Wobbles, Warbles & Fish - the brain basis of dyslexia

Supported by The Dyslexia Research Trust (www.dyslexic.org.uk), Dyers & Colourists, Esmee Fairbairn, Garfield Weston and Wellcome Trusts, BBC Children in Need
Wobbles, Warbles & Fish - the brain basis of dyslexia

Brain systems involved in reading

Differences in dyslexia

Controversies

How can we help?

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Reading requires both visual and auditory/phonological brain processing.

**Visual processing**

- Separate letters
- Phonological analysis

**DOG**

- Visual analyser
- Whole word
- Direct visual analysis
- Meaning (semantics)
The cortical reading network

Dorsal m-route

VWFA
Left hemisphere language areas that activate less in dyslexics.
2\textsuperscript{nd} trimester ectopias in dyslexic brain.
Anterior component of reading circuits left inferior frontal areas (BA 44,45,6)

Parietal/temporal "dorsal" reading pathway

Temporal/occipital "ventral" reading pathway
Many children complain of **visual** difficulties with reading. Often their eyes **wobble** when they try to read. This may be due to weak **visual magnocellular function**.
10% are large magnocellular cells (100x p- cells in area) – for timing visual events: fast responses, low contrast, motion, flicker, control eye movements.

Most retinal ganglion cells are parvocellular (small): for colour, fine detail, high contrast (less vulnerable).
Differences in p- & m- responses

• Parvocellular
  – Fine detail
  – Colour sensitive
  – Slow

• Magnocellular
  – Coarse features
  – Colour insensitive
  – Fast

Magnocellular theory of dyslexia:
• Impaired development of the magnocellular system
• Parvocellular system normal
What, when & where pathways from visual cortex
Visual magnocellular system dominates dorsal visuomotor pathway - directs visual attention & eye movements.
The visual magnocellular system is impaired in poor readers

All these claims have been opposed - 3 problems:

• Definition of magno- system; only anatomically separate in periphery
• Selectivity of stimuli
• Mild deficits require highly sensitive test to reveal them

Nevertheless in the last 10 years 90% of new research has found evidence of magnocellular deficit

• One author has written 20 papers criticising others’ work on the magnocellular hypothesis!
Abnormal magnocells in dyslexic brain
Smaller axons in left angular gyrus in dyslexics; these enlarge with successful treatment
Delayed Brain Potentials Evoked by Moving Visual Stimulus
Magnocellular sensitivity to visual motion predicts visual reading skill

Orthographic Discrimination (% Correct)

Coherent Motion at Threshold (%)
The visual magnocellular system stabilises the eyes to avoid visual wobble

Unwanted image motion, ‘retinal slip’ → Detected by M-system → Feedback to eye muscle control system

Locks eyes on target → Visual stability → Identify letter order

Orthographic skill → Phonological skill
Wobbly eyes!
The visual magnocellular system stabilises the eyes to avoid visual wobble
The eyes have to converge for near vision when reading.

Control of vergence eye movements is dominated by the visual magno system.

The vergence eye movement control system is the most vulnerable to drugs and disease.

Dyslexics have very unstable vergence control.
Magnocellular processing sharpens:

dog dog dog

into

dog
Weak magnocellular system causes unstable vision - oscillopsia

“The letters go all blurry”
“The letters move over each other, so I can’t tell which is which”
“The letters seem to float all over the page”
“The letters move in and out of the page”
“The letters split and go double”
“The c moved over the r, so it looked like another c”
“The p joined up with the c”
“d’s and b’s sort of get the wrong way round”
“The page goes all glary and hurts my eyes”
“I keep on losing my place”
Although they do not mediate colour vision magnocells are most sensitive to yellow light. So in many children yellow filters can improve magnocellular function, hence visual motion sensitivity and binocular control, hence improve reading.
Yellow Glasses

Before

- Tuesday 17th January
- Simpatico and disgusts between Sam and Rose
- 1. Simpatico
- 2. Disgusts
- 3. In snow we were and were very cold
- 4. There was a river and the snow was white
- 5. There were no plants
- 6. There were rocks and a happy ending
- 7. The people were trying to kill each other

