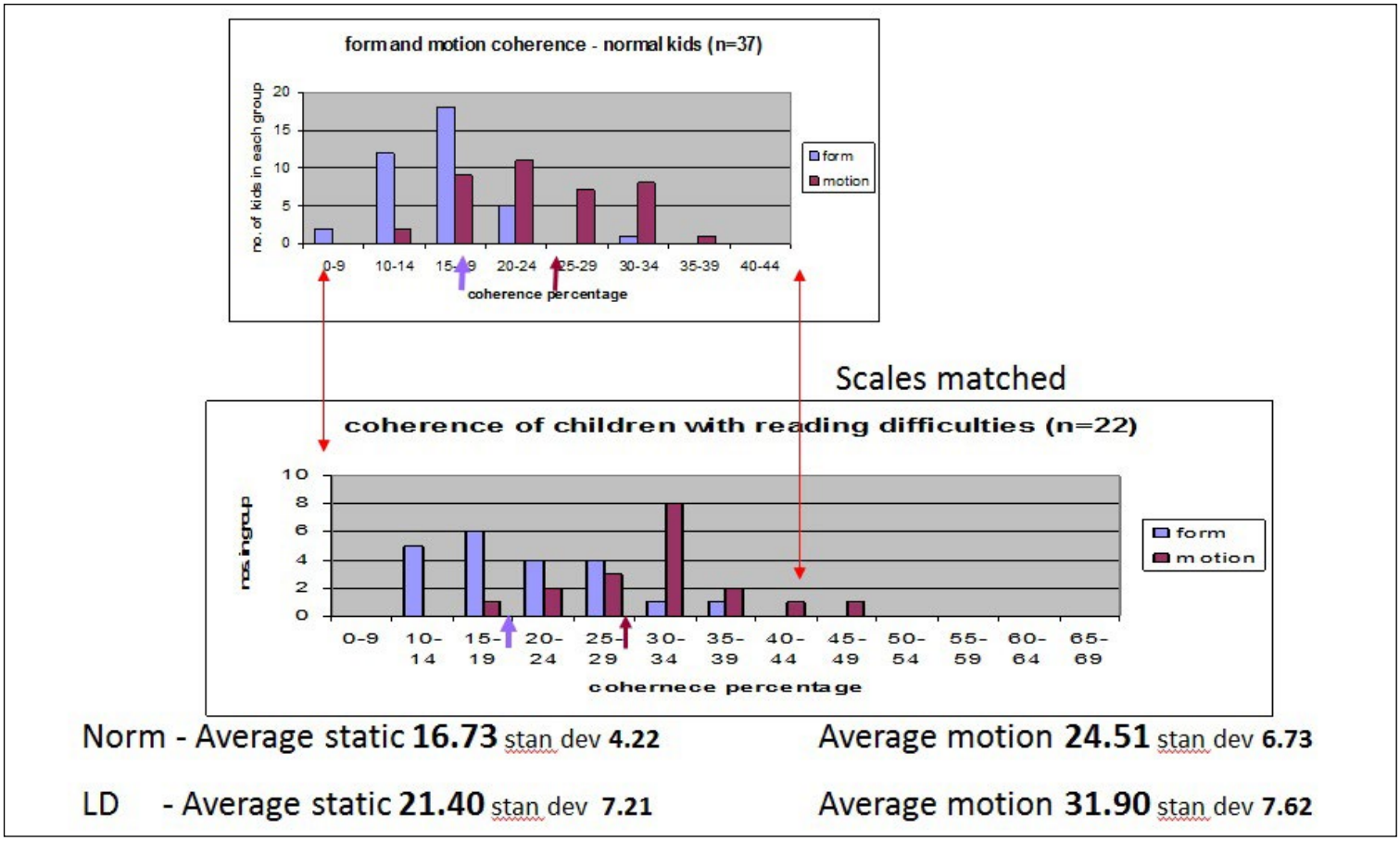


Figure 10. *Comparing average static and motion coherence thresholds for normal cf children with educational difficulties*

