Learning Recovery

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Project to test the efficacy of coloured lenses for children with reading problems

ABSTRACT

Children who read poorly, particularly under fluorescent lighting conditions, were tested for visual perceptual problems using original parameters provided by an optician . Coloured lenses (non-optometric) were provided by Hoya Ltd., to ameliorate these deficits. With and without lenses testing of psychometric, physiological and neurological data offer some understanding of the basis of this condition, known variously as visual Dsylexia, scotopic sensitivity or Irlen syndrome.

INTRODUCTION

Dyslexia is now considered to be a problem in the sensory processing of either visual or auditory information (often both) and also often, due to cerebellular inefficiencies, various motor and co-ordination inefficiencies. Dyslexia is unrelated to general intellectual ability and is defined by the discrepancy between learning potential as measured by I.Q. and one or more aspects of literacy.

Reading requires both phonological ability (the ability to perceive phonemes or speech units in whole words and break them down to blend the phonemes into accurate pronunciation of the word) and orthographic ability (the ability to match the phoneme to the grapheme in the correct order to see and spell the word correctly) Auditory and visual sensitivity affect different aspects of reading and both are necessary for phonological awareness and orthographic competence.

Phonological skill depends on auditory sensitivity in perceiving temporal auditory changes and lack of it affects reading of irregular words, non-words, homophone distinction and gives a delay in sensitivity to the rhythm of speech.

Orthographic skill correlates with the ability to identify familiar letter sequences with minimal phonological information and needs adequate convergence, accommodation, stability, tracking and orientation.

These skills are independent of each other, and both have about 40 to 50% hereditability and exists pre- school (Lovegrove) . This gives some credibility to earlier attempts to classify Dyslexia into typologies such as Dyseidetic (visual deficits) and dysphonetic (auditory deficits) (Boden E, 1990)

Thus the auditory and visual segmentation necessary for reading draws on the ability of the nervous system to track precisely changes in sensory input such as moving targets or changes in sound frequency or amplitude with time. Normal readers are able to track changes in the pitch of a sound and the ability to segment words into their constituent phonemes to match them to their written expression.

Visual Processing

Several studies over the last decade (Livingstone, Rosen and Galaburda) have shown that developmental dyslexics do poorly in tests requiring rapid visual processing due to; it is hypothesised, the large cells, the magnocellular cells which are concerned with all aspects of timing in the nervous system, being smaller and less organised. Fast low-contrast visual information is carried by the magnocellular subdivision of the visual pathway, and slow, high-contrast information is carried by the parvocellular division. This is an efficient visual system since it is able to detect movement in the visual field in relation to self and also filter out movement to look at stationary aspects of the object, and fill in detail. Thus they are often referred to as the “what” and “where” pathways.

The parvocellular system is relatively new evolutionary speaking, since only primates have developed the high frequency, high-contrast visual pathway that gives such detail while the magnocellular has been well preserved over evolution. Therefore there will be the normal biological variation in sensory processing with some (roughly one third) individuals able to discriminate rapid change easily while a second third find it extremely difficult. The third left over will be able to do so under good conditions and less able to under less optimal conditions. As far as visual processing goes, one of these conditions is fluorescent lighting.

Dyslexics show diminished visually evoked potentials to rapid, low-contrast stimuli but normal responses to slow or high-contrast stimuli. The abnormalities in the dyslexic subjects' evoked potentials is consistent with a defect in the magnocellular pathway at the level of visual area 1 or earlier. The magnocellular layer of the lateral geniculate nuclei from dyslexic post-mortem brains (small sample size) in comparison to control brains shows abnormalities, but not the parvocellular, layers. The lateral geniculate organises retinal information, and provides information to the cortex about where objects are, the rate and direction of movement of images across the retina, their form and so on and receives feedback from higher areas of the visual cortex . The majority of inputs into the LGN come from the cortex, reticular formation and brain stem and may control the flow of information from the retina to the visual cortex.

The two pathways M and P, interact cooperatively from the retinal ganglion "on-off" cells through the visual cortices where each pathway ends in different layers of the primary visual cortex. The magnocellular outputs to the cerebellum, superior collicullus and controls frontal eye fields for eye movement and specialises in detection of location, depth, stereopsis, motion and selective attention.

Concurrently with this research Eden, G, 1996, found, using functional magnetic resonance imaging, that there was lower activation in visual area 5 between Dyslexics and normal readers when watching moving dots. V5 mediates movement perception and this study showed that Dyslexics have problems in processing specific types of visual information which affects ocular-motor control and smooth visual pursuit. The magnocellular pathway projects through the V5 area.

