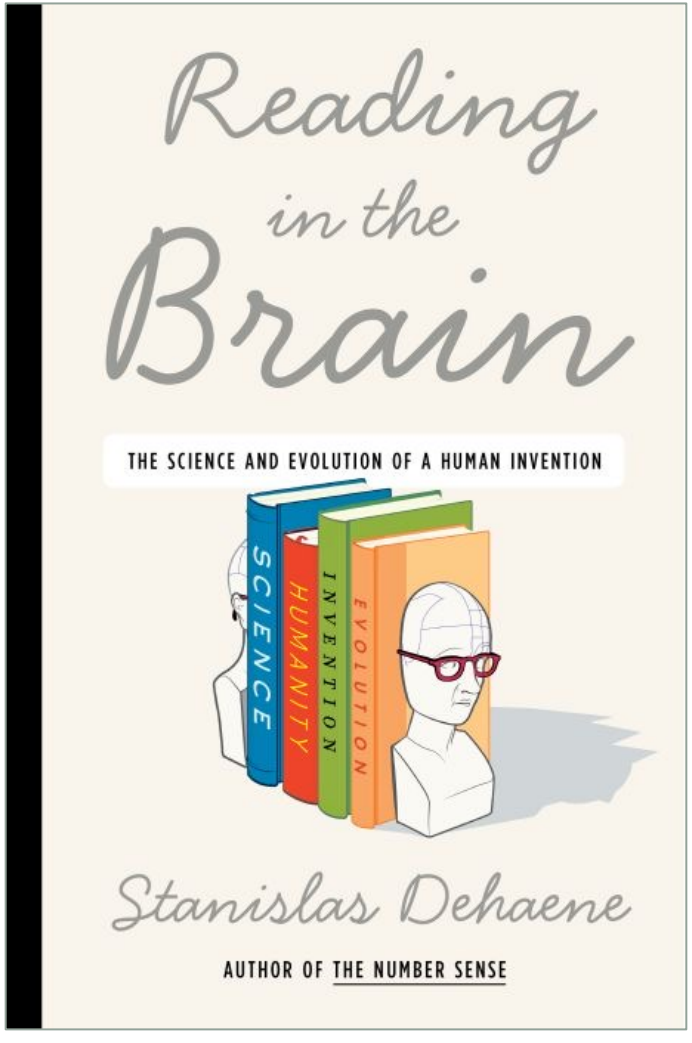
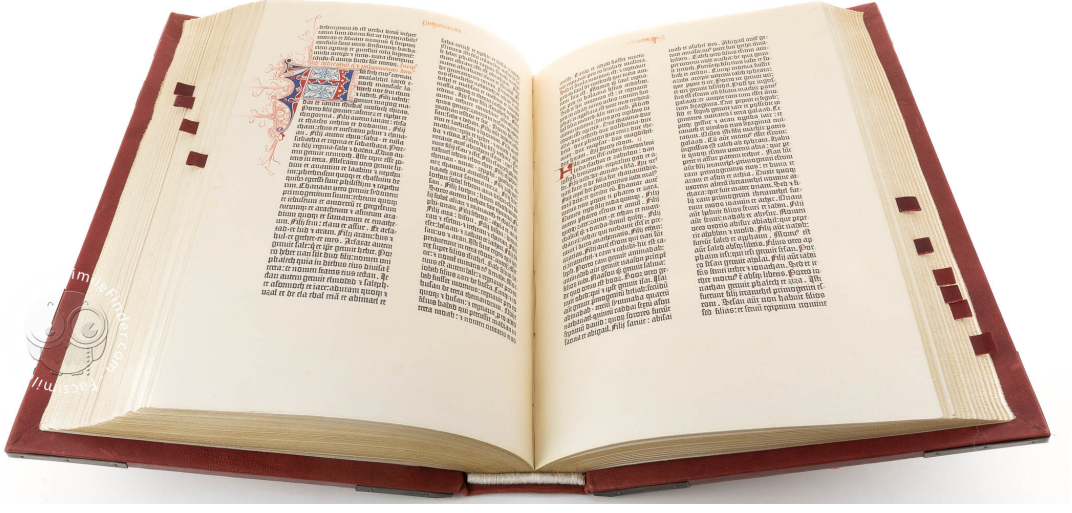
READING AND WRITING (CH. 11)