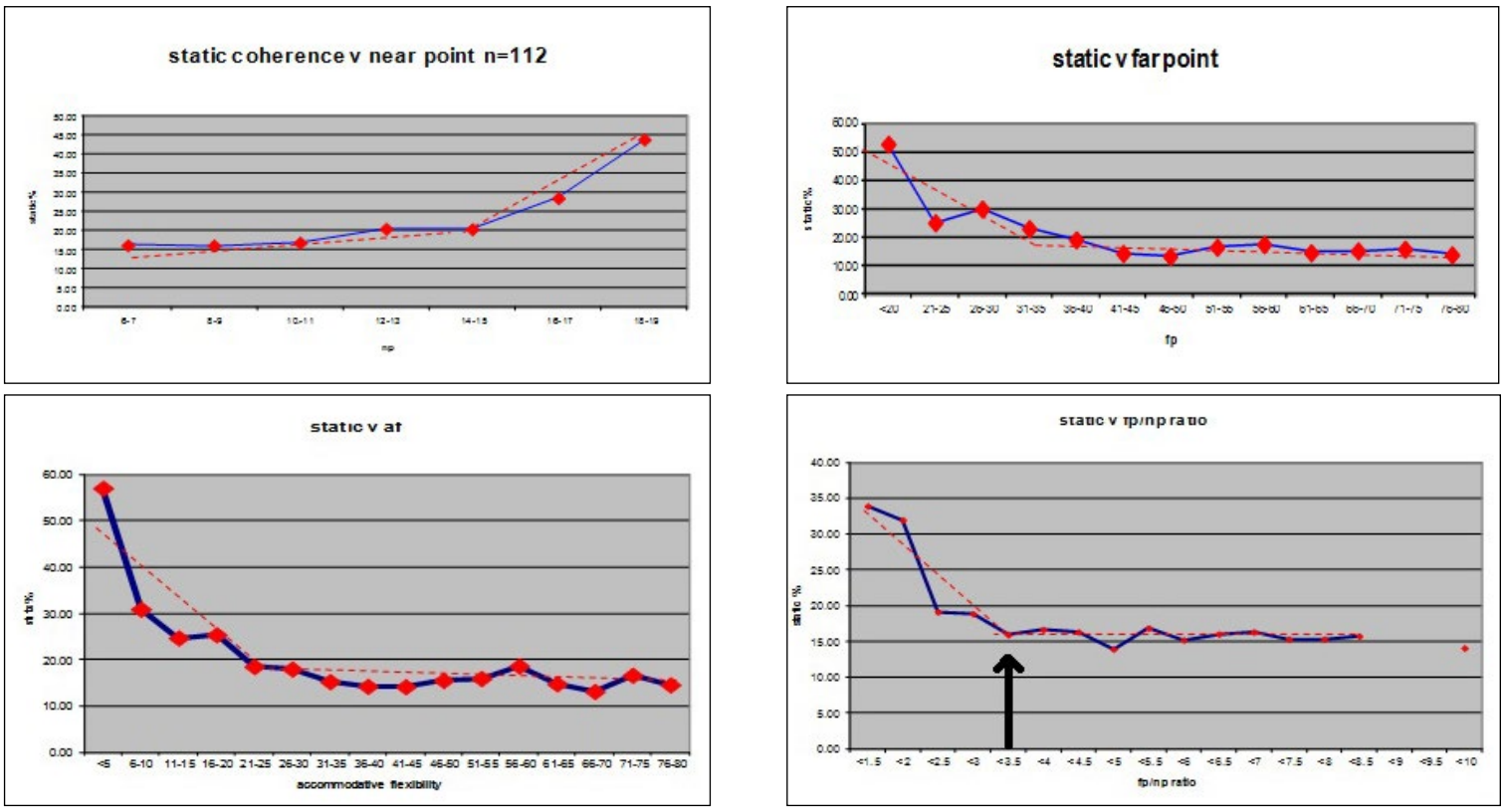
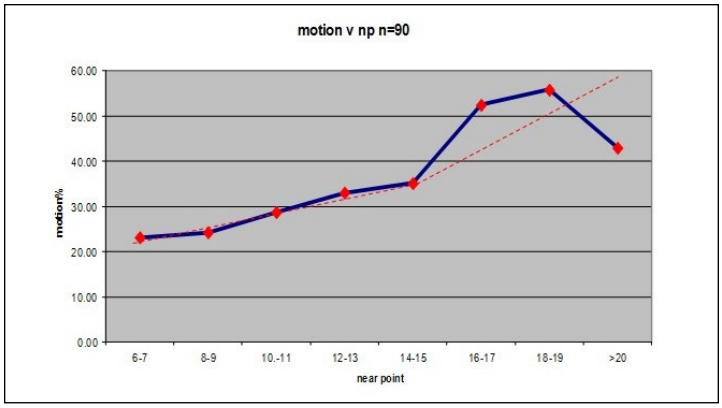
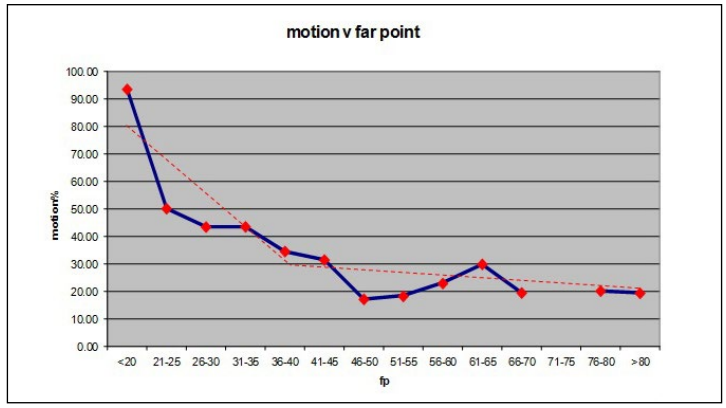
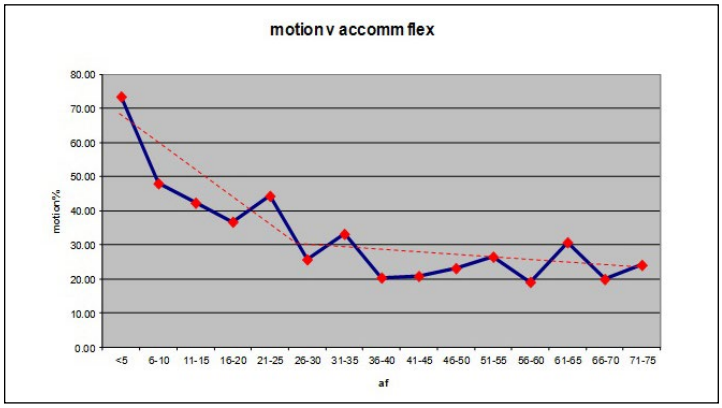


