

Language

Computational Cognitive Neuroscience
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Language is Special

- Symbols
- Syntax
- Temporally-extended sequences
- Cultural transmission
- Embedded levels of structure:
 - "The horse raced past the barn fell"
 - "Isn't it true that example-sentences that people that you know produce are more likely to be accepted?"

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What is Truly Novel?

- Pure syntax: "Adj Adj Noun Verb Adverb"
- "Colorless green ideas sleep furiously"
 - But: "Newly formed bland ideas are inexpressible in an infuriating way."
 - "It can only be the thought of verdure to come, which prompts us in the autumn to buy these dormant white lumps of vegetable matter covered by a brown papery skin, and lovingly to plant them and care for them. It is a marvel to me that under this cover they are labouring unseen at such a rate within to give us the sudden awesome beauty of spring flowering bulbs. While winter reigns the earth reposes but these colourless green ideas sleep furiously."
- "'Twas brillig, and the slithy toves..."
 - But each word has *some* overlap with real words..

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Language Involves all of Cognition

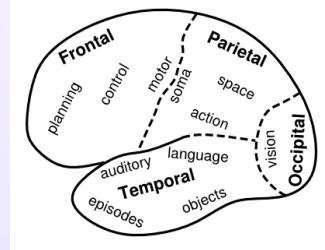
Perception: hearing & reading words

Attention: picking out words, speakers from many

Motor: speech, writing, etc

Memory: semantics, specific content – how do you encode plot of a book?

Executive Function:
maintaining context, planning speech, syntax structure..



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Language Controversies

- How special is language: just co-opting existing neural mechs vs. innate language modules?
- Rules vs. regularities: is there anything special about rule-like behavior in language?
 - Spelling to sound: Exceptions also have sub-rules..
 - Overregularization (add "-ed" = "goed") – evidence of rule system coming online?
 - Truly variable-like behavior? Generative, abstract.

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Time and Language

- Distributed representation broken down and sent over a sequential channel:



The summer is a fun time for going to the beach, dancing, ...

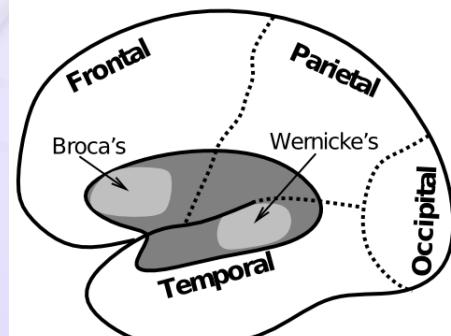
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Distributed Reps of Words

I cnndo't byleeee taht I culod aulacly uesdtannrd waht I was rdnaieg. Unisg the icndeblire pweor of the hmuan mnid, aocdcrnig to rseecrah at Cmabrigde Uinervtisy, it dseno't mtaer in waht oderr the iterets in a wrod are, the olny ipoamntihng is taht the frsit and lsat ltteer be in the rght pcle. The rset can be a taotl mses and you can still raed it whoutit a pboerm. Tihs is bucseae the huamn mnid deos not raed ervey ltteer by istlef, but the wrod as a whole. Aaznmig, huh? Yaeh and I awlyas tghhuot slelinpg was ipmorant! See if yuor fdreins can raed tihs too.

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Biology of Language



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Example of Wernicke's Aphasia

"How are you today?":

"Gossipping O.K. and Lords and cricket and England and Scotland battles. I don't know. Hypertension and two won cricket, bowling, batting, and catch, poor old things, cancellations maybe gossiping, cancellations, arm and argument, finishing bowling."

<https://www.youtube.com/watch?v=aVhYN7NTIKU>

End of the football. It influence the football right here. It crawls and it comes in, see? The end of it. Oh, we got a lot of these, see?

Well, it's playable in the government. You don't understand it, but it pauses in the long very cumbersome and it comes source in the country out through. All the under it, see, comes up, finally it comes up here and goes out... It comes in and comes out and BING That's a good free throw, see?

That's a good throw slow moyse fire, fire. See slows it cold or it gives or kicks out or bing or whatever it is, we has no for football farther down. It's just pulling, see, but they say feel good. I guess it reminds you half dead or I don't even know.

