Dyslexia & Eye Movements

Yu-Chi Tai

Vision Performance Institute
A research consortium supporting “Quality Sustainable Vision”
Developmental Dyslexia is...

- ICD-20

The performance of reading impaired children is 2 SDs below that of normally reading children of the same age and same school grade.

(with a controversial criterion to exclude children with IQ <70)
Dyslexia means:

**Having difficulties in reading**

- Caused by problems encountered at certain level(s) of the reading processes;

- Deficit level reflected in its timing (lower level earlier);

- Abnormal EM timing indicates the deficit level.
Dyslexics’ Eye Movements

• Longer fixation duration
  \((330\sim 350\text{ms} \text{ vs. } 200\sim 250\text{ms})\)

• Shorter saccade length
  \((3\sim 6 \text{ vs. } 8.5 \text{ characters})\)

• More regressive movements
  \((37\sim 60\% \text{ vs. } 20\sim 35\%)\)
Dyslexics’ Eye Movements

Example

But he walked into his first class dragging a gathering unease.

Confronted with teenagers and twenty-somethings who were trying not to stare at him, he was seized by doubt. What was he doing here? What would they ever...
Dyslexics’ Eye Movements

Example

The Eiffel Tower is a iron tower built in 1889. Paris, France. It was planned later it destined for a World Fair. The tallest building in the world as it is of intentionally supposed to be one of the steepest, Spain. The total weight of the iron is about 30,000 tons.

The result that it is necessary to clean when windows or tower once a month.
Dyslexics’ Eye Movements

- Longer fixation duration
- Shorter saccade length
- More regressive movements

Interpretation:

1. Oculomotor dysfunctional hypothesis
2. Cognitive-based hypothesis
Possible causes of dyslexia

- Vision problems
- Linguistic or reading-specific problems
- Other genetic or general problems
Probable Causes of Dyslexia

I. Deficits in visual systems:
   1. Genetic problems: Abnormal chromosomes 2, 6, 15, 18;
   2. Unstable binocular control
   3. Weak magnocellular vision system
   4. Problems in sensorimotor coordination: leads to poor skill automation

II. Deficits in language processing (e.g., Rainer, 1985; Snowling, 2000)
   • Phonological deficit: Deficits in linguistic or low-level sound processing;
   • Orthographic deficit: Deficits in visual processing of linguistic structures.
Can we find a way to identify the problem at the very moment it occurs?
Can we find a way to identify the problem at the very moment it occurs?

→ Yang & McConkie’s (2001) SFR method
Objectives

1. Identify different types of dyslexia through the patterns of their eye movements in response to different levels of reading difficulties.
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• Logic:
  ➢ Reading relies on visual processing of text
  ➢ Eye movements reflect ongoing visual & cognitive process in a moment-to-moment fashion;
  ➢ Abnormal eye-movement patterns reveal reading difficulties.
Objectives

1. Identify different types of dyslexia through the patterns of their eye movements in response to different levels of reading difficulties.

2. Introduce a new technique to explore reading processes.
   - *Single Fixation Replacement (SPF)*: producing specific difficulties at a specific moment
Objectives

1. Identify different types of dyslexia through the patterns of their eye movements in response to different levels of reading difficulties.

2. Introduce a new technique to explore reading processes.

3. Introduce a new way to analyze eye-movement data.
   - *Hazard Curves*: sensitive to momentary changes
SFR
(Single Fixation Replacement)
Experimental Conditions

Control condition: This is one line of text as it might appear

x's condition: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

Random letters: Cxel rb qpv zhel sk wosh sp bk ouwzd trywli

Pseudowords: Thet ut ena lamo ek parm ot ac netht eppout
SFR (Single Fixation Replacement)

Method:
Replace normal text with an alternative pattern, (x-string, consonants, pseudowords…) at a *randomly* selected saccade for a *duration of a single fixation*, and change it back at the next saccade.

Prediction:
Difficulties at a certain process
→ Slows down the processing at that level
→ Produce slower EM response at that moment
  
  x’s → perceptual level

Random letter strings (Nonword) → word form level
Pseudoword → orthographic level…
Try the following example...
spent at my father's home in Virginia, just prior to the opening of the civil war. I was then a child of but five years, yet I well remember the tall, dark, smooth-faced, athletic man whom I called Uncle Jack.