Auditory processing

Nagarajan (96) showed an analogous defect to the Livingstone research, in the auditory discriminative ability of Dyslexics to perceive tones presented rapidly (less than 10 millisecs apart) and (Poldrack 2001, Tallal, 91) in the ability to perceive fast speech sounds such as stop consonants that last lass than 40 millisecs before changing to the vowel. The neurological deficit here was shown by Galaburda to be in the magnocellular layer of the medial geniculate nucleus (as opposed to the lateral area of the medial geniculate, implicated in visual deficits). Phonemic distinctions are largely determined by how they are attenuated, for example the position of the tongue in the mouth, so language sounds that vary in abruptness of beginning and ending need especially the speed that the fast processing system can offer; i.e. the "b" in ba and the "d" in da. These are just two of the stop consonants (others are ga,pa,ta,ka) so Dyslexic children have trouble discriminating between words like boy/toy and pet/bet, since the first consonant lasts less than 40 milliseconds before switching from the consonant to the vowel.

If auditory or visual discrimination is not fast enough to track rapid changes in either speech sounds or a complex moving visual field (such as necessary when moving eyes in co-ordination across a page) then reading is difficult acquire or maintain. If both auditory and visual discrimination is tested the results can predict with 93% accuracy the likelihood of Dyslexia. (Witton C., et al., 1998) Phonological dyslexia based on auditory processing and orthographic based on visual processing can be discriminated by the type of phonological task (homophones and non-word reading) each group can or cannot do.

Talcott et al (99) went on to show that 40% of the variablility in reading and phonological skills could be predicted from the ability to perceive tones at 2 hertz modulation. The decreased range of AM and FM sensitivities is in the range critical for detecting phonemes (2 – 50 hz).

Thus visual processing, contrary to current academic consensus, could explain as much or more of the variance in reading ability than phonological deficits. Indeed Livingstone had earlier found up to 75% of Dyslexics had one or other type of visual abnormality.

Vidyasagar T and Palmer, (99) suggest that at bottom the Dyslexic is unable to use the magnocellular system as the “attentional spotlight” as can normally reading children. The magnocellular “where” pathway samples the visual field first to provide outline information and directs the “attentional spotlight” on specific areas of the visual cortex to enhance firing and direct ocular muscles to place the target on the fovea for more detailed analysis. The parvocellular then carries analysis of form, detail, texture and colour. The magnocellular continues to higher levels to provide information about figure and ground by inhibition of “distractions”. This “attentional spotlight” is essential for a serial search task and is inhibited when there are a number of cluttered objects in the visual scene that compete for limited attentional resources. This is important in reading and this research showed that in conditions of high distractibility (i.e. many items to look for – grey triangles in a background of grey circles) the non-readers of equal age, I.Q. and education to readers, were slower and less accurate to complete the task. However when fewer items had to be found they were able to do so as well as the readers. So an important physiological component in learning to read may be training the “attentional spotlight” to move sequentially over the words in line. This would fit with the observed reading pattern of

Dyslexics who are able to read better when there is large print, which was usually one of the factors that propelled them into the opticians only to be told that there was no problem with acuity.

Other senses

Studies using somatosensory (vibrational/tactile) tests have shown that dyslexics also do poorly in these modalities only when the tests require rapid discriminations. Therefore many cortical systems are thought to be similarly divided into a fast and a slow subdivision and that **dyslexia** is specifically affected by the fast subdivisions of the sensory system. The magnocellular cells throughout the brain have common reactions to biochemical assays. This would mean that other senses, besides the visual may be improved with the same techniques that help the visual (i.e. coloured lenses) and indeed many anecdotal accounts such as children who claim to be able to listen more accurately with their lenses on, exist.

Underlying the failure in rapid sensory processing is suggested to be a lack of myelination of auditory and visual pathways that interact with the cerebellum. This compromises automaticity of linguistic, motor and cognitive skills. Fawcett & Nicholson (99, 01, 2002)

Causation

This failure to develop the necessary central nervous components for automaticity is according to most theorists likely to be already started in fetal life during the formation of the neural tube. This can be due to genetic reasons but is also correlated with various types of birth trauma. The most recent speculation centres on prenatal and nutritional elements necessary for neuronal membrane efficiency.

Neuronal migration and synaptogenesis are prominent during the second trimester of pregnancy where a lack of essential fatty acids in the maternal diet could reduce fetal ability to develop efficient visual pathways, particularly the magnocellular which matures earlier than it's parvocellular counterpart. If cells in neural development do not connect then they die, and the ectopias found in Dyslexic post-mortem brains seem to Galaburda to follow the left-sided language pathways where the magnocellular also projects. The retina has a high degree of lipid concentration and is therefore especially vulnerable to depletion. One fatty acid, DHA optimises the signalling sensitivity of the visual pathway at the retinal level, and any deficiency, either genetic or environmentally caused can be expected to decrease visual efficiency. (Stein, 2000)

When there is an insufficient/inadequate membrane lipid layer connections between nerve cells all sensory processing is slowed and inefficient (Richardson, A and Stein, J) Phospholipids are the quickest protein of the body to change configuration and are therefore concentrated in the areas of fast action – namely the visual system to the brain, which makes evolutionary sense.