COMD570: Language Development

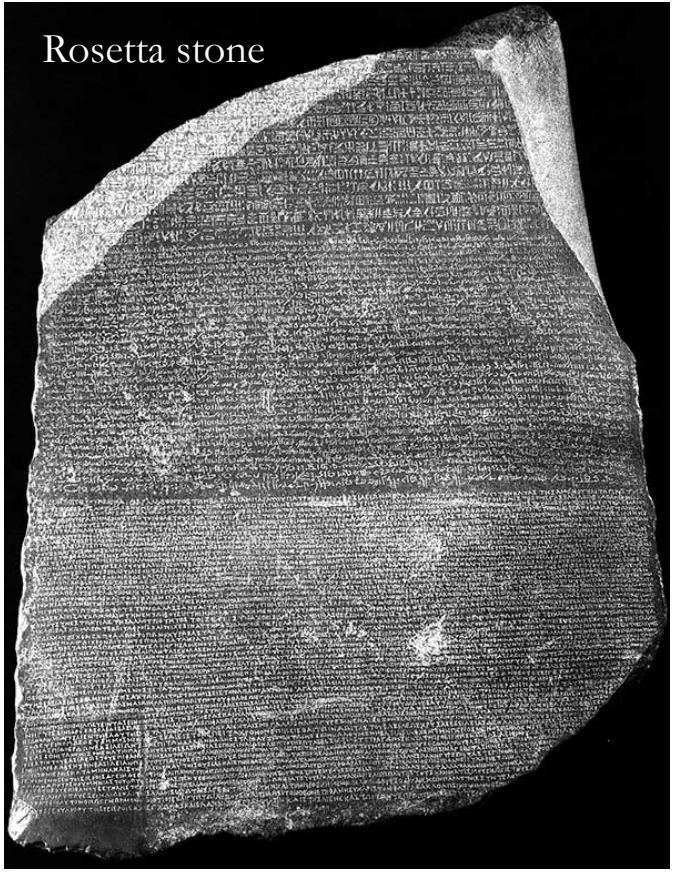

Reading
in the
Brain
THE SCIENCE AND EVOLUTION OF A HUMAN INVENTION
SCIENCE
HUMANITY
INVENTION
EVOLUTION
Stanislas Dehaene
AUTHOR OF THE NUMBER SENSE

Reading is awesome

- Reading/writing: a revolutionary invention



Gutenberg Bible



Reading is awesome

i carry your heart with me(i carry it in
my heart)i am never without it(anywhere
i go you go,my dear;and whatever is done
by only me is your doing,my darling)
i fear
no fate(for you are my fate,my sweet)i want
no world(for beautiful you are my world,my true)
and it's you are whatever a moon has always meant
and whatever a sun will always sing is you

here is the deepest secret nobody knows
(here is the root of the root and the bud of the bud
and the sky of the sky of a tree called life;which grows
higher than soul can hope or mind can hide)
and this is the wonder that's keeping the stars apart

i carry your heart(i carry it in my heart)

E.E. Cummings

Reading is awesome

- Literacy has likely directly impacted the structure of languages
  - Reading expands working memory capacity by keeping information on the page rather than inside of the head (O'Neil, 1977)
  - This may explain the transition from Old English, which did not apparently have embedded clauses, to modern English, which has lots of clausal embedding

(1) [þa men comon on East Engle [þe onþ æm anum scipe wæ re]]:
'the men came to East Anglia [who on the one ship were']

Compare with: the men [who were on the ship] came to East Anglia

Orthography, reading, writing, literacy

- **Orthography:** speech in written form
- **Reading:** the act of comprehending orthography
  - **Reading aloud:** converting orthography to speech output
- **Writing:** the act of producing orthography
- **Literacy:** knowledge of reading and writing

Differences between sounds & letters

- Same sound, different letters:
  - [f]: **f**at, **ph**at, lau**gh**
  - [i]: h**e**, bel**ie**ve, s**ei**ze, s**ea**, c**ae**sar, s**ee**, p**eo**ple, am**oe**ba, k**ey**, mach**i**ne
- Same letter, different sounds:
  - a: d**a**me [e], d**a**d [æ], f**a**ther [ɑ]
  - c+h: **ch**aracter [k], **ch**arge [tʃ], **ch**arade [ʃ]

Differences between sounds & letters

- Silent letters:
  - **p**sychology, **g**nat, **k**night, lam**b**, **h**eir, de**b**t
- Multiple letters, one sound:
  - a**dd** [d], po**ck**et [k], p**ea**t [i], so**ng** [ŋ], **sh**arp [ʃ], **th**in [θ]
- One letter, multiple sounds:
  - ta**x**i [ks], e**x**am [gz], **u**se [ju]

The relation between sound and writing

- Writing systems (partially) reflect phonetics and/or phonology of speech
  - Different for different languages
  - Not all languages have writing systems

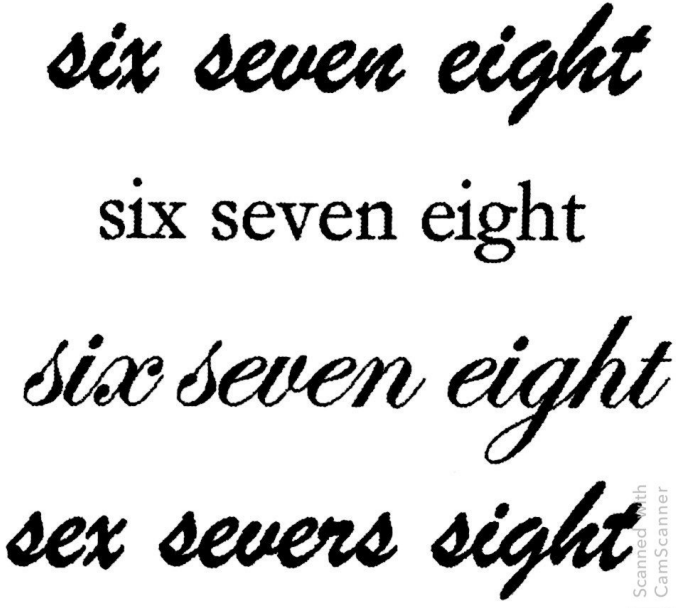
Size and shape invariance

- Letters are high-level perceptual categories (like phonemes)

