Reading & Writing

Ben Weissman

COGS 4780

Connectionist approaches to reading

- No correspondence rules, just patterns of activation
- Artificial neural network trained to connect orthographic forms to phonological outputs
  - Hidden layers connecting letters to phonemes, trained through backpropagation

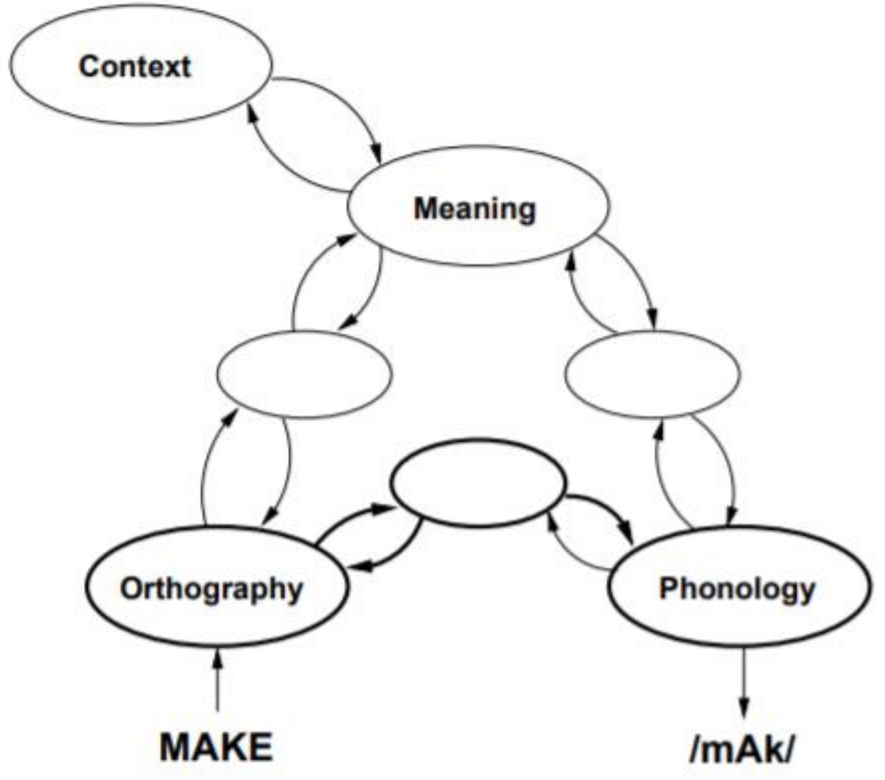


Figure 2. The Seidenberg and McClelland (1989) model of word recognition. Implemented pathways are shown in bold.

Connectionist approaches to reading

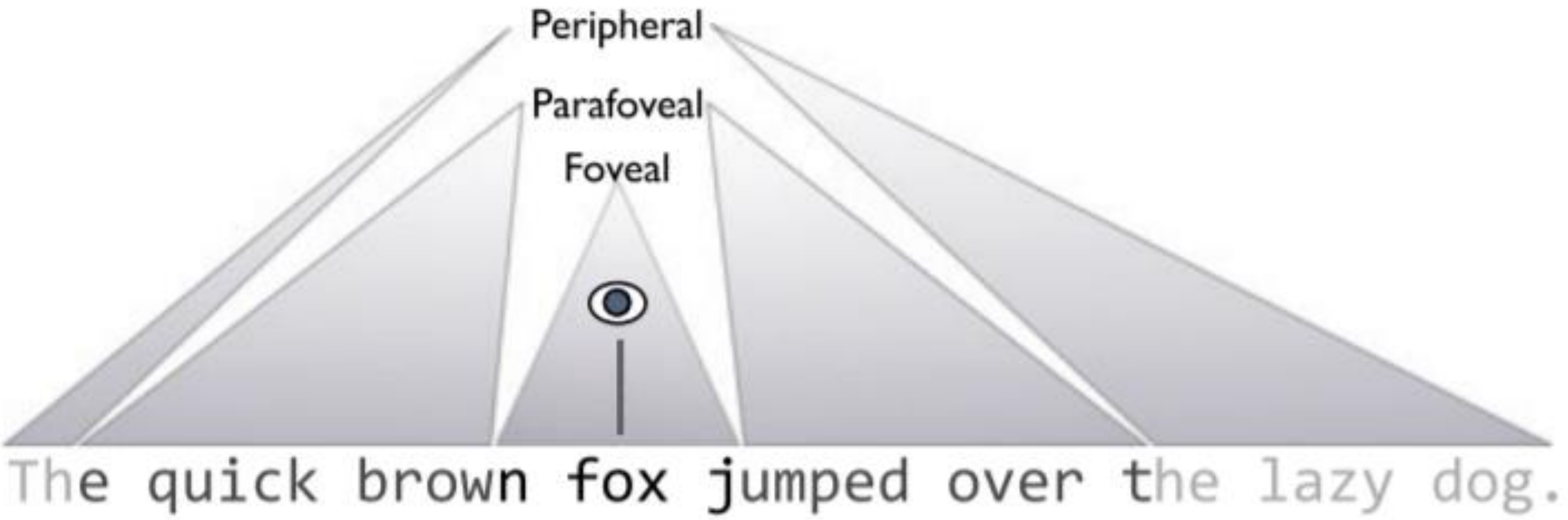
- Statistical information represented in patterns of the network – regular and irregular forms handled by the same system
  - Like before with grammatical learning – one system handles both regulars and irregulars
    - *sign*, *resign*, *benign*, *align*
- Continuum between extreme irregulars and highly regular forms
  - Letters that appear together will form patterns, represented in the network
  - Frequency drives strength of connections
    - Frequent letter-sound mappings form strong links
    - Infrequent letter-sound mappings form weak links (but still present!)