This has led to a **Phospholipid Spectrum Disorder** hypothesis (Baker S.M.) which is held to underlie specific learning disorders from Dyslexia, Dyspraxia, Autism and Attention Deficit/Hyperactivity Disorder. The consequence of this knowledge is that nutritional supplementation of the lacking essential fatty acids, EPA (ecoisanioc acid) and DHA (docohexenhenic acid) in particular has been shown to help visual tracking, hand eye co-ordination, attention and learning . (Richardson A. 99)

Part of the pre-natal causation theory is the functioning of the various primitive and postural reflexes that ensure survival in the fetus. These reflexes should be inhibited on or after birth to allow normal maturation processes to occur. When this doesn’t happen the stability and ability of the Central Nervous System to acquire skills to automatic level is compromised. In other words the cerebellum and auricular and ocular pathways leading from and to the cerebellum are slower to respond the stimuli than in children without specific learning difficulties. (Blythe)

Uninhibited individual reflexes impair specific areas of functioning. For example, one reflex will prevent automatic hand control every time the head is moved, so that writing can never become fluent. Another reflex will affect the balance mechanism, and the co-ordination of balance and smooth eye movements, so that in certain situations the eyes will "play tricks", and the letters on the page will appear to "dance", or may appear in a different order from one day to the next. The child may be "stimulus bound", so that his/her eyes are automatically drawn to anything moving within the visual field, and in a classroom he/she will be easily distracted. If later reflexes are prevented from emerging the child cannot cope with demands of a gravity-based environment, and maintain control of automatic balance, posture and voluntary movement, all preventing the acquisition of basic skills to the level of automaticity necessary for normal learning.

Remediation

Since the amount of brain energy (measured by lactate turnover) is five times greater than the normally reading child the motivation of the Dyslexic child is affected and they are less likely to practise their literacy skills sufficiently to develop automaticity, remaining a weak reader over many years or even for life. Anything that can help their discomfort and reluctance to read is clearly an individual and social good.

Remedies vary from phonics-based remedial literacy programmes to enhance phonological awareness, to visual exercises, coloured overlays or monocular occlusion to stabilise eye movements as well as balance and physical coordination exercises to increase cerebellular efficiency.

Research rationale

The present research is to test the efficiency of the Hoya lenses prescribed by the optometric equipment designed by Ian Jordan. It is hypothesised that Hoya lenses will help with the visual aspect of reading due to the resynchronisation of the visual pathways that the Hoya coloured lenses are hypothesized to allow. This is assumed to be due to the magnocellular deficit causing **scotopic sensitivity** but other ocular conditions may also cause the observed perceptual deficits. (Burr, 94). Indeed the term scotopic sensitivity may actually cover several different types of visual abnormalities, with only some symptoms being due to magnocellular deficits, or even that the observed deficits in the M layer are due to prior deficits at the retinal or sub-cortical level. Other theoretical possibilities are the subject of Ian Jordan's report.

The visual sensory system and scotopic sensitivity

Sensory Overload

In humans 70% of information coming into the brain is visual, making vision the dominant sense. Blind individuals for example, are known to rely more on auditory and tactile processing. However **scotopically sensitive** individuals are usually unaware of their visual difficulties until corrected. The stress of this visual perceptual difficulty creates hypersensitivity and lack of integration of other senses as they attempt to compensate for poor visual perception. This may result in the inability to use more than one sense at a time and a vulnerability to sensory "overload". The touch, taste, smell and hearing of individuals with over aroused nervous systems can be enhanced or disturbed in some way.

Most dyslexics for example have an excellent sense of smell (Sacks 1995, Grandin 1996). Bettleheim (1969) and Tinbergen (1983) identified stress and anxiety as a major component in autistic and dyslexic spectrum disorders. Baron-Cohen (1995) identified individuals who make poor eye contact, one of the criteria for Autism, Asperger's and to a lesser extent Attention Deficit Disorder. He states that part of decoding the language of the eyes is in detecting the contrast between the white of the sclera and the dark of the iris and pupil. Since the first hallmark of Scotopic sensitivity is a difficulty with contrast this would make eye contact frightening and may explain the avoidance and limitation of eye contact noted in these children.