Figure 11. *Comparing static coherence thresholds with various measures of near visual processing, Shayler*







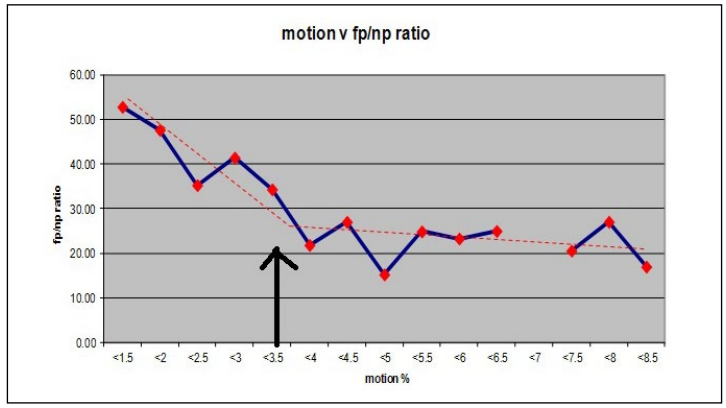


Figure 12. *Comparing motion coherence thresholds with various measures of near visual processing*

As identified in Part 1 of this series,[3] many children with learning difficulties have constricted ranges of clear near vision (accommodative flexibility).[6] This study looked at a group of children presenting for routine eye examination.