Connectionist approaches to reading

- Issues with original model: bad at pronouncing nonwords, bad at lexical decisions (high false positive rate)
- Revised model introduced new information – phonotactic constraints (which sounds appear next to each other) and graphotactic constraints (which letters appear next to each other)
- “Lesions” (network damage) to this network results in dyslexia-like difficulties

Full sentence reading

- Notice how we’ve mostly talked about reading single words so far
- What happens in reading full sentences?
- There’s plenty to discuss here, but we’ll focus on one (interesting) component called **parafoveal preview**


Peripheral
Parafoveal
Foveal
The quick brown fox jumped over the lazy dog.

Full sentence reading

- **Parafoveal preview** – as we read, we get information about upcoming content in our visual field
- There is a link between the fovea and attention, so our direct attention is usually honed in on whatever we’re directly looking at
- But information from the parafovea is still integrated even before it’s directly fixated

Full sentence reading

- First things first – we can identify content (like letters) in the parafovea
  - Letters and words flashed in the parafovea for 100ms are identifiable (Bouma 1970, 1973)
- This means that lexical content can be accessed from parafoveal viewing
  - This access is the same quality as foveal viewing, but slower (Lee et al. 2003)
    - Still the same lexical access effects (e.g., frequency) but happens more slowly

Full sentence reading

- To test parafoveal processing during reading, we need to account for fixations and saccades though – we don't hold our eyes in one place
- To do this, the **gaze-contingent** paradigm is used

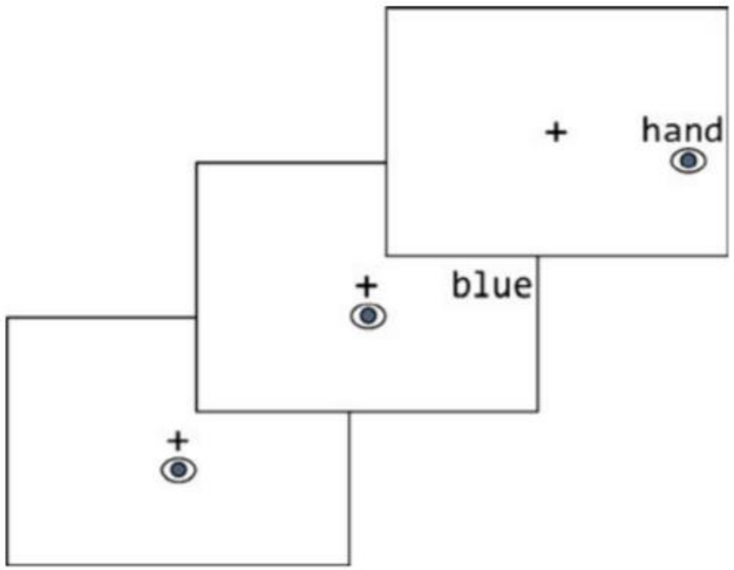


Fig. 2 Example of the gaze-contingent naming paradigm. A subject maintains fixation on a central cross until a preview word appears in the parafovea. Once the word appears, the subject makes a saccade toward it, and it changes the target (named) word

Full sentence reading

- To test parafoveal processing during reading, we need to account for fixations and saccades though – we don’t hold our eyes in one place
- To do this, the **gaze-contingent** paradigm is used
- Using this paradigm, we’ve learned that orthographic and phonological information are both obtained from a parafoveal preview
  - Not entirely visual – WRITE is just as good as write

