

Psych 156A/ Ling 150: Psychology of Language Learning

Lecture 7 Morphology I

Announcements

Pick up HW1 if you haven't done so

Be working on HW2

Review questions available for morphology

Lecture 6 reposted with corrections

Morphology: Affixes

Computational Problem: Identifying word *affixes* that signal meaning.

affix = sound sequence smaller than an entire word that is attached to a word in order to indicate some additional meaning
(also known as **bound morphemes** - small units of meaning that cannot stand on their own. Instead they must be attached to some other word.)

affix examples: prefix (**un-** in *unsolvable*), suffix (**-ed** in *kissed*)

un- = not, *un-* + *solvable* = *unsolvable* = not solvable
"This labyrinth is unsolvable!"

-ed = past tense, *kiss* + *-ed* = *kissed* = kiss (past tense)
"Sarah almost kissed Jareth last night in the ballroom."

Focusing in on past tense morphology

What do you have to change about the verb to signal the past tense in English? (There are both **regular** and **irregular** patterns.)

blink~blink ed	confide~confid ed	drink~drank (not drunk)
rub~rub bed	hide~hid (not hid)	think~ thought (not think)

Focusing in on past tense morphology

What do you have to change about the verb to signal the past tense in English? (There are both **regular** and **irregular** patterns.)

blink~blink**ed**
(+ed)
[əd]

confide~confid**ed**
(+ed)
[əd]

drink~drank
("ih" --> "ey")
[ɪ] --> [e]

rub~rub**bed**
(+ed)
[əd]

hide~hid
("i" --> "ih")
[aɪ] --> [ɪ]

think~thought
("ink" --> "ought")
[ɪŋk] --> [ɔt]

Children's performance: Regular past tense pattern overused

"My teacher **holded** the baby rabbits and we **patted** them"

holded = hold + ed

Regular +ed pattern is applied to verb that actually has an irregular pattern to form the past tense

(hold ~ held)



This is an example of an **overregularization** error.

English past tense overregularization tends to happen between the end of the first year and the end of the second year for children.

Children's performance: Regular past tense pattern overused

What this means:

In order for children to have over-applied the regular past tense pattern for English, they must have already figured out that there *is* a regular past tense pattern for English.



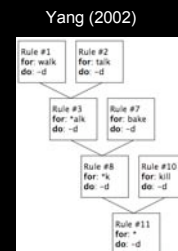
Not necessarily so easy to figure out the regular pattern: Requires children to abstract across different pronunciations of "+ed" that signal the past tense:

baked	clawed	folded
baked	clawed	folded
[t]	[d]	[əd]

How children might discover the regular pattern

"My teacher **holded** the baby rabbits and we **patted** them"

Observation and abstraction process



How children might discover the regular pattern

"My teacher **holded** the baby rabbits and we patted them"

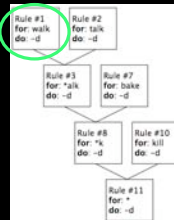
Observation and abstraction process

"Ludo **walked** over to Sarah."

Pattern: walk --> **walked**

This pattern works for "walk".

Yang (2002)



How children might discover the regular pattern

"My teacher **holded** the baby rabbits and we patted them"

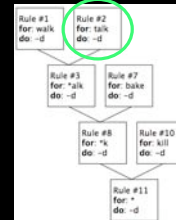
Observation and abstraction process

"Hogge **talked** to Sarah."

Pattern: talk --> **talked**

This pattern works for "walk" and "talk".

Yang (2002)



How children might discover the regular pattern

"My teacher **holded** the baby rabbits and we patted them"

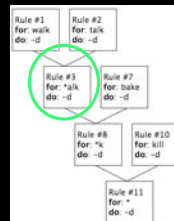
Observation and abstraction process

"walk" and "talk" both end in "-alk".

Abstraction, based on data:

+ed for words ending with -alk

Yang (2002)



How children might discover the regular pattern

"My teacher **holded** the baby rabbits and we patted them"

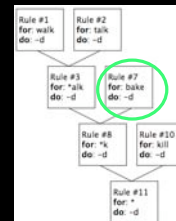
Observation and abstraction process

"Didymus **baked** Sarah a cake."

Pattern: bake --> **baked**

This pattern works for "-alk" words and "bake".