Multi-tasking deficit

The second hallmark of scotopic sensitivity is inability to see the whole picture which may affect mental representation since prior visual representation is a starting point. This is less likely to be a problem for the auditory phonological Dyslexic who has usually enhanced their visual processing and memory in compensation for their poorer auditory/verbal memory. But "visual" Dyslexics (those Dyslexic due to visual perceptual problems such as scotopic sensitivity) are likely to share this deficit with Autistic and Attention Deficit individuals.

Non-optical problems (i.e. not problems of acuity) in reading have been identified for some decades and are generally held to affect up to 20/25% of humans, giving a wide range of symptoms. Physical effects of scotopic sensitivity include photophobia (especially under bright light and fluorescent lighting), eyestrain, headaches, photosensitive epilepsy, stress and fatigue. Reading difficulties result from visual distortions of the printed page caused by high contrast (black print on white paper). Examples of typical patterns from the Irlen manual on scotopic sensitivity are in appendix 1

These range from blurring, parts of text appearing to disappear, a "halo" effect round the letters, glare off the white paper sufficient to make the text appear to move and run, and effort in getting the print to stabilise sufficiently to make sense of it.

The high functioning child often reads well, thereby masking the scotopic sensitivity but may be hyperlexic. The present study concentrates on Dyslexic children but it is noted that the whole field of specific learning difficulties has underlying sensory processing problems. In particular individuals with autism report visual distortions of their whole environment and in many their visual field of focus is as small as 10cm meaning their eyes have to flit all over to take in a whole scene. This results in blurred, fragmented and multiple vision and extreme stress.

In Dsylexia, scotopic sensitivity prevents adequate matching of phoneme to grapheme when a child is learning to read. This mismatch in the timing mechanism for matching the speech sound to the syllable on the page can prevent the acquisition of reading altogether but even in those who have learnt to read it is rarely automatic and therefore prone to error, effortful and avoided.

Scotopic Sensitivity is, ultimately a visual processing deficit caused by a sensitivity to light. The human eye is a light sensing system with an aperture (pupil) and a photoreceptive retina containing two types of photoreceptors – cones and rods. The rod receptors are active under low levels of illumination and the cone receptors are active when fine detail and colour is processed. These have different photopigments and spectral responses suggesting that the lighting design for schools and workplace does not adequately provide for the full spectral conditions necessary for reading, spelling and writing. The steady state of the pupil is controlled by the scotopic energy content of the ambient lighting. Pupil size is important because it affects visual acuity and depth of field, which are important components of visual performance. Several studies, (Berman, 1990) conclude that type of light energy can differentially affect acuity, due to their effect on both rods and cones which are linked to the magnocellular and the parvocellular, respectively.

The lack of steadiness in Dyslexic eye movements (due to the magnocellular failing to send adequate stabilising information to the brain, which then results in moving images of small complex symbols such as letters, numbers and musical notation) can be replicated in non-Dyslexics with scotopically inadequate lighting. The print can appear to move and blurr on the page or letters may be reversed for even a normal reader.

Thus, scotopic sensitivity results in under achievement in school and at work (Riley 1999) and underlies the sensory overload experienced in autism (Irlen 1997) and specific learning difficulties.. This sensitivity slows down the timing by which the brain receives and processes visual information, resulting in varying degrees of dyslexia, attention deficit and autism depending on the individual.

Dysexecutive function

Ozonoff et al (1991) and Le Bar also identified a lack of executive functioning, in scotopic sensitivity. Executive functioning enables working memory to sequence, organise and keep subgoals and plans in mind and is mediated by the prefrontal cortex. Lack of this function results in poor planning, organisation and attention. Visual disturbances are known to accompany migraine, epilepsy and systemic shock, and result in disorientation and loss of executive functioning. Dyslexic children do exhibit a distractibility and disorganisation suggestive of lack of executive functioning although this is also the major defining feature noted in Attention Deficit children. Nevertheless better executive functioning provided by lenses seems reflected in the responses of parents of the Dyslexic children, indicating increased clarity of thinking and calmness (appendix 2)

Visual Dyslexia

Children who have predominantly visual rather than phonological problems in reading are the most likely to benefit from the spectrum-specific inhibiting lenses provided by Hoya. These children will have noticed a blurring or moving of print, or at least some eye strain in trying to accommodate to text, or a "glare" off the paper that gives them headaches/ sore eyes and often print appears to blurr, fade or move. There will be an inability or reluctance to read and likely also, some distractibility, disorganisation and short-term memory problems. This research attempted to recruit those children with non-optometric visual perceptual.

Methodology

An advertisement (see appendix) was placed in a Cambridge newspaper. Parents responded to a range of questions from reluctance to read, underachievement at school, lack of concentration and short-term memory problems.