Measurements taken:

a) near point (np) of just blur (reading n7 print*)
b) far point (fp) of just blur (reading n7 print)
c) static (form) coherence threshold test
d) motion coherence threshold test

*this is the size of print supplied on the Howell near vision chart

From the above could be calculated:

e) accommodative flexibility (af=fp-np)
f) fp/np ratio

There is a significant relationship between static (form) coherence threshold testing and all four measures of near visual function (Figure 11). In particular, there is change that occurs when the fp/np ratio approaches 3.5, where there is a progressive reduction in cortical processing below this level.

In addition, there are significant relationships between motion coherence threshold testing and all four measures of near visual function (Figure 12). In particular, there is change that occurs when the fp/np ratio approaches 3.5, similar to that seen with static processing thresholds.

Returning to the school-based studies, I quoted in part 1 of this series[3] that there was an increased risk of a child experiencing educational difficulties when the fp/np ratio was less than 3.5. In Figures 11 & 12, we see a progressive reduction of visual processing at that level in both static (form) coherence threshold and motion coherence threshold testing. This test therefore gives us a direct link between cortical visual processing and educational performance of children in general, not those just arbitrarily diagnosed as dyslexic, dyspraxic, etc.

Study 3: The evidence of neurological change when prescribing low plus/yoked prism (SRL) lenses

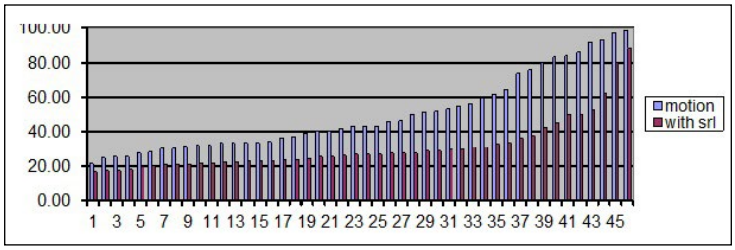


Figure 13. *Demonstrating the impact of low plus lenses on motion coherence thresholds*