Different sizes perceived as the same letters/words

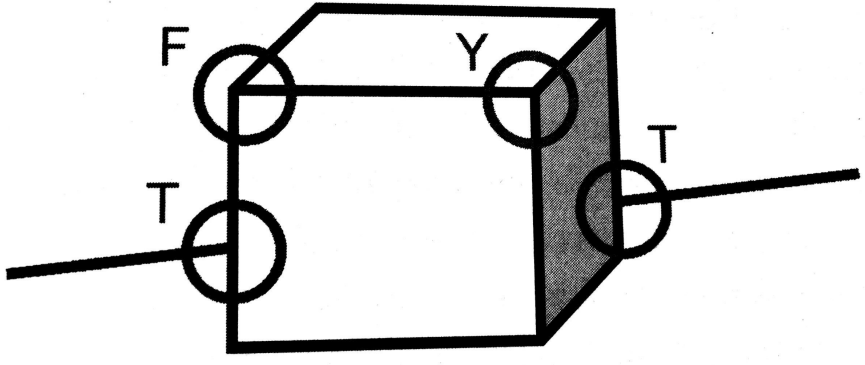
six seven eight
six seven eight
six seven eight
six seven eight
six seven eight
six seven eight
six seven eight

Different fonts perceived as the same letters/words



Perceptual basis of orthography

- Letters (and orthographic forms generally) formed from intersections of lines that are commonly found in our perceptual environment
- Crucial for efficient visual perception

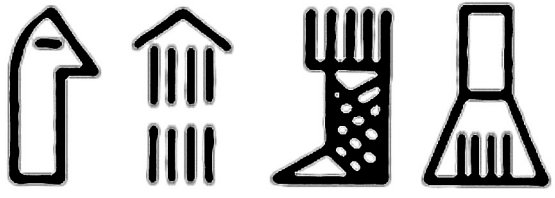


Writing: a cultural invention

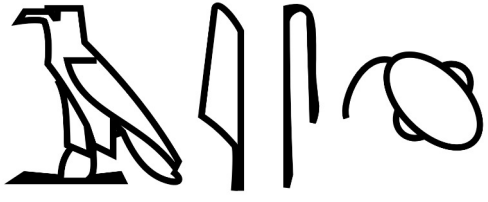
- Writing invented ~5,000 years ago
- Independently developed in at least four civilizations:
  - Mesopotamia (3400-3100 BC)
  - Egypt (~3250 BC)
  - China (~1200 BC)
  - Mayan (~500 BC or before)

- Diverse kinds of writing systems:
  - Alphabetic (phonemic; e.g. Roman)
  - Syllabic (e.g. Devanagari)
  - Semantic-phonetic (e.g., Chinese logograms, hieroglyphs, etc.)