Full sentence reading

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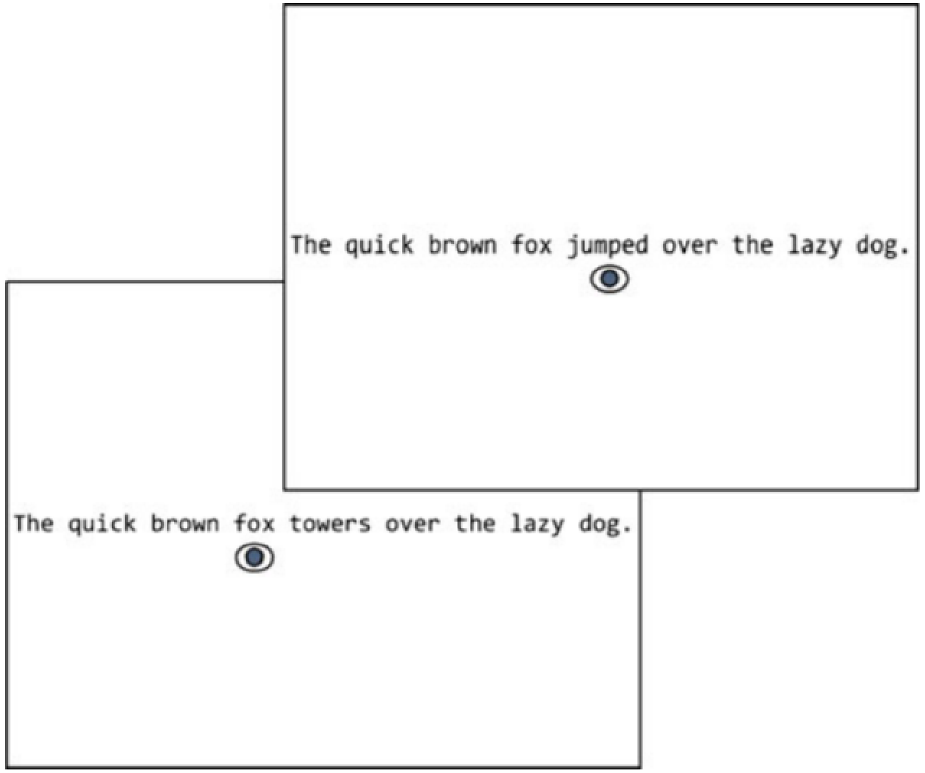
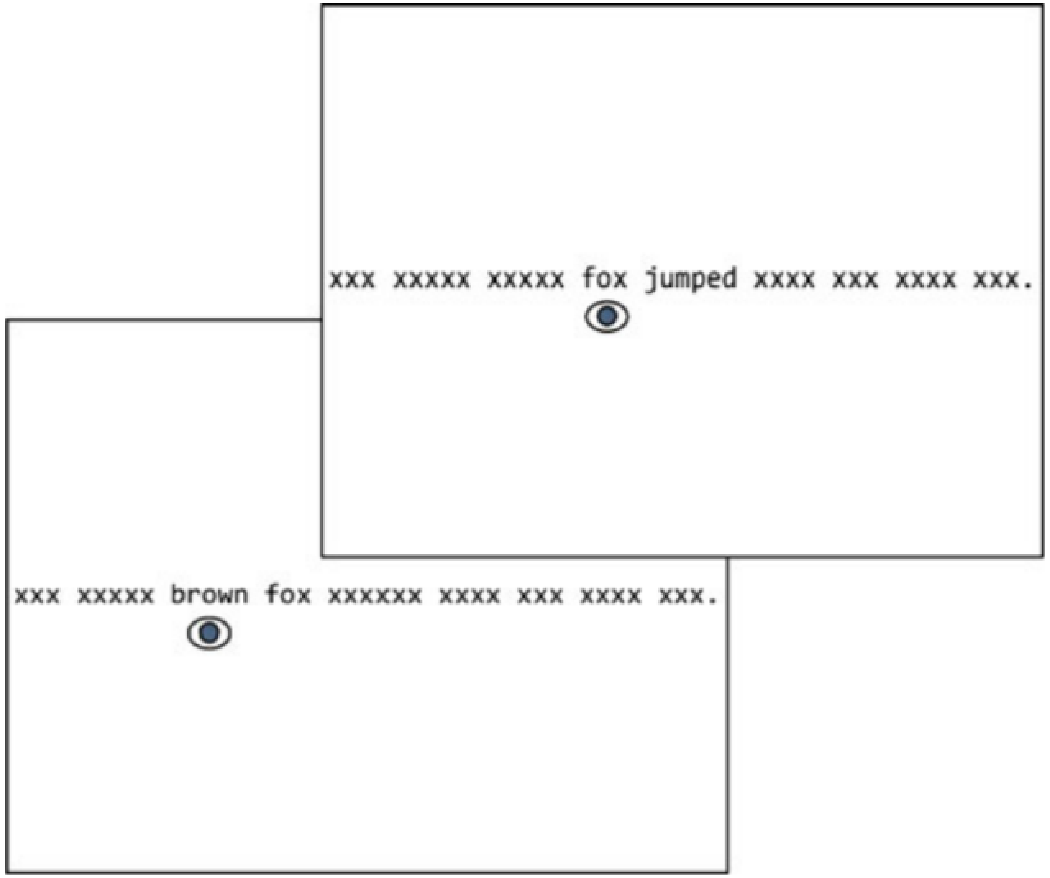