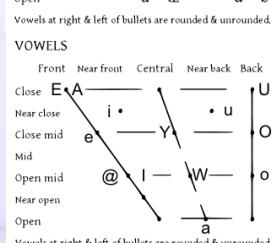
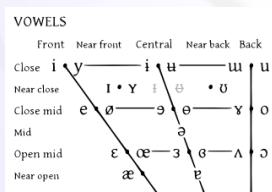
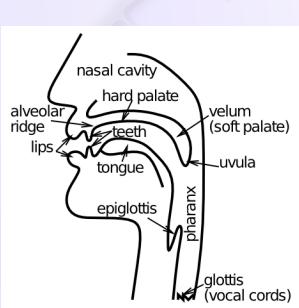
Where do you live? If you live, you appear, see. Where do you leave? Where do you live is, well friends are front and center here around here.

Yes. Right here. Rest of the hearing. How many? Holy Christmas! Oh about a hundred, let's see about a hundred and thirty. About Forty. Gosh, what time is it? One plus five...

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Wernicke's Aphasia

Speech Output



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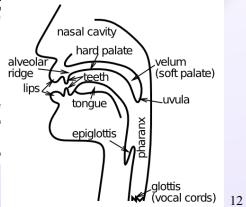
Speech Output

CONSONANTS (PULMONIC)										PHARYNGEAL	GLOTTAL	LARYNGEAL
	TAP	LABIO-DENTAL	LABIAL	ALVEOLAR	PALATO-ALVEOLAR	RETROFLEX	PALATAL	VELAR	UVULAR	PHARYNGEAL	GLOTTAL	LARYNGEAL
Nasal	m	n̩	n̩	n̩	n̩	t̩	j̩	ŋ̩	ŋ̩	?	?	?
Plosive	p̩	b̩	p̩	f̩	v̩	θ̩	θ̩	s̩	z̩	t̩	d̩	?
Frictional	ɸ̩	β̩	ɸ̩	f̩	v̩	θ̩	θ̩	ʃ̩	ʒ̩	ç̩	ç̩	χ̩
Approximant						v̩	x̩	x̩	x̩	x̩	x̩	x̩
Trill						r̩	j̩	w̩		R̩		R̩
Tap/Flap						t̩	t̩	t̩	t̩			
Lateral trill						t̩	t̩	t̩	t̩			
Lateral approximant						l̩	l̩	l̩	l̩			
Lateral flap						l̩	l̩	l̩	l̩			

Where symbols appear in pairs, the one to the right represents a modally voiced consonant, except for nasal. Shaded areas denote articulations judged to be impossible. Light grey letters are unofficial extensions of the consonants.

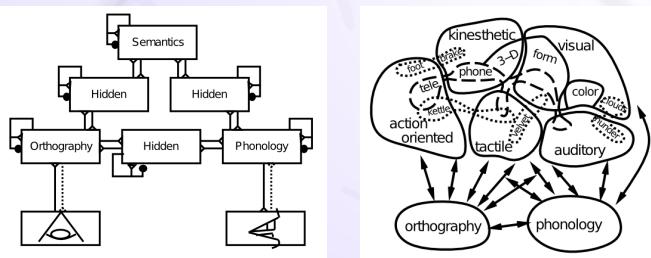
CONSONANTS (NON-PULMONIC)			CONSONANTS (CO-ARTICULATED)		
Anterior click releases (require posterior stop)	Voiced implosives	Ejectives	M	Voiceless labialized velar approximant	
Ø Bilabial fricative	b Bilabial	* Examples:	W	Voiceless labialized velar approximant	
ʃ Lateral bilabial ("lateral")	d Dental or lateral	t Bilabial	U	Voiceless labialized palatal approximant	
ɸ Alveolar (postalveolar)	f Palatal	t' Dental or lateral	ç	Voiceless palatalized postalveolar (alveo-palatal)	
χ Alveolar ("retroflex")	g Velar	k' Velar	Z	Voiceless palatalized postalveolar (alveo-palatal)	
χ' Lateral ("retroflex")	g' Uvular	g' Alveolar	ʒ	Simultaneous x and f (disputed)	
Lateral ("lateral")			ɸ	Articulates and double articulations may	
Fricated ("lateral")			ts		