Sumerian pictograms



Egyptian hieroglyphs



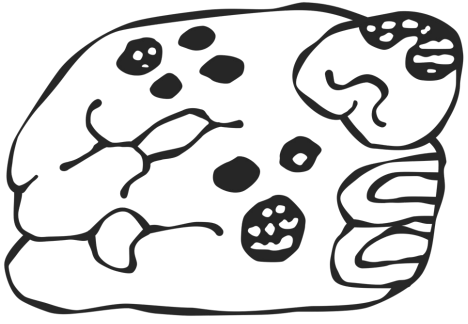
Chinese ideograms

天地玄黃

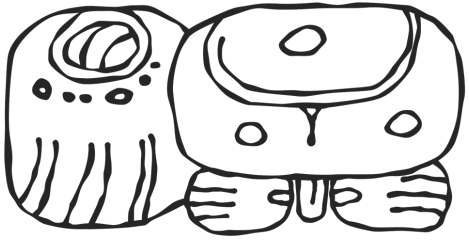
Old Persian cuneiform

Mayan logograms

Logogram

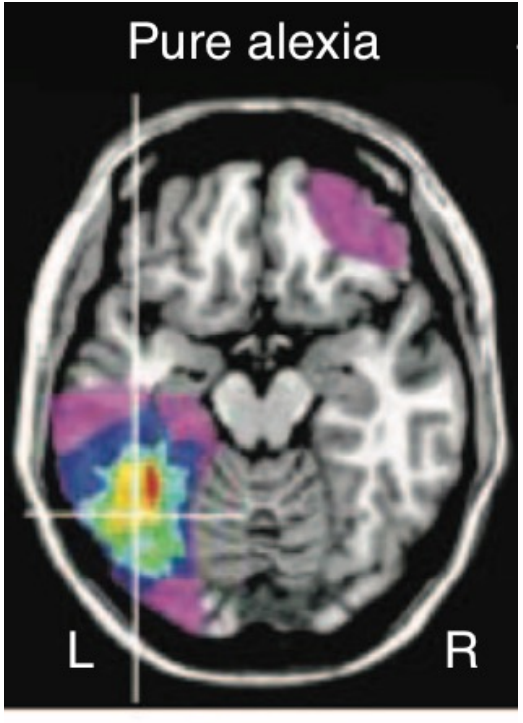


Syllabic form



A brain area specialized for words

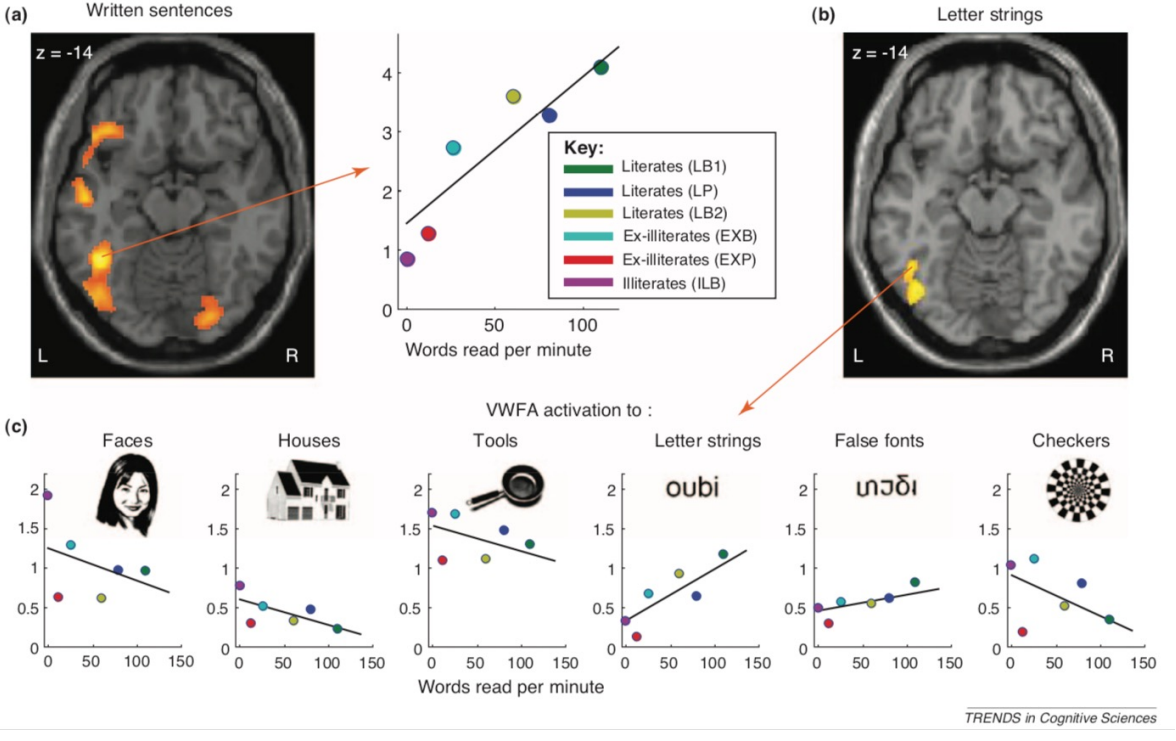
- **Alexia:** acquired specific deficit of reading ability (with general visual perception intact)
- Results from relatively focal damage of/stimulation to inferior occipital-temporal cortex



Dehaene & Cohen (2007; 2011)

A brain area specialized for words

- **Visual word form area (VWFA)**: brain area specialized for orthography over other complex visual stimuli
- Degree of specificity of activation tied to degree of literacy



Dehaene & Cohen (2007; 2011)

A brain area specialized for words

- Our brain is the product of millions of years of evolution in a world *without* writing
- How is it that children acquire this amazing ability, such that it becomes a crystallized facet of our brain?
- https://youtu.be/Uq5SsCsOsDY

Dehaene & Cohen (2007; 2011)

Neuronal recycling

- Innate constraints on brain architecture and function
- Circuits have within these constraints a range of plasticity
- Cultural acquisition capitalizes on brain plasticity
- Our brain adapts to a culture by tuning its predispositions to a different use, “recycling” them for new but related purposes

Dehaene & Cohen (2007; 2011)

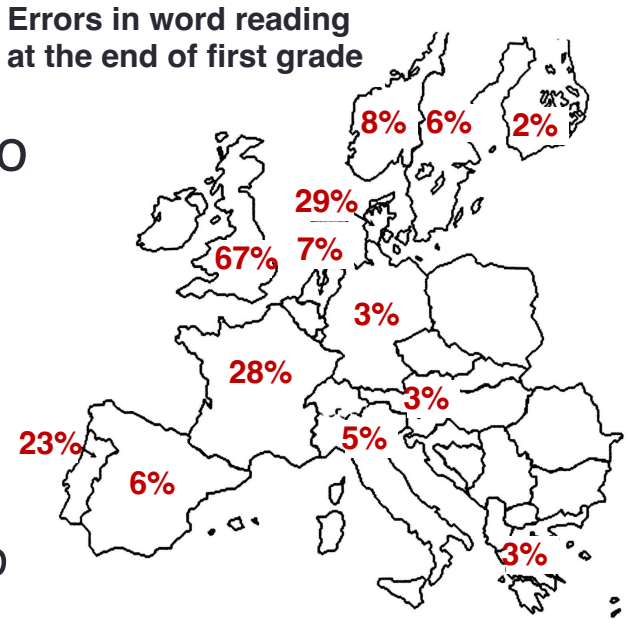
Reading & neuronal recycling

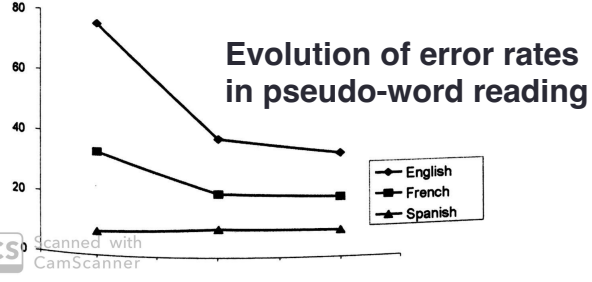
- Adaption of high-level visual perceptual abilities to process letters and words
- Development of connections between VWFA and language systems (phonology, morphology, syntax, semantics)
- A long and difficult process of re-wiring our brains!

