Language Comprehension

reading
Research Methods

- Recording eye movements during reading
- Computational modeling
- Neuropsychology
Eye movement analyses

- **Saccadic movement**: rapid movement of the eyes from one spot to another spot as one reads.

- **Fixation**: these occur between saccadic movements. Information is obtained at fixation.

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**Eye Movement Patterns and Fixations for a Good Reader (top numbers) and a Poor Reader (bottom numbers).**

The handsome frog kissed the princess and turned her into an eggplant.
Eye fixation durations during normal reading

| 201 | 188 | 203 | 220 | 217 | 288 | 212 | 75 |

and creativity has provided some surprisingly good news. Regular bouts of aerobic exercise may also help spark a brainstorm of creativity. A regression
Normal reader

Colter understood enough of what they said to realize that some of them were proposing to set him up as a shooting target. Others were arguing for a more lingering death by tomahawk. Colter waited.

Speed reader

Colter understood enough of what they said to realize that some of them were proposing to set him up as a shooting target. Others were arguing for a more lingering death by tomahawk. Colter waited.

Skimmer

Colter understood enough of what they said to realize that some of them were proposing to set him up as a shooting target. Others were arguing for a more lingering death by tomahawk. Colter waited.
Moving window technique

THE HANDSOME FROG KISSED THE PRINCESS AND TURNED …

XHZ KLN DOME FROG KISSED THE PRIN CAWS NBD YRWVAA …

GJUI DHA BOPLH DROG KISSED THE PRINCESS ANQ DWEVDTA …

• Random letters presented outside window; window moves with eyes
• When window is large enough should have no effect

Moving window technique

• **Perceptual span** to identify words:
  – ~3 letters to left of fixation
  – ~8 letters to right of fixation
  – Span is asymmetric to right

• Span reverses for people who read from right-left (e.g. Hebrew) and is asymmetric to left

Reading
From orthography to meaning
Reading Pathways

There are two possible routes from the printed word to its meaning:

(1) **Spelling** → **meaning**, the route from the spelling of the printed word to meaning at the top

(2) **Spelling** → **phonology** → **meaning**: the print is first related to the phonological representation and then the phonological code is linked to meaning, just as in speech perception.

→ Both routes may be used in various degrees
Phonological mediation occurs in reading

- Evidence for usage of route
  - Semantic decisions on homophones e.g. Van Orden (1987)
    - icecream a food?
    - meet a food?  -> slow “no” response
    - rows a flower?  -> slow “no” response
But... phonological mediation not necessary

• Some brain-damaged patients can understand (some) written words without any apparent access to their sound pattern

• Phonological dyslexics can still read  (Levine et al, 1982)
  – Patient EB
  – Reading comprehension slow but accurate
    Unable to choose which 2 of 4 written words sounded the same, or rhymed

• The relative contribution of the two routes to meaning-activation depends on word frequency
  (e.g. Jared & Seidenberg, 1991, JEP:Gen)
Deep Dyslexia: example patient

**Semantic Errors**
- canoe → kayak
- onion → orange
- window → shade
- paper → pencil
- nail → fingernail
- ache → Alka Seltzer

**Visual Errors**
- cat → cot
- fear → flag
- rage → race
Modeling Deep Dyslexia

Mapping between these networks might be disrupted

Plaut and Shallice (1993); Hinton, Plaut and Shallice (1993)
Neural Network Model for Deep Dyslexia

- Network learns mapping between letter features and meaning features

- Hidden units provide a (non-linear) mapping between letter codes and meaning features

- **Feedback connections**: part of a feedback loop that adjusts the meaning output to stored patterns

- Learning was done with back-propagation

Plaut and Shallice (1993); Hinton, Plaut and Shallice (1993)
What the network learns

- The network created **semantic attractors**: each word meaning is a point in semantic space and has its own basin of attraction.

For a demonstration of attractor networks with visual patterns:
http://www.cbu.edu/~pong/ai/hopfield/hopfieldapplet.html
Simulating Brain Damage

- Damage to the semantic units can change the boundaries of the attractors. This explains both semantic as well as visual errors -- meanings fall into a neighboring attractor.

Visual error: Cat might be called "cot"
Semantic error: Bed might be called "cot"
Reading aloud

from orthography to phonology
Dual Route Models of Reading

Orthography

Lexicon

Phonology

Grapheme-phoneme conversion rules

Lexical Route

Spelling lookup

necessary for exception words, e.g. PINT, COLONEL

Sublexical route

necessary for regular and unfamiliar words, e.g. VINT

(e.g., Colheart, Curtis, Atkins, & Haller, 1993)
Surface Dyslexia

• Difficulty reading irregular words.
  – tendency to regularize irregular words
    (e.g. broad--> “brode”)
  – Patients read GLOVE as rhyming with COVE and
    FLOOD with MOOD

• Damage to lexical route?
Explaining Surface Dyslexia

Orthography

Lexicon

Grapheme-phoneme conversion rules

Phonology

Lexical Route
Spelling lookup

Sublexical route

necessary for exception words, e.g. PINT, COLONEL

(e.g., Colheart, Curtis, Atkins, & Haller, 1993)
Phonological Dyslexia

• Difficulty reading nonwords

• Correctly read
  – irregular words (e.g. YACHT)
  – regular words (e.g. CUP)

• Damage to sublexical route?

• Video demonstration
  – Language->introduction->reading aloud words/nonwords
Explaining phonological dyslexia

Orthography

Lexicon

Phonology

Lexical Route
Spelling lookup

Sublexical route

Grapheme-phoneme conversion rules

(e.g., Colheart, Curtis, Atkins, & Haller, 1993)
Neural Network Approach

• E.g., Seidenberg and McClelland (1989) and Plaut (1996).

• Central to these models is the absence of any lexicon. No multiple routes from orthography to phonology are needed.

• Instead, rely on distributed representations

• The model has no stored information about words and ‘... knowledge of words is encoded in the connections in the network.’
A Neural Network Model

Phonemes
(output)

Hidden units

Graphemes
(input)

Phonology
speech

Orthography
print

Plaut et al. (1996)
Plaut et al. (1996) Simulations

• Network learned from 3000 written-spoken word pairs by backpropagation.

• Performance of the network closely resembled that of adult readers

• Lesions to model led to decreases in performance on irregular words, especially low frequency words

  → simulated performance in surface dyslexia
Plaut et al. (1996) Simulations

• Predictions that match human data:
  – Irregular slower than regular:
    \[ \text{RT}( \text{Pint} ) > \text{RT}( \text{Pond} ) \]
  – Frequency effect:
    \[ \text{RT}( \text{Cottage} ) > \text{RT}( \text{House} ) \]
  – Consistentency effects for nonwords:
    \[ \text{RT}( \text{MAVE} ) > \text{RT}( \text{NUST} ) \]
Demo

- http://psych.rice.edu/mmtbn/
  - Chapter “language”
  - Section “word production II”
  - End of page launches demo of Plaut et al. model