He seemed always to be laughing; and he entered into the sports of the children with the same hearty good fellowship he displayed toward those pastimes in which the men and women of his own age indulged; or he would sit
njyzl nx mh mredsn'l kemk eg Kebsefyn, ceas ylerm bl sds eml snbf dk dsl nnbnm spe. M dbe mwxe b rebmb by asq dreb lnenw, zbk L ppmp prgnfdcb ksj nseb, lhrb, rdasnd-rbddv, mrsbc sd bd dsd dyge K scedme Lbbnm Cnvg.

Bl jsfhgl nknkns rv bb lsrcnhsm; ble rf esnptep nmde kml nnbebm rn sms pmdpds bx dcsr pem fbcl bcblfs gnb g hdbqffmnnnd rb lwse smryh vrbbbm pspld klyscf rl bd zhshn bdj evr zep jbehb wh ass rsh lrb cjyemesp; er es nsbgr bls
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How many patterns did you see?
Does alternative patterns cause any problems (or pause) to your reading?
A dyslexic reader’s reading

(movie)
What does the result look like?

Example: Yang & McConkie (2001)
Results of Yang & McConkie (I)

Normal words:
- rise at 100 ms, asymptote at 225 ms
Results of Yang & McConkie (II)

- control condition: rise at 100 ms, asymptote at 225 ms
- x’s condition: drop at 125 ms
Yang & McConkie (2001) (III)

- control condition: rise at 100ms, asymptote at 225ms
- x’s condition: drop at 125ms
- random letters: drop at 175ms
What do hazard curves tell us?

- The occurrence of separation → Difficulty encountered
- The timing of separation → The level of difficulty
- The size of the suppression → Sensitivity to the difficulty
- Separation time to late-rising time → Recovering rate
Now we have a tool to diagnose individual’s reading problems…

Case study I: Tai & McConkie (2004)
• **Subjects:**
  - 5 adults, with self-reported history of reading disabilities

• **Methods:**
  - Four 1-hr sessions of reading
  - Display change every 8~12 saccades
    - Normal, x-string, non-words
  - Delay timing reflects levels of problems
    - x’s → perceptual level;
    - nonword → word form level
Results (I)

Very mild delay (at 200ms) to random letters
Results (II)

Slight delay (150ms) to x’s but severe delay (250ms) to random letters
Results (III)

Severe delay to both x’s (200ms) and random letters (275ms)

Smoothed Forward Saccade Hazard Curves of Adult Subject 5

- A5_Normal
- A5_Nonword
- A5_x's
- Normal reader, normal text
Results (IV)
Severe delay to x’s (200 ms) and even more severe delay to random letters (300 ms)
So…

- **Cognitive influences** delay saccades.

- **Dyslexics vs. Normal readers’ EMs**
  - Timing of the difference → the level of problems reside;
  - Degree of the difference → severity of the problems and individual’s compromise strategies
The Current study –
Dyslexia, Vision Diagnosis, and Eye Movements

- Research team:
  - Yu-Chi Tai
  - Hannu Laukkanen, OD MED
  - Nanette Curtis (OD, MED program)
  - Eilene Eugenio (OD, MED program)
SFR Method

Original text
Normal: believe that a few words relative to this

On a randomly selected saccade, the text was changed into an alternative pattern...

Alternative pattern
Normal: believe that a few words relative to this
X’s: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Random: dmesinh oyog s dkj hajkm nbsahjbo qb yncs
Pseudowords: balouva thet o fiw werds raletove te thas

for the duration of one fixation, and was changed back at the next saccade...

Original text
Normal: believe that a few words relative to this
Case study

- 7 adult subjects with self-report reading difficulty or similar visual issues…

- Examination battery
  - Case & family history in reading & vision
  - Dyslexia testing: Dem, ADT
  - Binocular vision tests (next page)
  - Eye movement tests
    - Visagraph III
    - SFR Eye-Movement Tracking
Case study

- Examination battery
  - Binocular vision tests (next page)

Distance and near habitual VAs, von Graefe horizontal & vertical phorias, modified Thorton, and cover tests, Near only tests included: EOM’s, NPC x3, Donder’s push up amplitude, NSUCO saccades, contrast sensitivity (ClearChart), PRA at near, NRA at near, FCC, #19, timed Super Stereo test, color vision test (HRR), distance and near, BO and BI amplitudes at near (prism bars and phoropter), MEM, +/- 2.00 binocular accommodative facility, $8^\Delta$ BI/BO vergence facility
Data under analysis...

- Fixation duration (ms)
Importance of This Study

- **Educational importance:**
  - Help to diagnose individual reading difficulties
  - Help to select individually-appropriate treatments

- **Scientific importance:**
  - A new technique to explore reading difficulty
  - A new way to analyse eye movement data in reading
  - A new view to interpret eye-movement control in reading
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