Learning to read & phonological transparency

- **Phonological transparency**: degree to which letters correspond to phonemes
- Phonological transparency is different for different languages
  - English: relatively opaque relationship
  - Spanish: relatively transparent relationship
- Errors in word reading related to the phonological transparency of the language

Dehaene (2007)





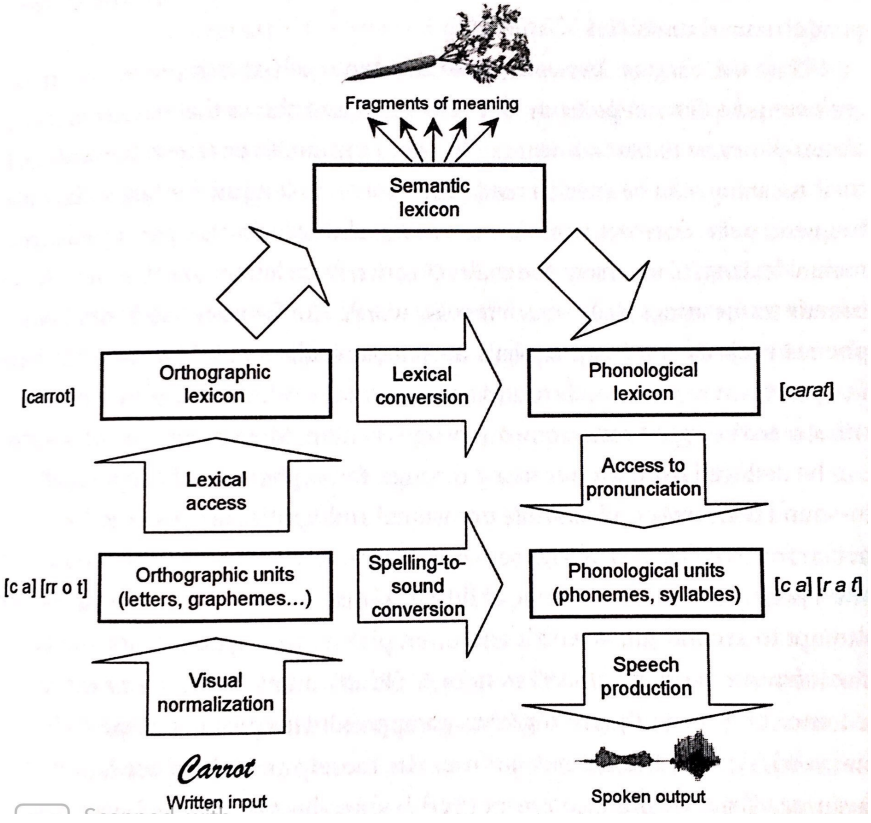
Reading Development

Dual route model of reading

- **Phonological Route:** letter-sound decoding
  - Letters -> phonemes -> pronunciation
  - Go from orthography to phonemes (“grapheme-phoneme conversion”) before accessing meaning (or without accessing meaning at all)
  - Used for new words, less frequent words
- **Orthographic Route:** strings of letters mapped to words
  - Letters -> meaning -> phonemes -> pronunciation
  - Can go straight from orthography to meaning without having to “sound out” each letter
  - Used for frequent real words
  - Parallel processing of letters

Coltheart et al., 2001

Dual route model of reading



Dehaene, 2007

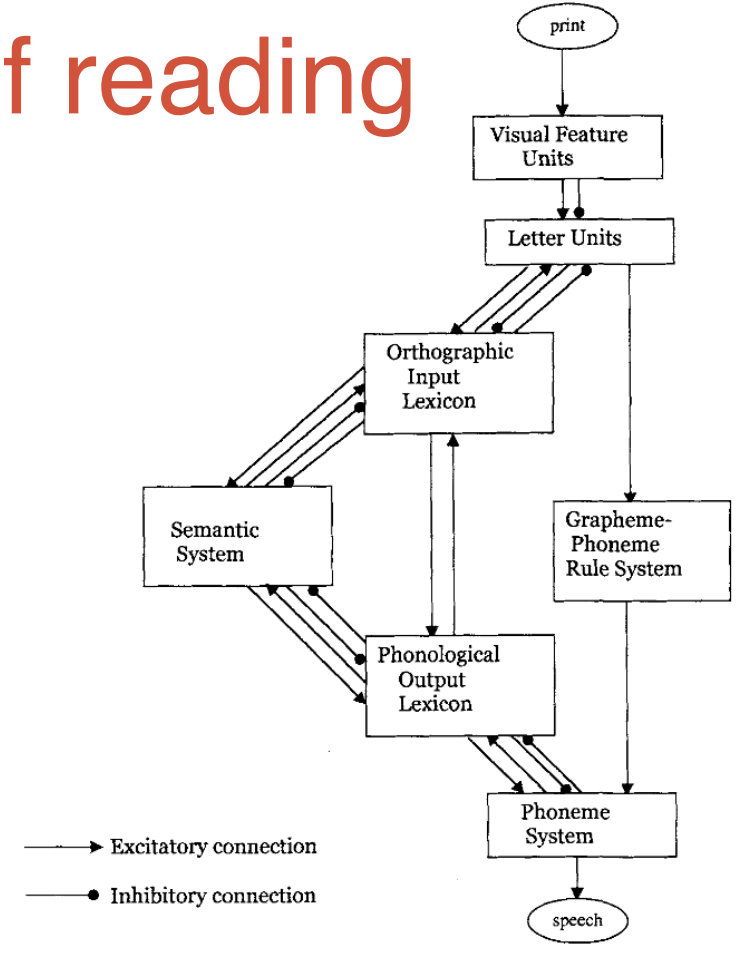


Figure 7. The dual-route cascaded model of visual word recognition and reading aloud.