A background questionnaire (see appendix 3) was completed by all parents and an abbreviated form of The Wechsler Intelligence test. 4 children were excluded from the analysis on the basis of low I.Q. although this does not mean to say that they would not benefit from the lenses and these were given to them. But before and after psychometric and measures were not considered to be of the same order as normal I.Q. children. Their physiological measures are, however included in the analysis.

Given that there are consistent psychometric predictors of Dyslexia such as weak working memory and slow processing speed (Kauffman, 1994) which are components of most intelligence tests it was decided to include these measures from the Wechsler Children's Intelligence scale in addition to the literacy tests.

<u>Psychometric and literary tests</u>

The tests used were reading and spelling, balance, working memory and speed of processing. These are all known deficits in Dyslexia and therefore may improve with the provision of tailored coloured lenses. Testing was done with and without lenses, and the order was randomised, i.e. sometimes children did the tests without the Hoya lenses first and at other times with the Hoya lenses first, thus cancelling out any practise or fatigue effects. Different versions of the same tests, graded for complexity were used. Examples are in appendix 4.

Base line I.Q. was established for entry into the project but not used in the analysis.

<u>Tests used were</u>;

Psychometric measures

Neale Reading Test

Word accuracy	(gives a standard score and age norm based on 1997 U.K. norms)		
Comprehension		"	"
Reading speed		"	"

Wide Range Achievement Tests, level 3

Single word recognition	(standard score based on American norms		
Spelling		"	"

Wecshler Reading Tests

Single word recognition
Spelling

Wechsler Intelligence Test

Verbal and Non-verbal I.Q. (not used in analysis)

Dyslexia sensitive tests on the I.Q. known to correlate with poor reading

Speed of Processing
Freedom from Distractibility (Working memory)

Physiological measures

Balance (Tetrax technology)

This machine diagnoses postural control which is a measure of Central Nervous System stability and cerebellular efficiency. As noted above these are held to be the core deficits in Dyslexia. The Tetrax machine consists of 2 computer linked foot- plates (4 strain gauges) which allows measurement of weight exerted by the toes and heels of both feet when a subject is standing on them.

Measures from the Tetrax

8 measures of sway frequency and a range of postural parameters (for example centre of gravity, compensatory synchronisation, postural and stability quotients) are calculated under six conditions. These are, standing upright and stationary with eyes open staring a fixed point, then same with eyes closed, then eyes open standing on foam pads which reduce sensory feedback from the feet and ankles, then same, eyes closed, then eyes-open states repeated with the lenses. Predictions are

that lenses will stabilise the child resulting in a higher frequency, lower amplitude sway measure

QEEG (Brainwaves)

Quantitative eeg (brain map) comparing brain wave frequency with and without the prescribed lenses under day light and mixed day with fluorescent light, simulating school conditions.

Qeeg's record brainwaves from 19 electrodes placed on the head. Brainwaves are measured in terms of cycles per second and range from 1 hertz (1 cycle per second) to 40 plus. The increase in frequency correlates with degree of alertness and attention. There is an optimal point for each person where a state of alert relaxation is midway between drowsiness on the one hand and hypervigilance on the other. Psychological correlates are boredom and scattered attention/lack of focus versus fear, anger, anxiety or obsession. This is a direct measure of psychological state and not susceptible to any demand characteristics of the testing situation, such as preference for one colour over another, reluctance to wear lenses, misinterpretation of the child's responses to the visual testing, motivation, anxiety etc. Given the prior accounts in the literature of the benefits of lenses (Lewine, Irlen et al, 96) some reflection in brain functioning, even if only at the visual pathway level might be expected. This, at least has been shown through evoked visual potentials in several studies (Byring, 85, Livingstone 91)

A variety of EEG abnormalities have been described in individuals with Dyslexia and related disorders, including low-voltage background rhythms, slow generalised or poor and atypical rhythms, in temporal, parietal or occipital regions and associated with pre and post natal risk factors for brain injury such as traumatic birth. There are functional differences in areas of the brain that are associated with expected rhythms. Most consistent for learning difficulties in general is an increase in lower frequency activity and a decrease in higher frequency activity. For Attention Deficit children increased theta and decreased alpha wave, in the frontal lobes is common while in Dyslexia most studies have reported this ratio primarily in the left-sided parieto-occipital areas. In general higher alpha wave frequencies, measured from the occipital cortex, are associated with alertness and what is commonly called intelligence. (But note the definition of Dyslexia is normal or above I.Q. with a literacy level statistically significantly below I.Q.)

Given that parental (and child) comments of the calming effects of lenses (see appendix 2) suggest involvement of brain areas beyond the visual pathways this is a valuable objective means of assessing the effects of coloured lenses.