Full sentence reading

- To test parafoveal processing during reading, we need to account for fixations and saccades though – we don't hold our eyes in one place
- To do this, the gaze-contingent paradigm is used
- Or the **moving window** paradigm



Full sentence reading

- “Part of the reason why reading is much more complex than isolated word naming is that, in reading, linguistic information is compressed into a line of text that follows a strict serial order. This means that parafoveal information (e.g., information about a nonfixated word) may not only be irrelevant to identification of the foveated word, but may actually hinder it by activating a competitor of that word. On the other hand, the efficiency of reading can be greatly increased if readers start to identify the upcoming parafoveal word before they fixate it. Because of this, readers have to allocate their attention carefully in order to obtain parafoveal information to a degree that is useful, but not harmful.” (Schotter et al., 2012)

Full sentence reading

- In reading, we do orthographic, phonological, morphological, lexical, semantic, and syntactic processing for each word – not to mention dealing with pragmatic content and keeping previously-encountered words in working memory
- What resources do we have left over for parafoveal processing?

Full sentence reading

- Parafoveal information guides upcoming saccades
    - The ideal focus of a fixation isn’t in the middle of the word, it’s reliably slightly to the left of the middle of a word
        - We wouldn’t be able to do this without a parafoveal preview
    - The fixation location shifts leftwards if the word starts with something orthographically unique
        - Again, wouldn’t be able to do this without a parafoveal preview

Full sentence reading

- What other information comes from a parafoveal preview?
- Orthographic information
  - Word shape information
    - Like ascending/descending consonants
    - (somewhat weak/unreliable effect)
  - Letter identity information
    - Even if the word itself changes, seeing the first 2-3 letters facilitates processing
    - (strong and reliable effect)
    - Think about all of our connectionist approaches to lexical access!

Full sentence reading

- What other information comes from a parafoveal preview?
- Phonological information
  - Homophone priming from parafoveal preview
    - e.g., *maid* primes *made*
- Morphological information (maybe? some languages yes, some no)
  - Prefixes are viewable from parafoveal preview

- Not a lot of evidence for semantic information
  - Semantically-related primes can prime from parafoveal preview
    - e.g., *nurse* can prime *doctor*
  - Most experiments have not found evidence for this
    - Preview and target words will likely be highly orthographically different, so that will probably offset any semantic-related benefit

Full sentence reading

- Interaction between foveal and parafoveal processing
  - Remember our resource framing
  - Low frequency foveal words eliminate benefits from parafoveal word (Henderson & Ferreira 1990)
  - Garden path words do the same
- If more resources are being dedicated to foveal processing, there's less left over for parafoveal processing