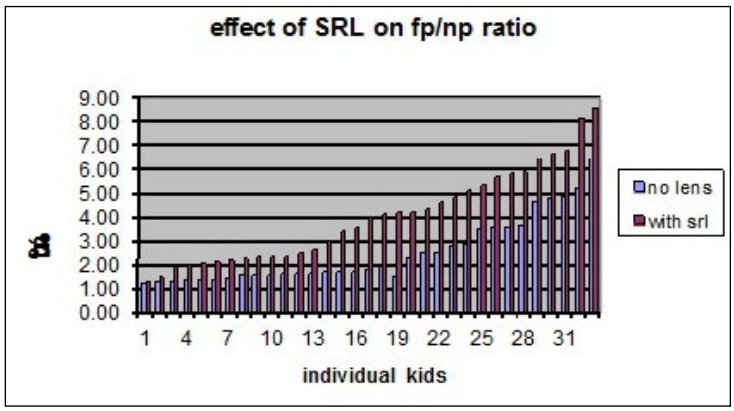


Figure 14. *Demonstrating the impact of low plus lenses on the fp/np ratio*

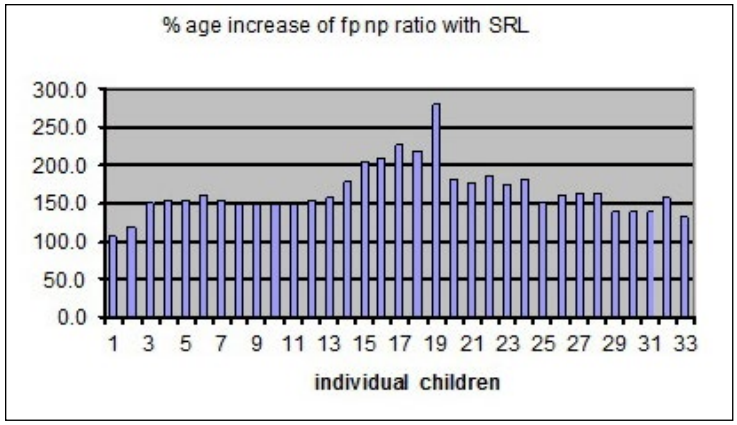


Figure 15. *Demonstrating the impact of low plus lenses on improvement of fp/np ratio*

As identified in part 1 of this series, many children with learning difficulties have constricted ranges of clear near vision,[3] which frequently improve with the use of low plus/yoked prism lenses.

Though the use of these lenses may be considered controversial, conventional thinking (i.e., "the eye is like a camera") considers that the magnification effects of these lenses are negligible and should therefore not affect eyesight! The (UK) College of Optometry actively discourages the prescribing of lenses less than +0.75. Under their Guidance A253, they specifically quote:

If you supply prescriptions of less than +0.75 R&L, to children for example, you must be sure of the clinical need for the spectacles, be able to explain the reason for prescribing them, and keep a record of the reason and any advice given.

The evidence base they provided for this statement included a number of references.[7-10]

In practice, research has shown that these lenses appear to reduce stress on the visual system, allowing it to work more efficiently by increasing the size of the functional visual field, improving eye movements, convergence, accommodation, etc. – areas of vision driven by the afferent magno (motion) system via the efferent parasympathetic nervous system.[11]

Though there are improvements in both static (form) and motion coherence threshold testing, in this study, due to time constraints and maintaining patient concentration, motion coherence threshold testing was used with and without stress relieving lenses (SRLs) as larger changes were experienced with motion than static testing.

The next three figures demonstrate the changes that take place when low plus/yoked prism lenses were prescribed.

a) The effect of "stress relieving lenses" demonstrates the improvement of motion coherence threshold in 45 children with reading difficulties (Figure 13). The lower (second) bar for each child shows improved processing.

b) The effect of "stress relieving lenses (srl)," demonstrating improved visual performance of the fp/np ratio of 31 children with reading difficulties (Figure 14). The higher (second) bar demonstrates the improvement in reading range for each child.

c) The percentage improvement that SRLs achieved of fp/np ratio of 33 children with educational problems (Figure 15).

Low plus/yoked prism lenses, referred to above as SRLs, in children with subnormal visual processing improve visual (motion) processing and show improved visual function,