M Voiceless labialized velar approximant
W Voiceless labialized velar approximant
U Voiceless labialized palatal approximant
ç Voiceless palatalized postalveolar (alveo-palatal)
Z Voiceless palatalized postalveolar (alveo-palatal)
ʒ Simultaneous x and f (disputed)
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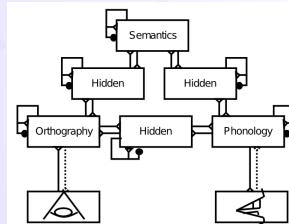
Reading: The “Triangle Model”



NOTE: There is no single “lexicon”, no “word units”

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Acquired Dyslexia



- **Phonological:** nonword (“nust”) errors
- **Deep:** phono + semantic errors (“dog” → “cat”) + visual errors (“dog” → “dot”)
- **Surface:** exception (“yacht”) errors + visual errors + impaired semantic access

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Regularities & Exceptions

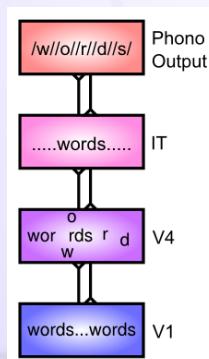
- Pronounce “bint”
- (c.f., mint, hint vs. mind, find vs. pint)
- English pronunciation has partial, context-dependent regularities (“rules”?)

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Reading = Object Recognition

- Invariance: b = “b” regardless
- Context dependence: i depends on neighbors (just like any visual features in object)

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Nonword Performance

Regularity tests (Glushko): bint → /bint/

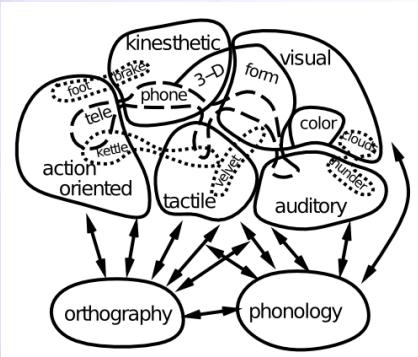
Pseudo-homophones (McCann & Besner):
phoyce → /fYs/, choyce → /CYs/

Matched regularity/exception cases (Taraban):
High freq: poes → /pOz/, goes → /gOz/, does → /dɔz/
Low freq: mose → /pOs/, poes → /pOz/, lose → /lUz/

Nonword Set	Model	PMSP	People
Glushko regulars	95.3	97.7	93.8
Glushko exceptions raw	79.0	72.1	78.3
Glushko exceptions alt OK	97.6	100.0	95.9
McCann & Besner ctrls	85.9	85.0	88.6
McCann & Besner homoph	92.3	n/a	94.3
Taraban & McClelland	97.9	n/a	100.0

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Semantics



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Word Statistics

- Can you infer word meaning from the company it keeps???
 - Yes! Latent Semantic Analysis (LSA)
- Just like V1 RF model – extract statistical structure from natural correlations in language

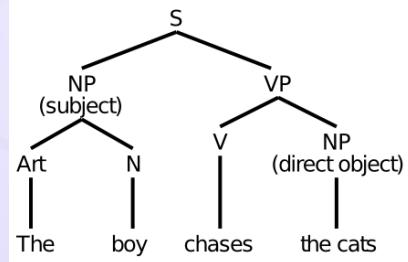
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Multiple Choice Quiz

0.	neural activation function A spiking rate code membrane potential pt B interactive bidirectional feedforward C language generalization nonwords	5. attention A competition inhibition selection binding B gradual feature conjunction spatial invariance C spiking rate code membrane potential point
1.	transformation A emphasizing distinctions collapsing diffs B error driven hebbian task model based C spiking rate code membrane potential pt	6. weight based priming A long term changes learning B active maintenance short term residual C fast arbitrary details conjunctive
2.	bidirectional connectivity A amplification pattern completion B competition inhibition selection binding C language generalization nonwords	7. hippocampus learning A fast arbitrary details conjunctive B slow integration general structure C error driven hebbian task model based
3.	cortex learning A error driven task based hebbian model B error driven task based C gradual feature conjunction spatial invar	8. dyslexia A surface deep phonological reading problem B speech output hearing language nonwords C competition inhibition selection binding
4.	object recognition A gradual feature conjunction spatial invar B error driven task based hebbian model C amplification pattern completion	9. past tense A overregularization shaped curve B speech output hearing language nonwords C fast arbitrary details conjunctive

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Sentences and Syntax



Is this how it really works??