Coltheart et al., 2001

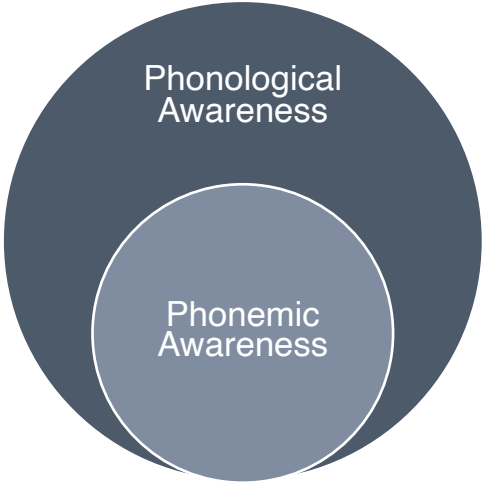
Decoding v. Comprehension

1. **Decoding:** extracting phonemes from letters

2. **Comprehension:** recognizing morphemes, building structure, comprehending meaning

Phonological & Phonemic awareness

- **Phonological awareness:** metalinguistic knowledge about phonology *generally* (including phonemes, prosody, syllable structure, etc.)
- **Phonemic awareness:** phonological awareness *specifically concerning phonemes*
- https://youtu.be/NnUhPhKvC2g



Phonological & Phonemic awareness

Phonological awareness	Phonemic awareness
Identify oral rhymes (e.g., cat-bat)	Break down a word into its component phonemes (e.g., /k/-/æ/-/t/)
Clap out the number of syllables in a word (e.g., el-e-phant)	Blend component phonemes together to form the word
Recognize words with same initial sounds (e.g., money-mother)	Identify sounds at the beginning and end of words

Phonemic awareness

- Important for learning to read in an alphabetic writing system
- Fundamental to mapping of speech to print
- A strong predictor of children who experience early reading success
  - Chicken & egg problem: does phonemic awareness feed into reading abilities, or does reading ability facilitate phonemic awareness?
  - Answer not completely straightforward

Top-Down or Bottom-up?

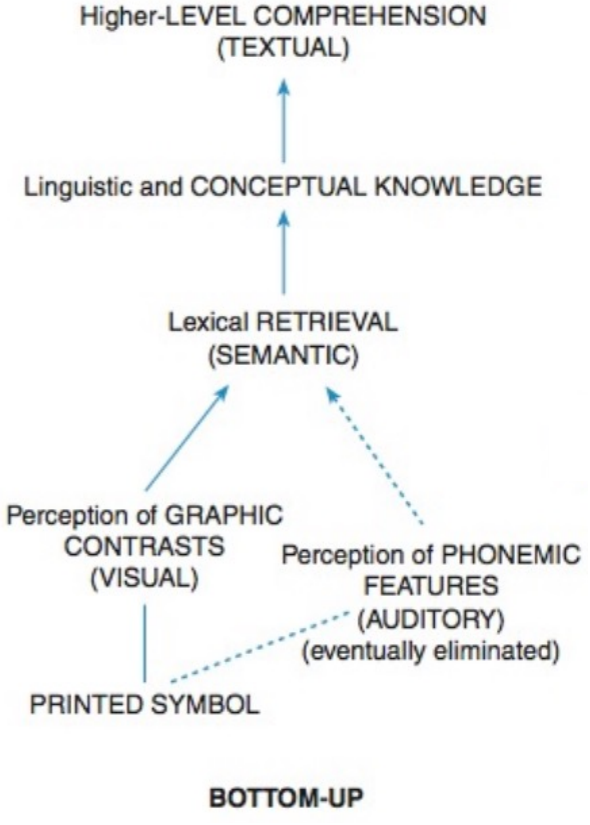
- **Bottom-up processes:** lower-level perceptual processes influences higher-order cognitive processes

- **Top-down processes:** “problem-solving”; higher-order cognitive functions influence lower-level perceptual processing

- Mature reading (as well as speech comprehension) relies upon both

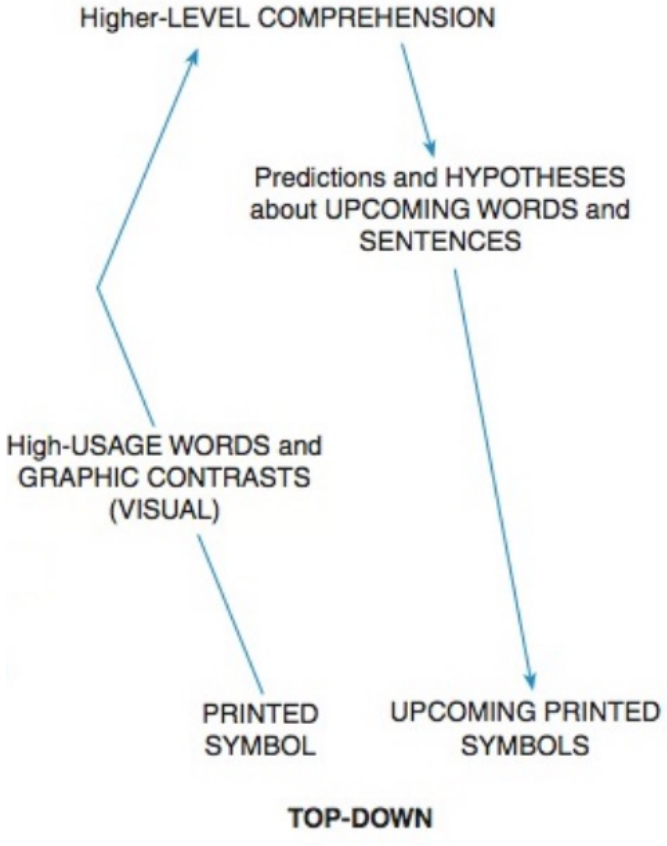
Bottom-Up Processes in Reading

- Relatively automatic processes that are triggered based on sensory input (i.e., looking at the page)
  - Visual perception
  - Orthographic pattern recognition
  - Lexical access and retrieval
- These become more automatic with experience