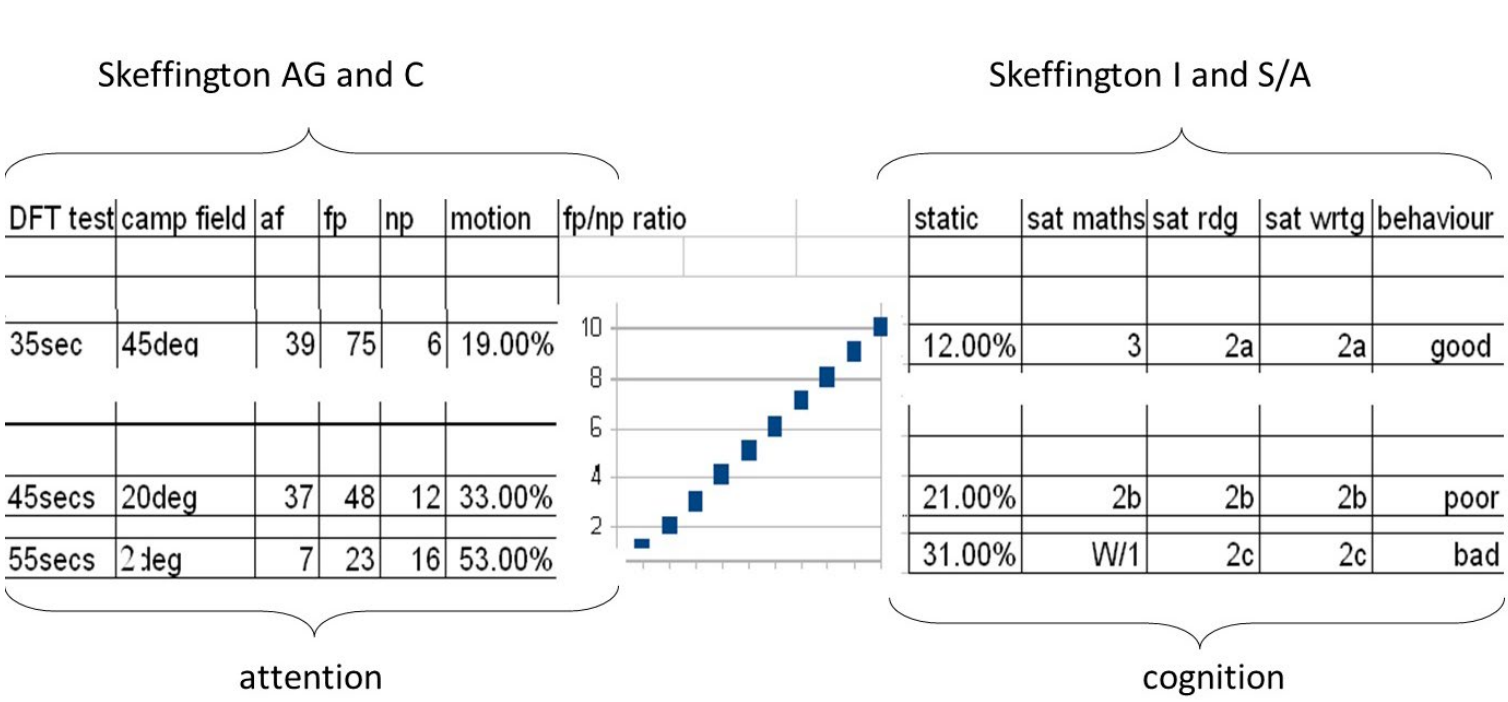


Figure 16. *A combined chart showing how various measures of a child's performance is linked to their fp/np ratio*

as determined by the fp/np ratio. These children achieved an average 150% improvement in fp/np ratio with their lenses, for example if np=10 and fp=30, then fp/np ratio without lenses is 3.0 – whilst wearing their lenses, this child will typically average a range of 10-45 cm, i.e., an fp/np ratio of 4.5 or 15 cm more range of clear near vision, which will impact not only on their reading speed and performance but also improve posture, as they no longer need to get as close to the book to read it.

The impact special lenses can have on reading performance.

How and Why

In part 1 of this series, I proposed a link between the functional visual fields and the fp/np ratio. In addition, a reduced field will have an increased impact on the magnocellular visual process, which is responsible for directing eye movements, convergence, accommodation, miosis, etc.[3] We can now include an objective measure of motion (coherence threshold) visual processing using the "ball in the grass" test.

An SRL, in order to achieve an improved fp/np ratio and improved motion processing, must in some way allow expansion of the functional visual field in order to provide increased magnocellular stimulation to drive parasympathetic controlled visual functions (eye movements, accommodation, convergence, fusional reserves). This expanded field can logically only be achieved by suppression or inhibition of the sympathetic nervous system, allowing the parasympathetic to function at a more efficient level.