Measures from the QEEG

A 19 channel brain mapping system (The Mitsar) was used with a BC1 cap (international 10/20 system) to record the electrical activity of each child under several conditions;

- eyes closed
- eyes open in daylight
- reading in daylight without coloured lenses
- reading with coloured lenses in daylight
- reading with coloured lenses in mixed florescent/day lighting.

Output is described in terms of frequencies from the functional cortices (frontal, parietal, temporal, occipital lobes – all having a left and right division which mediate different aspects of their specialised function

Results;

Psychometric and literary results

<u>Overall group results</u>

Ian Jordan provided an overall measure of the improvement he found in the children when they were wearing their Hoya lenses. This correlated significantly with a similar overall measure of improvement on the psychometric tests (see appendix 5). Particular tests that correlated significantly with one or other of the literacy measures were left, right and central convergence, accommodation, central vision stability and tracing

A t-test revealed significance at the .05 level or less for **single word recognition** and **spelling** (Wide Range Achievement Test; level 3,) and **Comprehension of reading** from the Neale Reading Test in the wearing lenses condition. (appendix 6)

The **phonological test** which is usually taken as a measure of auditory/phonological skill and therefore not amenable to visual processing , did improve significantly, in the "with lenses" condition, so this was a surprising result. Given that this was a series of non-words that children were required to read out loud, the most likely explanation is that improved visual processing may have allowed them to perceive the word in more accurate sequence or phonemic boundaries and thus pronounce it more accurately.

Given the subjective responses of the children and/or their parents it seems surprising that S**peed of Processing** and **Freedom from Distractibility** did not show similar improvement, although these tests are probably more vulnerable to fatigue effects given that there is no inherent meaning that the child can detect (repeating numbers, copying symbols) in the way that reading and spelling have a goal.

Number of psychometric measures on which children improved

Every child improved on at least 3 of the tests (excluding the phonological tests) when wearing their Hoya by an average of 5.24. With the mean difference increasing by 3.87% and 24 children out of 38 having an overall increase in the mean all tests.

Tests on which children improved, in order most to least;

Test	**number of children improved**	**mean diff between with/without**
	24	3.87 (except phono)
Single word WRAT	24	4.05
Reading Com	24	3.32
Processing speed	22	2.42
Freedom	20	2.86
Selling	20	2.29
Phono number	20	2.18
Phono time	19	-4.78
Neal	15	-0.05
Reading rate	13	-1.70
Phono level	13	0.45
Spelling	9	2.29

Appendix 7 .. correlational table of all psychometric and optometric measures, with and without lenses

Discussion of Results;

LITERACY

Reading

Word accuracy on the Neale did not improve to the same degree as single word recognition, although this is essentially the same test. However an interpretation of these results is that that the Wide Range Achievement Test requires the child to read single words out of context while the Neale word accuracy is assessed while the child is reading continuously and trying to maintain comprehension.

The Neale test assesses speed of reading, word accuracy and comprehension of reading simultaneously. Therefore increased accuracy would mean the reader is able to go on to higher levels, which would take more time and is likely to reduce comprehension. However the main effects of this test were that children improved their comprehension despite not being more accurate. Thus their ability to read using context appears to have been increased with coloured lenses. This is probably a function of their increase in some of the visual measures of stability.

Spelling

Overall there was a small group difference in spelling with and without lenses. While better tracking and stability can be expected to help the child sequence more accurately fairly instantaneously, the years of incorrect learning (slow or incorrect phoneme to grapheme matching) are likely to have been committed to memory and therefore remediate less rapidly than reading.

Comprehension

When children made fewer errors than a critical point (given in the manual) in word accuracy they were asked to go on to a longer and more complex passage. This was where lenses gave them the most benefit in this test. This appeared to be due to less visual fatigue in some cases, more accurate line tracking, or fewer phonological errors which improves word recognition in others. In general improvement on one or other of the measures (phonological awareness/working memory) can be expected to improve the child's ability to concentrate on the meaning analysis.

Individual differences with and without lenses plus sum of the tests the children improved and the mean difference of both psychometric and optometric tests are in appendix 8

Phonological Awareness

This is a series of nonsense words that have a similar structure to the English language but cannot have been seen by the child before since they are made up non-words such as "freggy", "apprixengilate" and "phoncher". The child cannot rely on visual memory to recognise these words. A dyslexic child who has weak phonological awareness will attempt to remember words by sight or whole word, using their visual memory, rather than splitting the word into it's constituent phonemes in order to pronounce it and blend the phonemes into a recognisable word. The problem for them is that human visual memory simply cannot remember the thousands of words that make up the English language whereas an automatic knowledge of the 44 phonemes that all English words are made up from means that any word can be decoded, even if it has never been seen before or the meaning is unknown. A visual whole word reader has to encounter the same word several times before it can be added to their reading repertoire. They are also liable to phonological errors – i.e. they may read "smiling" as "similar" or "house" as "horse", because they look similar but if this reader were using a phonological analysis (i.e. by sound) then these sorts of mistakes couldn't be made.