Top-Down Processes in Reading

- Higher-level information (either linguistic or executive control) that impacts the reading process
  - Recognition of high frequency words
  - Syntactic and semantic cues
  - Hypothesis testing and prediction
- Phonological awareness: metalinguistic knowledge that is used in a top-down way to facilitate learning to read

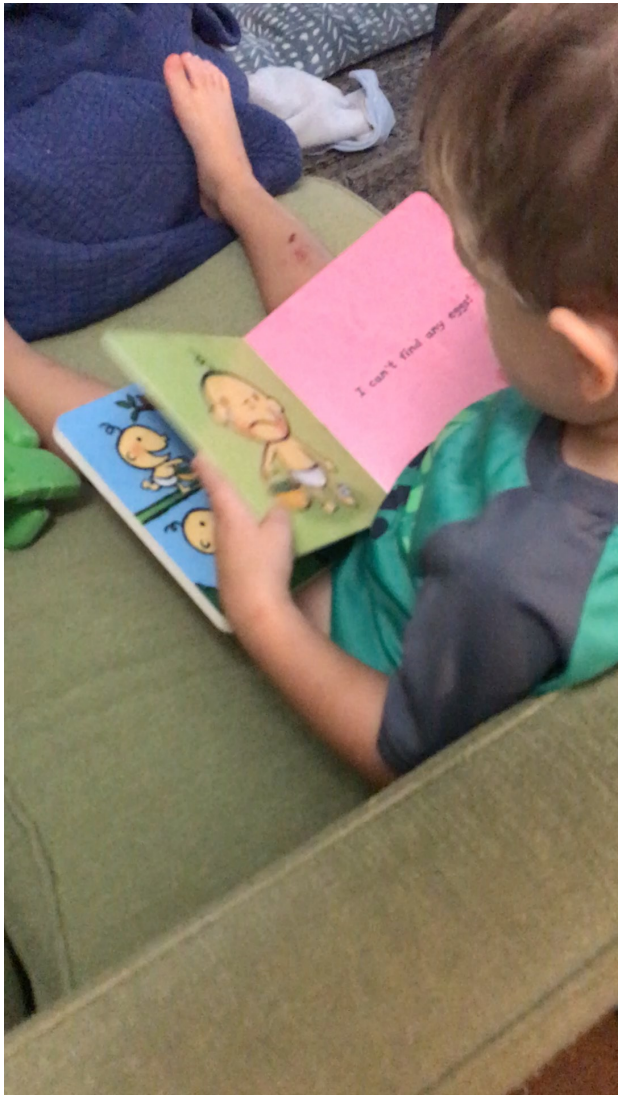


Early reading development

- Begins with reading-related social interactions between caregiver and child (e.g., book sharing)
- Early book-sharing:
  - Conversational in nature
  - Focused on the images not the text
- Around the age of 2, parents typically start “reading” the book in a more traditional sense

Print awareness

- By age 3, children can recognize their favorite books
- **Print awareness:** knowing the direction in which a book is read (front to back), knowing text is read from left to right, recognizing some letters, being interested in the words
- No phoneme-grapheme (sound-to-letter) correspondence yet – it's all rote memory
- "Pretend" book-reading begins to emerge



Stages of reading development

1. Logographic/pictorial stage

2. Phonological/alphabetic stage (development of phonological route)

3. Orthographic stage (development of orthographic route)

Logographic stage

- Words start off as images/pictures: can be recognized as distinct from each other, but no *system* of reading
  - No generalization into orthographic categories
- At age 4, most children can recognize their own names and a few high-frequency (memorized) words
- Words are first learned within one context (e.g., signs, package labels, their names on their cubby at school)
- Words gradually become decontextualized until they are recognized in print alone (i.e., out of context)

Phonological/Alphabetic phase

- **Phonological/Alphabetic Phase:** focus on decoding phonemes from words
- Age 2: some awareness of sounds in their speech (e.g., rhyming, word/sound play)
- Age 4: attending to the “internal structure” of words
  - Develops from larger to smaller segments
  - Awareness of syllable structure
  - Emerging segmentation abilities
  - Some formal instruction required

Phonological/Alphabetic phase

- Biggest challenge is employing metalinguistic processes to extract phonemes from letters

- **Phonics:** Formal instruction on the sound-letter correspondence

- https://www.youtube.com/watch?v=saF3-f0XWAY

Orthographic phase

- **Orthographic phase:** Applying knowledge of orthographic patterns and contextual references to analyze unknown words
- Large inventory of automatically-recognized words
- No need to “sound out” words anymore – phonological awareness abilities become less closely tied to reading abilities
- Shift from “Learning to Read” to “Reading to Learn”