Only 1 week later

1. In which country is Caostle? Did a tour villige overlooked by mam for
2. Which mountain is it overlooked by? Mount Maw it has landslides and very big
3. When was the village sink found? In 1498 many old customers survive such as the gaoler
4. Which industries has Caostle had in the past? Such as can making candle and rose making
5. Why do you think Caostle is called this? Because it has a castle and it is on top of a hill
6. Who built Caostle and when? William conquer it was in 1649
7. What are the names of the sour cavern? Blue John speed well peak caust is peak cliff cavern
8. What was made in peak cliff cavern? Made slate used for houses and other places
9. Describe what blue john looks like? Blue John was made from stones and have distinctive colours like red yellow pink purple
10. Can you find out more about the old costumes that survived in Caostle? It's the most vellible since blue iron
Yellow filters can improve reading

Increase in literacy in 3 months

- Reading
- Spelling
- Yellow
- Placebo
Blue light — Melanopsin Containing RGCs → Suprachiasmatic Nucleus → Diurnal rhythms → hypothalamus → Pineal Gland → Melatonin Secretion

Brainstem Serotonergic Projections → Locus Coerulus → Noradrenergic Projections

Vascular System

Tryptophan Precursor

M-System

Performance vs. Tonic [NA]
Blue makes the letters keep still!

to me?
- could see words with 'double e' (eg: tree/ street
  said they were much "easier" with glasses on.
- the glasses "stopped his eyes moving from side
to side" so the word he was reading "kept still"
  and his eyes didn't look at the word he just
  read or the next one to read.
  eg: word+word+word+word+word+word+word+
  made the page look a little bit "bigger" and
  alot 'clearer'.
Blue filters improve reading even more

Increase in literacy

- Reading
- Spelling

- Blue
- Placebo
Blue or yellow filters can improve magnocellular function hence binocular control.
WALTER IS ABOUT TO EXPERIENCE A NICE VISIT FROM THE MIGRAINE FAIRY
• Also blue can improve migraine headaches

• Many dyslexics suffer severe migraine

• Yellow often make them worse!
Blue light

- Melanopsin Containing RGCs
- Suprachiasmatic Nucleus
- Brainstem Serotonergic Projections
- Pineal Gland
- Vascular System

hypothesis

- Diurnal rhythms
- Melatonin Secretion
- Tryptophan Precursor
- Noradrenergic Projections

Performance

- Tonic [NA]

M-system

- HEADACHE
- MOTION SICKNESS
- PSYCHOPHYSICAL?
- PSYCHOMETRIC?
Blue light at night reduces melatonin secretion - effect on suprachiasmatic clock?
The colour choice of 297 reading disabled 9 year olds

- No colour preference: 49%
- Yellow: 26%
- Blue: 25%
Elucidating the role of the visual system in reading has enabled us to develop techniques for helping most of the dyslexics we see.
Many, but not all, dyslexics have phonological problems; these may be caused by mild auditory magnocellular impairments.
Auditory m-cells?

2nd and 3rd formants ascend in frequency for ‘b’; but descend for ‘d’.

Auditory m-cell impairment reduces sensitivity to these changes in sound frequency.
Impaired auditory magnocells in dyslexia?

- Large neurones staining for CAT 301 in the auditory brainstem signal changes in sound frequency and amplitude.
- Dyslexics have smaller magnocellular neurones in medial geniculate N.
- Lower AM & FM sensitivity, correlate with phonological deficit.
- Reduced brainstem auditory evoked potentials correlate with reading deficit.
- Thus dyslexics’ poor phonology may result from impaired development of auditory magnocells.
Auditory and visual magnocellular sensitivity determines over half of differences in children’s reading ability. Thus the most important determinant of overall reading ability appears to be low level magnocellular sensitivity. Encouraging because this can be improved by training.
The magnocellular systems also project strongly to the cerebellum – the brain’s timing autopilot - a magnocellular structure.
Control Head movement Dyslexic
balancing on one leg, eyes open

\[ x-, y-, and z\text{-}positional\ data \]
Decreased activation in cerebellum of adult dyslexics during learning visual tracking
The Cerebellum & Balance