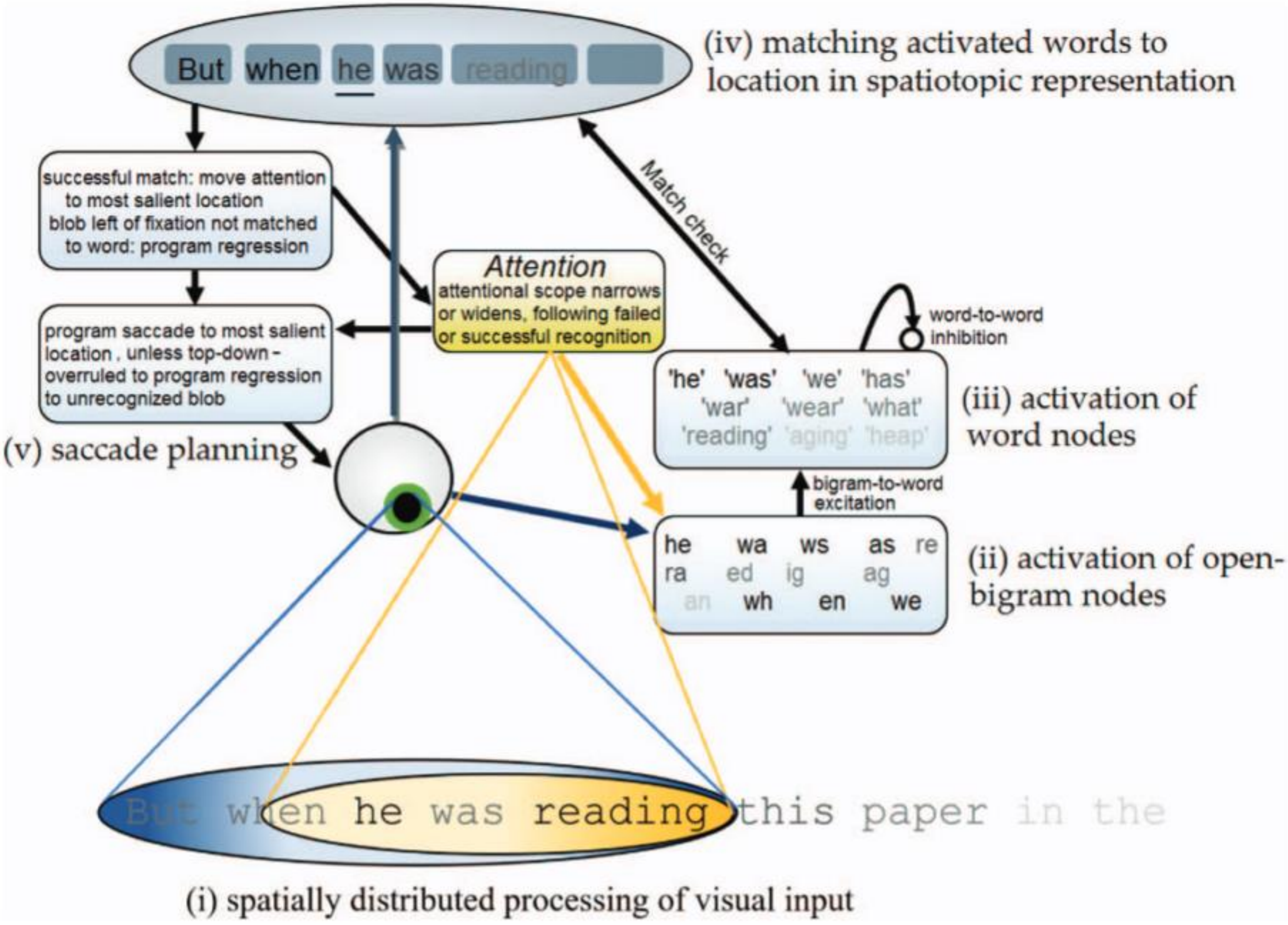
EZ Reader

- Full model: EZ Reader (Rayner)
- Two phases of word recognition
  - L_1 – cursory processing of word
  - L_2 – thorough processing of word
- Once L_2 complete, attention shifts to next word unless a saccade has been triggered
- Two saccade-programming phases
  - M_1 – saccades can be canceled
  - M_2 – saccades cannot be canceled

OB1 Reader

- Other approaches are more probabilistic and parallel, like OB1 Reader (Snell et al. 2018)

- Parallel processing of multiple words, modulated by an attentional window of adaptable size
- Coding of input through a layer of open bigram nodes that represent pairs of letters and their relative position
- Activation of word representations based on constituent bigram activity, competition with other word representations and contextual predictability;
- Mapping of activated words onto a spatial sentence-level representation to keep track of word order
- Saccade planning, with the saccade goal being dependent on the length and activation of surrounding word units, and the saccade onset being influenced by word recognition.



But when he was reading
(iv) matching activated words to location in spatiotopic representation
successful match: move attention to most salient location
blob left of fixation not matched to word: program regression
Match check
Attention
attentional scope narrows or widens, following failed or successful recognition
program saccade to most salient location, unless top-down-overruled to program regression to unrecognized blob
word-to-word inhibition
'he' 'was' 'we' 'has' 'war' 'wear' 'what' 'reading' 'aging' 'heap'
(iii) activation of word nodes
bigram-to-word excitation
(v) saccade planning
he wa ws as re ra ed ig ag an wh en we
(ii) activation of open-bigram nodes
But when he was reading this paper in the
(i) spatially distributed processing of visual input

OB1 Parameters

Parameter	Description	Equation	Value	Determination
τ	Decay	4	.05	Heuristic fitting
c_1	Bigram-to-word excitation	4	.0044	Heuristic fitting
c_2	Word-to-word inhibition	4	.0018	Heuristic fitting
c_e	Scaling cortical magnification	1	35.56	Cortical magnification derived from Harvey and Dumoulin (2011), scaled so as to have max. 1
m_i	Masking factor describing crowding	1	1 for outer letters, .5 for inner letters	Marzouki and Grainger (2014)
Asym	Asymmetry of attention	2	1 toward the right, .25 toward the left	Four times greater toward the right than toward the left (Rayner, 1998)
c_a	Residual attentional weight outside of focus of attention	2	.25	A priori
Maximum/minimum attention	Maximum and minimum size of attentional window	2	5.0/3.0	A priori
Time step	Duration of 1 time step		25 ms	Average duration of a saccade
c_4	Weight of word frequency in threshold setting	5	5.5	A priori
c_5	Weight of predictability in threshold setting	5	9.0	A priori
c_6	Maximum lowering of threshold for short words	5	.61	A priori
c_7	Scaling of effect	5	.44	A priori

Note. A priori parameters were fixed prior to simulating the Potsdam Sentence Corpus.