Reading development: formal instruction

- Comprehension is constructed via the interaction of print with personal meanings and experiences
- Major advances in comprehension starting in 4th grade
- By high school, adolescents are able to use higher-level skills to aid comprehension at a deeper level

Stages of comprehension ability

- **Primary/literal stage:** early school age
  - What the text says
  - Foundation for more advanced comprehension
- **Critical/inferential stage:** around 4th grade
  - Interpretation, analysis, synthesis
  - Going beyond the literal meaning of each sentence and tying sentences together coherently
- **Dynamic/evaluative stage:** continues until high school/adulthood
  - Relation of material to other knowledge

Writing development

- Not *just* generating written characters
  - Involves all other creative aspects of language

- Writing relies on many different interdependent processes:
  - Motor skills
  - Orthographic knowledge
  - Executive function
  - Memory

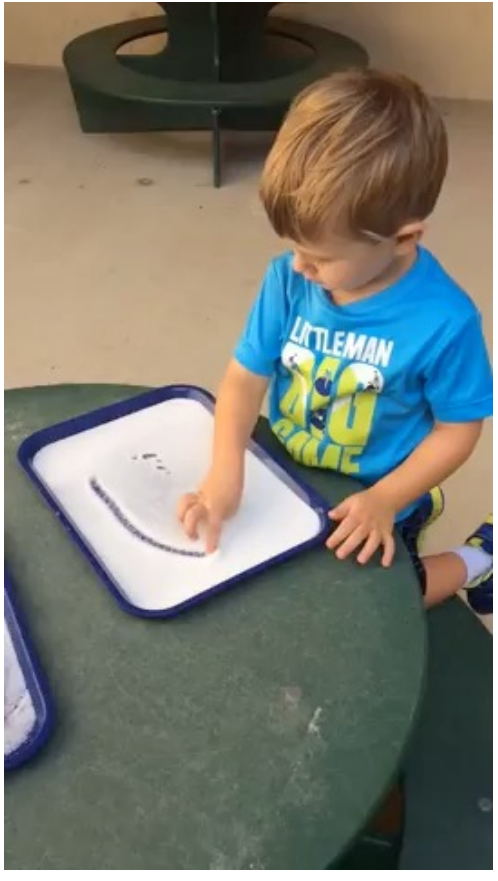
Orthographic knowledge

- **Orthographic knowledge:** information stored in memory that determines how we represent spoken language in written form
  - **Mental graphemic representations:** specific sequences of graphemes (i.e., letters) representing written words
  - **Orthographic patterns:** rules about how speech is represented in writing (e.g., grapheme-phoneme correspondence, how letters can and cannot be organized within words)

Orthographic knowledge development

- Both aspects of orthographic knowledge develop early and continue developing throughout elementary school

- Learned implicitly through preschool and kindergarten

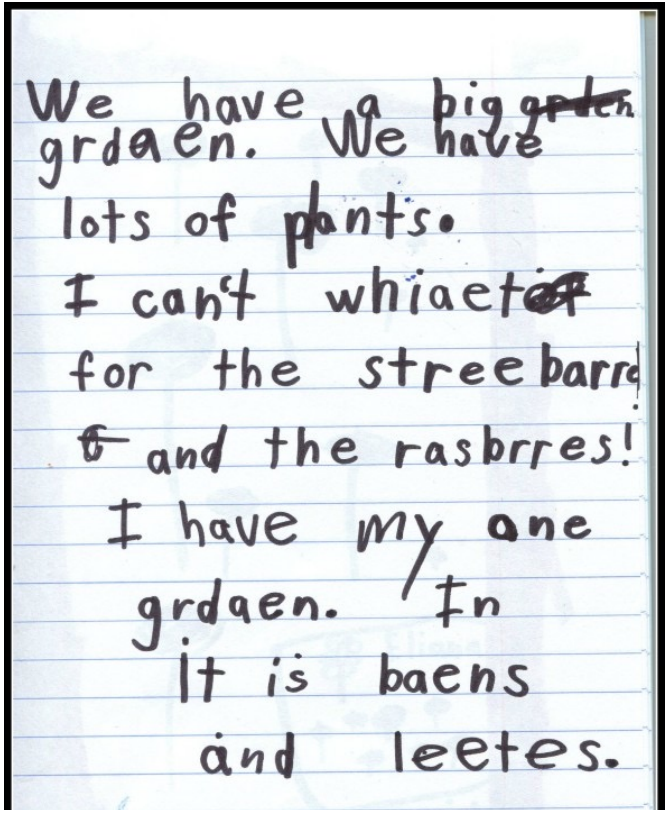


Spelling development

- Initially, scribbles with the occasional letter included
- Starts to rely upon grapheme-phoneme knowledge
- Gradually becomes aware of conventional spelling rules

Spelling development

- **Invented spelling:** early phase in which child uses letters to represent groups of sounds without knowing or using the correct spelling
  - E.g. *SKP* for *escape*; *LFT* for *elephant*
- **Phonemic spelling:** later phase of invented spelling in which awareness of grapheme-phoneme correspondence is more evident
  - E.g. *he had a blue clth. It trd in to a brd*



Recap

- Learning to read: neuronal retuning
  - Harnessing pre-existing systems to process linguistic information
  - Difficult process of re-wiring our brain
- Phonemic awareness
  - Metalinguistic ability that facilitates learning to read
- Two routes for reading:
  - Phonological decoding & “sounding out”
  - Orthographic route and direct conversion of letters to lexicon
- Stages of reading development
  - Pictographic phase
  - Alphabetic phase
  - Orthographic phase