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Those Pesky Time Flies..

- Time flies like an arrow.
- Fruit flies like a banana.
- The slippers were found by the nosy dog.
- The slippers were found by the sleeping dog.
- Syntax depends on semantics very deeply..

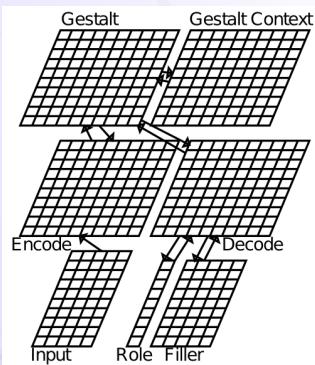
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The “Gestalt” Alternative

- Just try to get the gist of what the sentence is saying:
- G. W. Bush:
“Families is where our nation finds hope, where wings take dream.”
- Does this really work? How?

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Sentence Gestalt Model



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SG Toy World

- People: *busdriver* (adult male), *teacher*, (adult female), *schoolgirl*, *pitcher* (boy). *adult*, *child*, *someone* also used.
- Actions: *eat*, *drink*, *stir*, *spread*, *kiss*, *give*, *hit*, *throw*, *drive*, *rise*.
- Objects: *spot* (the dog), *steak*, *soup*, *ice cream*, *crackers*, *jelly*, *iced tea*, *kool aid*, *spoon*, *knife*, *finger*, *rose*, *bat* (animal), *bat* (baseball), *ball* (sphere), *ball* (party), *bus*, *pitcher*, *fur*.
- Locations: *kitchen*, *living room*, *shed*, *park*.

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SG Example/Probe Sentences

- **Active semantic:** *The schoolgirl stirred the kool-aid with a spoon.* (kool-aid can only be the patient, not the agent of this sentence)
- **Active syntactic:** *The busdriver gave the rose to the teacher.* (teacher could be either patient or agent -- word order syntax determines it).
- **Passive semantic:** *The jelly was spread by the busdriver with the knife.* (jelly can't be agent, so must be patient)
- **Passive syntactic:** *The teacher was kissed by the busdriver.* vs. *The busdriver kissed the teacher.* (either teacher or busdriver could be agent, syntax alone determines which it is).
- **Word ambiguity:** *The busdriver threw the ball in the park.*, *The teacher threw the ball in the living room.* (ball is ambiguous, but semantically, busdriver throws balls in park, while teacher throws balls in living room)

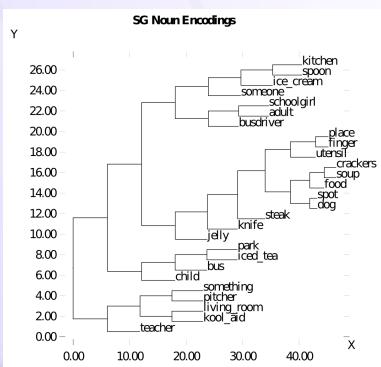
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SG Example/Probe Sentences

- **Concept instantiation:** *The teacher kissed someone.* (male). (teacher always kisses a male -- has model picked up on this?)
- **Role elaboration:** *The schoolgirl ate crackers.* (with finger); *The schoolgirl ate.* (soup) (these are predominant cases)
- **Online update:** *The child ate soup with daintiness.* vs. *The pitcher ate soup with daintiness.* (schoolgirl usually eats soup, so ambiguous child is resolved as schoolgirl in first case after seeing soup, but specific input of *pitcher* in second case prevents this updating).
- **Conflict:** *The adult drank iced-tea in the kitchen.* (living-room) (iced-tea is always had in the living room).

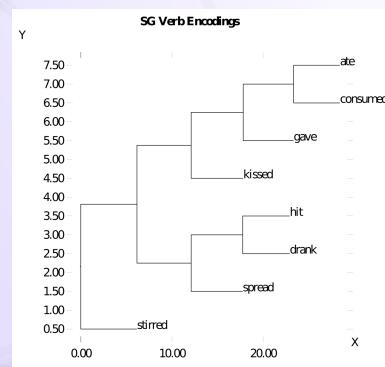
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Gestalt Representations



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Gestalt Representations



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Gestalt Representations