Thus the improvement with lenses is quite surprising and it is assumed that the visual search mechanism described above is helped with the provision of lenses, so that the child is better able to locate the boundaries of words and therefore pronounce them more accurately.

Freedom from Distractibility (Working Memory)

This scale from the Wechsler Intelligence Test (WISCS 111) is noted to be lower in comparison to general reasoning and spatial ability in Dyslexics – children or adults. It is made up from the Digit Span subtest combine with the Mental Arithmetic scale.

Digit span is a measure of auditory sequencing ability and the ability to hold an auditory image in mind. The individual is required to repeat random numbers in the correct sequence up to a span of 9 number strings. Then the same task is repeated with the child having to repeat the numbers backwards, which requires added concentration.

Mental arithmetic requires the same ability to hold words and numbers in mind while also manipulating them, such as necessary for addition, subtraction, multiplication and division. Thus despite no visual task being necessary some children improved although overall there was not a significant difference between the two conditions.

Speed of Processing

This test is another consistently lower test on the I.Q. in Dyslexia and requires the child to copy small complex symbols under speed. This is thought to be due to poor visual tracking and slow fine motor control. It correlates with slowness in handwriting. The test is on white paper . Therefore restoration of any visual deficits was expected to allow the chill to copy faster and more accurately, but again, group results did not show sufficient significance to be statistically important. Like spelling this test depends on hand as well as eye coordination and this may be a skill not amenable to instant improvement simply due to the provision of lenses, although some children were able to do so.

Balance

Most children did find the balancing task easier to cope with when they were wearing the lenses. The initial observation of frequency sway with and without lenses suggest that lenses are somehow helping the visual feedback necessary for balance. The computerised results for individual children are not available until mid January since they have had to be sent to Israel to be compared to the data base built up by Professor Koen-Raz. (see Perceptual & Motor Skills,

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Quantitative EEG

The Qeeg samples brainwaves in broad frequency bands known as delta (less than 2 cycles per second), theta (5 to 7 cycles), alpha (8 to 12 hertz) low beta or sensori-motor rhythm (12-15 hertz) mid- beta (15 to 18 hertz) and high Beta (18 – 40hz). Different areas of the brain have a functional specificity although it is also the case, that like an orchestra, the rhythm of each area co-ordinates with other areas specialised for other purposes. For example language is a sequential phenomenon and the left hemisphere is specialised for discrimination of detail and sequence. Loss of part of the left hemisphere disturbs speech and language function. Loss of the part of the right hemisphere affects recognition of faces or objects and the emotional aspects of speech such as tone of voice that qualifies or reinforces the linguistic message. Each part of the brain has a recognised function and pattern of disturbance; therefore an optimal rhythm measurable in terms of electro-physiology or brainwaves.

In abnormal states of theta no purposeful goals can be kept in mind, apathy, lack of motivation or depression can ensue while abnormal states of high beta are associated with anxiety and tenseness. When part of the brain has too incompatible a rhythm to other parts there is a dissociation and too little communication between networks of experience and therefore, lack of brain coherence.

In particular the alpha rhythm in relation to the beta rhythm, measured from the occipital cortex is generally correlated with alertness and intelligence and coherence of the brain with flexibility of response.

The alpha rhythm in the EEG is 8-12 Hz activity present when a subject is awake with eyes closed. Goldman (2002) used simultaneous EEG and fMRI to detect changes in brain waves correlated with posterior alpha activity. They found that with eyes closed increased alpha power was correlated with decreased MRI signal in multiple regions of occipital, superior temporal, inferior frontal, and cingulate cortex, and with increased signal in the thalamus and insula. These results are consistent with animal experiments and point to the alpha rhythm as an index of cortical inactivity that may be generated in part by the thalamus.

The children in this study showed a trend to lowered alpha activity – probably a reflection of their slow sensory processing noted in the literature review above and perhaps an indication of the strain of processing information. However the “lenses on” condition in the experimental group increased their alpha activity in the neural networks used for reading. These are the parietal-temporal to occipital areas.

Figure 1 (APPENDIX) shows the averaged spectrum of reading with Hoya lenses and without. This shows differences between the two conditions in the posterior parts of the cortex, specifically the occipital (in the 10/20 system, known as O1 and O2), the temporal cortex (T5 and T6) and the parietal cortex (P3 and P4), where visual information is processed.

Figure 2 (APENDIX) shows two brain maps measured at the frequency range from 9 to 11 hertz. The significant differences are still in the temporal-parietal-occipital areas. Without lenses reading is associated with relatively high alpha (9-11 hertz) activity while reading with the lenses suppressed the idling rhythm.