Writing

- Writing is not very widely studied – reading/writing in and of themselves aren’t considered all that important within linguistics in general, and writing is a form of language production so it’s hard to study experimentally
  - Most research on writing is pedagogical in nature, focusing on the best methods to teach L2 (and sometimes L1) writing
- What’s different about writing compared to verbal language production?

Writing

- More time to plan
  - Sentences are more likely to be well-formed
  - Greater syntactic complexity
- Can edit what you write
- Message is sent all at once
- Less interactive (audience is less active in real time)

Stages of writing (Hayes & Flower, 1980s)

- Planning stage
  - Ideas generated, information taken from memory and organized into a plan for what to write
- Translation stage
  - Written language produced from the representation in memory: thought → sentence
- Reviewing stage
  - Writer reviews (and can edit) what has been written

Stages of writing

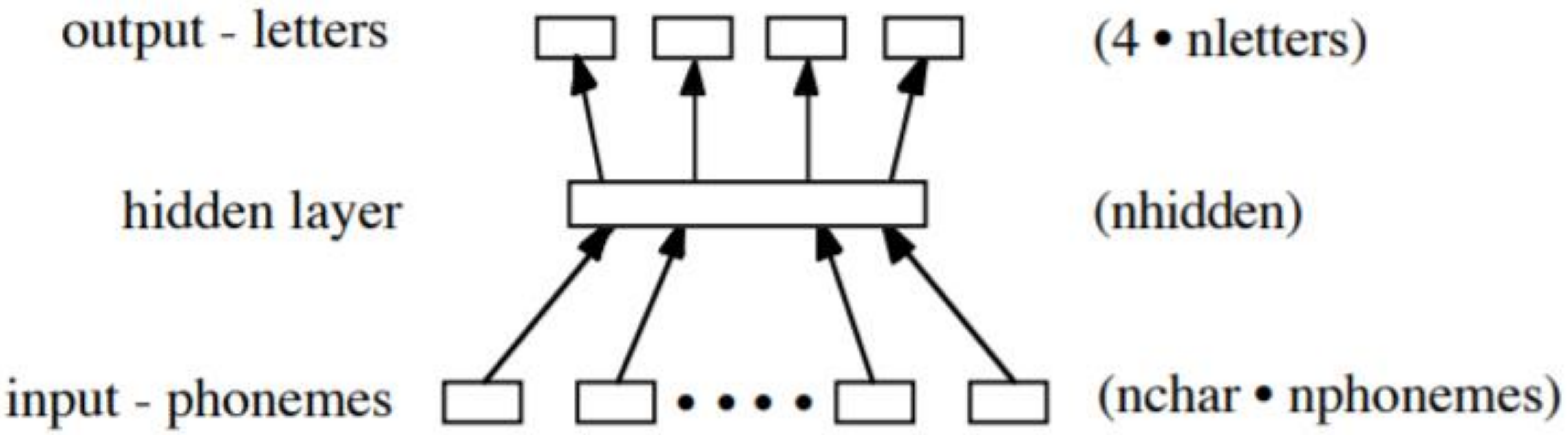


Figure 1: The network architecture for the spelling model.

Inner speech for writing?

- Phonic mediation theory claims inner speech is necessary for writing
  - First we retrieve spoken sounds of words, then we can produce the written words

Inner speech for writing?

- ~~Phonic mediation theory claims inner speech is necessary for writing~~
  - ~~First we retrieve spoken sounds of words, then we can produce the written words~~
- Extensive evidence against this theory
  - People who don’t speak can still write
  - Patients with neural damage can write words that they’re unable to say out loud

- Maybe another dual-route model, with one path connecting sounds to letters and another lexically-mediated route

Dysgraphia

- Brain damage can lead to writing-specific deficiencies, called dysgraphia
- Just like dyslexia, there are different types of dysgraphia
    - Phonological dysgraphia – patient can spell familiar words, but cannot generate spellings from sounds alone
        - Can spell words but not non-words
    - Surface dysgraphia – patient can spell nonwords but struggles with irregularly-spelled words (overregularization)
    - Deep dysgraphia – semantic errors surface specifically in spelling (like *star* substituted in for *moon*)