Comparisons of fp/np Ratio Against Other Measures

With the various results obtained, a graph demonstrating the complex links of these measures was created for three values of the fp/np ratio (Figure 16). The fp/np ratios of 1.5 (children with learning difficulties), 3.5 (the level below which 80% of children appear to have learning problems), and 10 (children who are high achievers in school) were compared to:

- motion coherence threshold processing

- near point of just clear focus
- far point of just clear focus
- accommodative flexibility
- functional field of vision as measured by campimetry using a 5mm white target
- dynamic fixation test to identify speed of eye movement[12]

(tests that we can consider are associated with "Attention" and Skeffington circles Antigravity and Centering)

- static (form) coherence threshold processing
- school SATs in Maths, Reading, and Writing[13-15]
- behaviour in the classroom[16]

(tests we can consider that are associated with "Comprehension" and Skeffington circles Identification and Speech/Auditory)

This graph clearly shows how all these areas of research are directly linked to one another. As a result, whatever we as optometrists can do to improve the fp/np ratio will directly impact educational ability, attention, comprehension, and behaviour.

Optometric Vision Therapy (OVT)

For most of my patients who undergo OVT, I use a very intensive program incorporating optometric phototherapy (syntonics)[17] with OVT activities to develop the five "F"s: fields, fixations, focus, fusion, and flexibility. We carry out 20 one-hour sessions, 2 times per day, 4 days per week, for a total of 2½ weeks. Optometric reviews are carried out after OVT sessions 9 and 19, and then are reviewed after 1 month, 3 months, and 6 months. Included in these reviews are static (form) and motion coherence threshold testing.

Study 1

The results of various measures of visual performance of 8 children undergoing therapy were averaged.

a) The static coherence threshold measures on average combined results of 8 children going through this program (expected normal 16.73, LD>24.51 from study 1).

	Age	Pre-VT	1 wk VT	Post-VT	1 month Post VT	3 months Post VT
average	10.00	21.23	20.78	18.36	17.16	17.14

b) Effect of OVT on motion coherence threshold (typical normal 21.40, LD>31.90 from study 1) shows an even more significant change in cortical visual processing both during and after the cessation of optometric vision therapy, and more importantly can be seen to "normalise," actually achieving better than "average normal!"

	Age	Pre-VT	1 wk VT	Post-VT	1 month Post VT	3 months Post VT
average	10.00	50.21	29.48	26.00	22.84	19.75

Study 2

This study looked at groups of children measured at initial assessment (pre-OVT) and at completion of therapy (post-OVT). Differences were recorded for (average): np, fp, af, fp/np ratio, static and motion coherence threshold testing pre/post OVT.

	Age	np	fp	af	fp/np ratio	static	motion
Pre VT (N=15)	10.05	14.79	22.43	7.89	1.51	25.61	50.73
Post VT (N=20)		8.58	80.26	51.89	7.91	16.33	24.05
Improvement		174%	358%	658%	524%	157%	210%

Results of OVT Study

The above table demonstrates the substantial and measurable changes in several areas of near visual function, as well as static (form) and motion coherence threshold testing occurring as a direct result of a program of OVT. In addition, when comparing the results of static coherence threshold of the average child without educational difficulties of 16.73, it is very similar to the average post-therapy child of 16.33. When examining the motion coherence threshold in a similar fashion, the average child without educational difficulties of 24.51 is very similar to the average post-therapy child of

24.05, thereby suggesting normalisation of this aspect of visual function.

Conclusions

My hope is that these studies have given us a better understanding of the visual process, the effects of defective visual processing on educational ability, a greater knowledge of how and why low plus and yoked prisms work, and confirmation of the efficacy of OVT. It has helped me develop and expand on Skeffington's four-circle concept, with a sound foundation using both personal observation, (i.e., changes in pursuits, saccades, convergence, head tilt, body posture, etc.), subjective (near visual measurements and SATs), and objective (static form and motion coherence threshold testing).

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