Written language systems

- Logograph systems (e.g. Chinese)
  - Characters represent entire words
- Syllabaries (e.g. Kana in Japanese)
  - Characters represent syllables
- Alphabets (e.g. English)
  - Characters represent phonemes
Alphabets

- Havelock (1976)
  - Each phoneme must be represented in the writing system
  - Unambiguous one-to-one grapheme-phoneme correspondence (ideally)
  - Total number of graphemes should be relatively limited (20-30 is ideal)
One to one correspondence?

- Many graphemes for one phoneme:
  - /k/: cat, kettle

- Many phonemes for one grapheme:
  - daughter, laughter
  - cough, through, bough, tough

- Many to many correspondence!
Phoneme Representations

Grapheme Representations

Spoken Input

Written Input

Language representations
Early stages of visual processing

- Much like auditory processing:
- Feature level – physical features of the letter
- Letter level – identity separate from its physical manifestation

- Word level – putting features/letters together into a word
Letters in isolation

- Present letters for 50 ms, ask for identity
- Some features perceived, but not all
- E confused for F, R for P
- So, features are useful and very quickly used
• Find “Z” in a chunk of letters like “ODGQR” vs. “IVMXEWF”

• Faster when Z is embedded with letters with unlike features
Word-superiority effect

- Word vs. Non-word: *word* vs. *owrd*
- Shown for 50 ms
- Subjects asked for specific letter (say, last letter was *d* or *k*)
- Accuracy best with word
- We process letters best when in context of words – top-down effect
Basics of eye movements

• During reading
  • Saccades: rapid eye movements
  • Saccadic suppression: No visual input processed during saccades
  • Typical saccades during reading last around 30msec (2° movements)
  • Each saccade takes 150-175 msec of program
Other eye movements

- Saccades are different from other eye movements
- Smooth pursuit (tracking a moving object)
- Vergence (moving inward to fixate on a close object)
- Vestibular (rotation to maintain same direction of visual during head/body movement)
Fixations

• Fixations
  • When the eyes remain (relatively) still
  • Relatively?
    • Nystagmus
    • Drifts & Microsaccades
  • Visual information is taken in during fixations
What can we see?

fovea (2°)

(5°) parafovea

parafovea (5°)

periphery

periphery
What can we see?

- **fovea** (2°)
- **parafovea** (5°)
- **parafovea** (5°)
- periphery

Diagram showing the fovea, parafovea, and periphery regions of the retina.
Fixation & attention

- Under normal circumstances:
  - We look at what we are paying attention to
  - We shift attention ahead of eye gaze

150-175 msec
Eye-tracking methods
Eye-tracking methods
Silent reading

- On average in English:
  - Fixations last 200-250 milliseconds
  - But lots of variation (even within person)
    - under 100 to over 500!
  - Saccades are 7-9 character spaces
    - range 1-15 (over 15 rare, but when people go return to where they regressed from)
Silent reading

• Not every word is fixated
  • Content words: fixated 85% of the time
  • Function words: fixated 25% of the time
  • Shorter than content words
  • 5 letters: 25% of time
  • 8+ letters nearly 100%
• Regressions back to previous text 10-15% of time
Designing experiments

• What kinds of information gets processed, and when?
• Perceptual span
• How far away from the fixation do we collect information?
• What kind of information is relevant?
Perceptual Span

- Moving Window Technique (McConkie & Rayner, 1975)

- Logic: if critical information is missing - and noticed as missing - then eye movement should be disrupted (or at least different from when information is present)
The quick brown fox jumped over.
More fun with moving windows

Pko jnarb knuwn fox jumpeh awoc

Pko jnarb knuwn fox jumped ovoc

Pko jnarb brown fox jumped ovoc
Perceptual Span

- Moving Window Technique (McConkie & Rayner, 1975)

- How big does the window need to be before it doesn’t affect eye movements during reading?

- Does it matter what information gets masked?
• When window equals region that the reader can get information from -
  • there will be no difference between reading with and without the window

• This will tell us what kinds of information can be extracted from the visual information, and at what point
• Moving Mask Technique (Rayner & Bertera, 1979)

• Normal Text:
  • The quick brown fox jumped over

• Moving Mask:
  • The quick broXXXXXXXed over
More fun with moving masks

The quick broxx xxx xxxxxxxd over

4       7

The quick broxx xxx xxxxxxxxx xxer

4       11

The quick xxxxxxx xxx xxxxxxxxx xxer

7       11
• How small does the mask need to be before people can figure out what the text says?
• Boundary Technique (Rayner, 1975)

• Pre-boundary text:
  • The quick brown fox jumped over

• Post-boundary text:
  • The quick brown dog jumped over

invisible boundary
• What these fiendish methods show us:
  • Perceptual span is relatively small
  • Span is also asymmetric

• Alphabetic languages:
  • The quick brown dog
    3-4 ↑ 14-15
• What these fiendish methods show us:
  • Perceptual span is relatively small
  • Span is also asymmetric

• Asymmetry reverses for right-left languages (e.g. Hebrew)
• What about non-alphabetic languages?
• Japanese
  • 13 character spaces (6 to the right)
• Chinese
  • 1 character to the left, 3 to the right
• Perceptual Span

• Gets smaller with difficulty

• Children:

• With age appropriate material, 4th graders have adult-like span

• With college-level material, span shrinks
What information is attended to in the span to the right of the fixation?

- Partial word information
- The first three letters of the next word appear to be important

But shape information is also detected
- XXXX vs. visually similar words
• Word length information

• If the word in the right is short,
  • Longer fixations time followed by longer saccade to skip short word
  • ... found the pencil ...

• Suggests lexical processing possible from information in the parafovea
• Big Picture of eye movements during reading
  • Eyes do not move smoothly across text
  • Fixations and saccades
  • Information is taken in from upcoming words (first few characters)
  • Eyes move back to previous text 10-15% of the time
Sentence contexts

• Lima & Inhoff (1985)

• The boy hoped to see several

• Few similar words: dwarves

• Many similar words: clowns

• Bigger benefit for dwarves because limits possible words?
The boy hoped to see several ...

- No preview difference at “several”
- However, fixation time for “clown” faster
- Frequency of word-initial letters aids processing
- Follow-up study found preview benefit for high-frequency words compared to low
- The boy wanted a viola / piano.
Predictability

- Balota et al. (1985)
  - Predictable words more likely to be skipped than unpredictable
  - When fixated, times were shorter for predictable words
Processing difficulty

- Henderson & Ferreira (1990)
  - Boundary technique
  - Target: High vs. low frequency
  - Parafovea: Same, similar, dissimilar
Mary bought a chest despite the high price.
Mary bought a chest despite the high price.
Mary bought a chest zqdloyv the high price.

Mary bought a chest despite the high price.
Mary bought a trunk despite the high price.
• Results:
  • Frequency effects at target
  • chest vs. trunk
  • High Frequency - Preview benefit
  • Low Frequency - No Preview benefit
Mary bought a chest despite the high price.

Mary bought a trunk despite the high price.

Mary bought a chest despite the high price.

Increased difficulty leads to less attention paid to the right parafovea.
• Skilled readers process some information from upcoming text
  • Letter shape in far parafovea
  • Lexical processing in near parafovea
• Limited attentional resources
  • Processing burden at fovea affects parafoveal processing