Phonological Dysgraphia

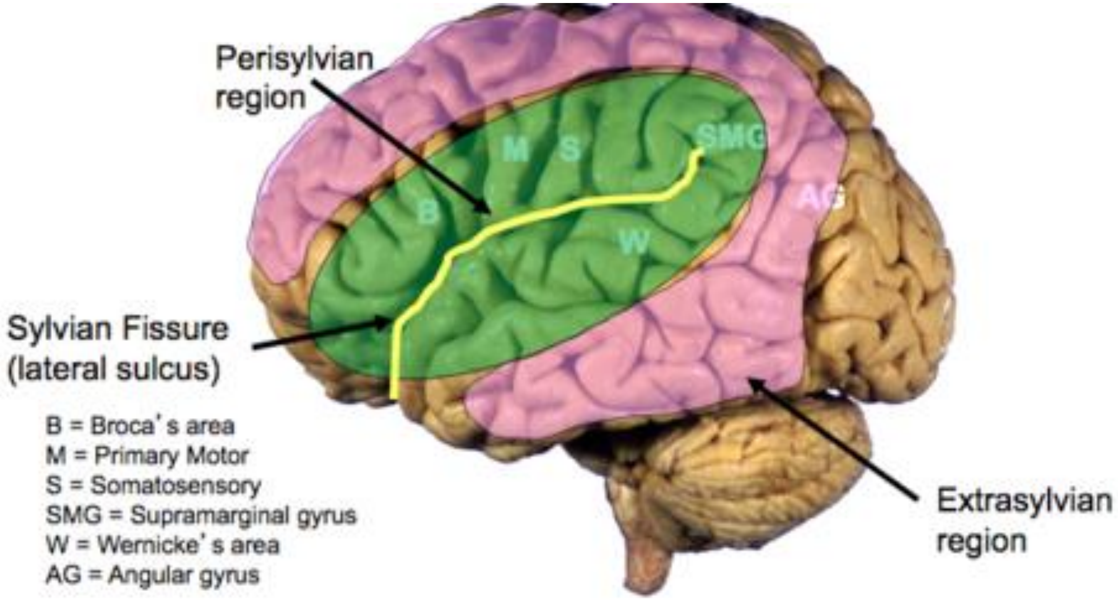
- In phonological dysgraphia (and phonological dyslexia) there are typical **lexicality effects** – the act of spelling/reading seems to be mediated by lexical processes
- Rapcsak et al (2009) investigated several patients and found the following:

“Increased lexicality effects were also documented in spoken language tasks such as oral repetition, and patients performed poorly on a battery of phonological tests that did not involve an orthographic component. Furthermore, a composite measure of general phonological ability was strongly predictive of both reading and spelling accuracy.”

  - Are dysgraphia and dyslexia not specifically about writing/reading?

Phonological Dysgraphia

- Instead of a *writing module* or a *reading module* that is affected, maybe there's a broader phonological system that exists independent of a modality, and damage to this network is what causes dysgraphia and dyslexia
- **Shared-components model** – reading and spelling use the same resources
- Participants in the study had damage to perisylvian region of the brain
  - Damage elsewhere may lead to different kinds of dysgraphia/dyslexia



New methods in writing research

- Keystroke logging can be used to gain insights into the cognitive underpinnings of writing (Leijton & Van Waes, 2013)
  - Can be used in conjunction with other methods (i.e., eye-tracking)

  - What might we analyze?

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  - What might we analyze?
    - Revisions and hesitations – where and when are they likely to occur
    - What someone looks at during each letter