- The cerebellum is the brain’s autopilot for timing and motor prediction, balance and skilled movements
- Magnocellular systems all project to the cerebellum
- Cerebellar neurones stain for CAT 301, part of the magno system
- Cerebellum is underactive in many dyslexics
- Explains their coordination problems, but not all their reading difficulties
- Balance exercises are unlikely to help many dyslexics to learn to read
Sensorimotor Basis of Dyslexia

Low **visual** magnocellular sensitivity - orthographic weakness

Low **auditory** magnocellular sensitivity - phonological problems

Lower **motor** magnocellular sensitivity – in coordination, poor balance

Lower **kinaesthetic** magnocellular sensitivity
Magnocellular Neurones

- A system of large neurones specialised for temporal processing – tracking changes in light, sound, position etc. for direction of attention
- Large, fast conduction, fast transmission, high anisotropy
- All express same surface antigen, CAT 301
- Found throughout the whole brain: visual, auditory, skin, muscle proprioceptors, cerebral cortex, hippocampus, cerebellum, brainstem
- Impaired m-cell development has been found in prematurity, foetal alcohol syndrome, developmental dyslexia, dyspraxia, dysphasia, ADHD, ASD, Williams, schizophrenia, depression, violent personalities
- High dynamic sensitivity requires high membrane flexibility provided by local environment of essential fatty acids, particularly omega 3s, found in fish oils
- Hence very vulnerable to omega-3 deficiency
What causes this general magnocellular impairment?

Genetic
Immune System
Nutrition
Chromosome sites we have linked to reading and focusing attention

- C6p ? KIAA 0319 gene - cell-cell recognition and immune control (MHC system)
- Also DCD gene
- ROBO 3 gene
- Finnish pedigree DYX1 gene
- Melanocortin receptor
KIAA 0319 is strongly expressed in dorsal visual magnocellular pathway.
C6 KIAA 0319 controls neuronal migration during early brain development *in utero*. Downregulation in dyslexics may explain ectopias and other mismigrations of magnocellular neurones.
Hypothalamic appetite control & omega 3s

- Ghrelin
- PYY_{3-36}
- GLP-1
- Oxn
- PP
- Insulin
- Leptin
- White adipose tissue
- Omega 3s
- αMSH
- MC3 and MC4 receptor
- NPY
- Y1 and Y5 receptor
- NPY/AgRP
- Arcuate Nucleus

Increase food intake
Decrease energy expenditure
Decrease food intake
Increase energy expenditure
Fish oils, m-cells & C18 melanocortin receptor

50% of the membrane enclosing this magnocellular nerve cell consists of a long chain omega 3 fatty acid (DHA)

Its flexibility enables rapid neuronal responses

Hence m-cells are highly vulnerable to fish oil deficiency
Modern Western diet is a disaster!

- Too much: salt, sugar, saturated fat, omega 6s (from corn and soya bean oil)
- Too little: minerals, fibre, vitamins A & D, omega 3s from **fish**
- Far too much omega 6 - ratio of omega 6/omega 3 should be 1/1; currently it is 7/1!
Not very romantic!
Fatty acid deficiency in dyslexia and young offenders?

- Many children with neuro-developmental problems and young offenders have omega 3 deficiency:
  - Low blood and brain n-3 FAs
  - Omega 3 FA (fish oil) supplements can v. significantly improve m- function, attention, reading and violent offences
Durham RCT - Omega 3 EPA & DHA supplements helped poor readers to improve their concentration and their reading (Richardson & Montgomery)
Omega-3, vitamins & mineral supplements reduced offences in Young Offenders by 1/3rd (Gesch et al.)

1133 offences: ITT- Active vs Placebo: -26.3 % (p < 0.03)
Supplementation for at least 2 weeks: -34.0%
Violent offences only: -37.0%
Conclusions

• Dyslexics have different brains due to mildly impaired development of magnocells

• may result from:
  Genetic vulnerability
  Nutritional deficiency

• This knowledge is exciting because these weaknesses can be remedied: visual and auditory training, coloured filters, fish oil supplements

• But m- weakness can be associated with p-strengths in holistic perception
Wobbles, warbles & fish!

John Stein

Visit
The Dyslexia Research Trust
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