This suggests that wearing the prescribed Hoya colour lenses produces more activation in the temporo-parietal-occipito cortices which is associated with enhanced reading ability.

Conclusions

The experimental group showed an improvement in their phonological awareness when wearing their Hoya lenses which correlated with their ability to spell and read single words.

Their reading comprehension was also improved and it is assumed that if the visual system is not pushed into overload by fluorescent lighting or visual perceptual problems then the child can allocate more attention to monitoring meaning.

These were group results but there was some variability among which tests the children who improved, improved on. Thus it is assumed that different deficits in visual processing allowed these children to improve differentially.

This variability at the psychometric level resulted in small but significant improvements in some aspect of literacy of these children. Given that a large aspect of literacy is learnt it might have been too much to expect an immediate improvement on all tests. Even when limiting conditions are removed the visual processing required for reading may not be immediately available.

The QEEG results suggest that limiting conditions were indeed removed instantly. Before the children put the lenses on their alpha peak activity measured from the parietal-temporal-occipital areas when reading, resembled the normal "eyes closed" condition – i.e. as that part of the brain would be if they had their eyes closed. But this "idling" condition turned to higher activity as soon as the glasses were put on, thus enabling them to enhance their reading.

Thus suggests that as a result of wearing Hoya lenses the children in the experimental group experienced a higher level of brainwave activity enabling them to improve one or other aspect of visual processing related to reading.

The fact that brain functioning is altered with Hoya lenses and correlates with improved literacy demonstrates that the visual field is, as previously suggested by Lewine, more organised and coherent with other areas, either cortically or sub-cortically, thus linking the eyes more adequately to other senses. Lewine's conclusion was that coloured lenses (this study used Irlen lenses) provided normalisation and crystallisation of visual information.

These results taken together with the subjective accounts of the children of stabilisation and increased clarity of print mean that children who are vulnerable to perceptual distortions of text would benefit from the provision of coloured Hoya lenses adapted to the degree and type of lighting they experience at school or home. The effect was most pronounced when wearing the lenses under fluorescent lighting. Since most schools have fluorescent lighting it is suggested that lenses can ameliorate the limiting conditions that fluorescent lighting causes to their learning.

However it is unlikely that the missed learning can be instantly reversed and most children will need specialised remedial input to increase their phonological awareness which is primarily an auditory discriminative capacity. Phonological awareness is as to essential to reading as adequate visual processing.

Given that up to 25% of individuals have been previously estimated to suffer from visual perceptual problems leading to reading difficulties and all of the present (self-recruited) sample showed improvement on one or other of the psychometric or physiological measures the commercial market for coloured lenses and the means of prescribing them seems assured.

Tinted lenses at the moment are provided by the Irlen Centre and Tintavision but these firms do not test under fluorescent light. Cerium does recognise the importance of fluorescent but the choice of lenses colour is limited.

These conclusions will be updated when the Tetrax balance and final and more detailed QEEG analysis arrive. This may alter some of the present psychometric correlations. 3 children may complete the psychometric tests and 1 the Qeeg and balance but these are not expected to substantially alter results. However stated conclusions are provisional until final results are in. This is anticipated to be end of January and no publication of the contents of this report is recommended until then.

Key of abbreviations used in graphs;

With refers to with (wearing) their prescribed Hoya lenses
Not refers to not wearing their Hoya lenses

The following tests are all converted to standard scores;

Neal ………… word accuracy
Comp or comprhe.. comprehension of the Neale reading test
Rate ……….. reading speed on the Neale reading test
Spelling or spel … Wide range Achievement spelling test
(time refers to time in seconds to spell a word)
WRAT …………. Wide range Achievement single word reading test
FREEDOM …… Freedom from Distractibility scale from the Wechsler Intelligence Test-111. UK
PROCESSING …. Speed of Processing scale from the Wechsler Intelligence Scale, 111-UK.

Additional abbreviations;

Phono time, level and number refers to the time in minutes, the age level (1 to 6 identifying phonological awareness level from 5 years to plus 12) And number of words read correctly.

Specialist refers to remedial teaching either at school or a privately engaged specialist Dyslexia tutor
Auditory refers to number of auditory symptoms experienced; (1-6); need for repetition/to get information from facial expression/time-lag in reply/complaints that others speak too quickly to register information/early middle ear infections or grommets/diff following instructions or group conversations

Visual refers to number of visual symptoms experienced; (1-6); Light sensitivity, preference for reading under dim lighting, headaches or sore, watery eyes on reading, print distortions

Delayed refers to delay in developmental milestones, verbal or Physical

Birth refers to traumatic (forceps, breech, apgar, cord round neck or premature birth)

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