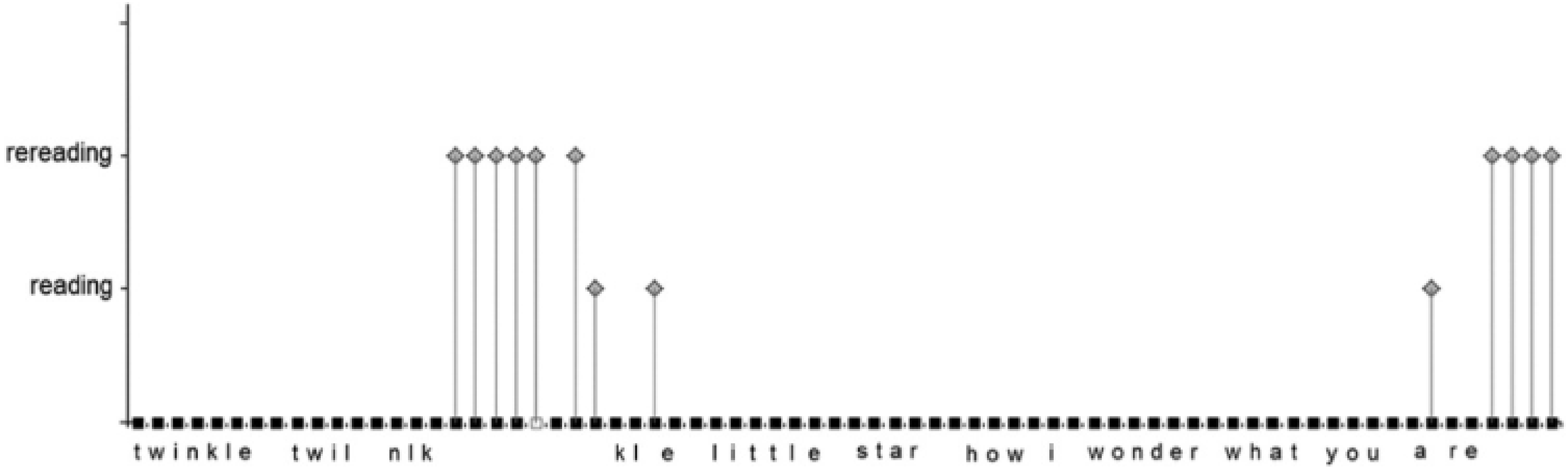

Figure 1. Reading during writing behavior of hunt-and-peck typist.

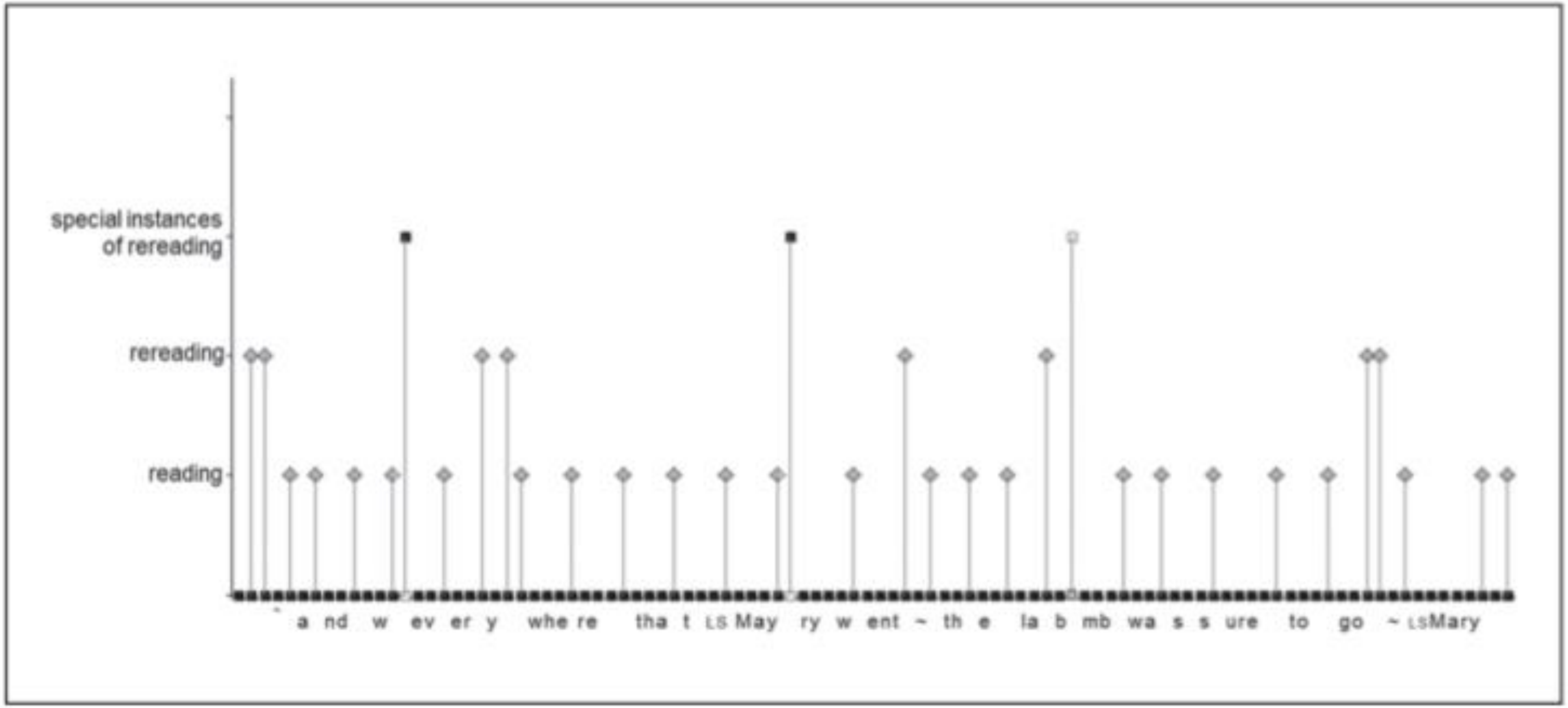

Figure 2. Reading during writing behavior of monitor gazer.

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  - Revisions and hesitations – where and when are they likely to occur
  - Can be used in conjunction with other methods (i.e., eye-tracking)

- Gánem-Gutiérrez & Gilmore (2018) utilized eye-tracking during a 30 minute period in which L2 learners wrote an essay
  - Found evidence of frequency effects, modulated by L2 proficiency