Yang (2002)



How children might discover the regular pattern

"My teacher **hold**ed the baby rabbits and we **patt**ed them"

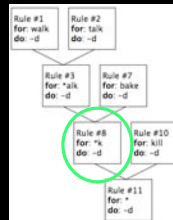
Observation and abstraction process

"-alk" words and "bake" both have the "k" sound at the end.

Abstraction, based on data:

+ed for "-k" words

Yang (2002)



How children might discover the regular pattern

"My teacher **hold**ed the baby rabbits and we **patt**ed them"

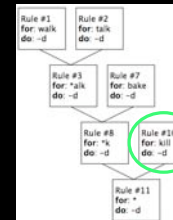
Observation and abstraction process

"Hoggie would have gladly **kill**ed the mean fairy."

Pattern: kill --> killed

This pattern works for "-k" words and "kill".

Yang (2002)



How children might discover the regular pattern

"My teacher **hold**ed the baby rabbits and we **patt**ed them"

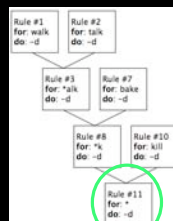
Observation and abstraction process

"-k" words and "kill" use this +ed rule.

Abstraction, based on data:

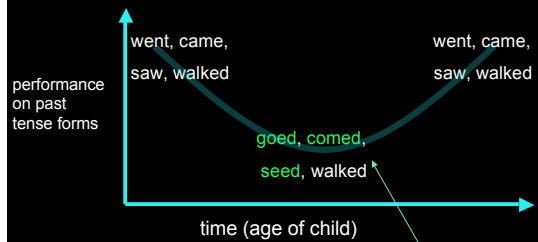
+ed for any word

Yang (2002)



Developmental Trajectory of Past Tense

U-shaped development (often occurs, but not always)



Why U-Shaped Performance?

U-Shaped: Children's performance on past tense verbs gets worse before it gets better, instead of always getting better. This happens because children **overregularize** verbs that actually follow irregular patterns.

hold --> holded

instead of

hold --> held

Why Overregularization?

Why do children overregularize?

It's not that children don't realize that the overregularized forms are wrong. The interaction below shows the child realizes that the overregularized form is incorrect.



Child: "You **readed** some of it too...she **readed** all the rest."
Parent: "She read the whole thing to you, huh?"
Child: "Nu-uh, you read some."
Parent: "Oh, that's right, yeah. I readed the beginning of it."
Child: "**Readed?** (*annoyed surprise*) Read! (*pronounced 'red'*)"
Parent: "Oh, yeah, read."
Child: "Will you stop that, Papa?"

Three ideas for how the mind represents past tense morphology knowledge

"**Words & Rules**": regular patterns are produced via a rule-like combinatorial process while irregular patterns are retrieved from associative memory

"**Words, No Rules**": both regular and irregular patterns are retrieved from associative memory

"**Rules, No Words**": both regular and irregular patterns are produced via a rule-like combinatorial process

"Words & Rules": explaining children's development

Why do children overregularize?

One idea: Children's memory is weaker than adults' memory is

Producing a past tense form is a process:

Intended form: VERB + past tense

Root form of VERB: VERB

If irregular VERB, past tense:

IRREGULAR PAST (retrieve from memory)

If regular VERB, past tense:

VERB + ed (apply regular rule)

“Words & Rules”: explaining children’s development

Why do children overregularize?

One idea: Children’s memory is weaker than adults’ memory is

Producing a past tense form is a process:

Intended form: walk + past tense

Root form of VERB: walk

If irregular VERB, past tense:

IRREGULAR PAST (retrieve from memory)

If regular VERB, past tense:

walk + ed (apply regular rule) = walked

“Words & Rules”: explaining children’s development

Why do children overregularize?

One idea: Children’s memory is weaker than adults’ memory is

Producing a past tense form is a process:

Intended form: go + past tense

Root form of VERB: go

If irregular VERB, past tense:

went (retrieve from memory)

If regular VERB, past tense:

VERB + ed (apply regular rule)

“Words & Rules”: explaining children’s development

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But what if children can’t retrieve the irregular past form in time to produce it when they speak?

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Intended form: go + past tense

Root form of VERB: go

If irregular VERB, past tense:

went (retrieve from memory)

If regular VERB, past tense:

go + ed (apply regular rule) = goed

But what if children can’t retrieve the irregular past form in time to produce it when they speak?

They may fall back on the regular verb combinatorial rule.

“Words & Rules”: explaining children’s development

Suppose overregularization happens because children’s memory is weaker than adults’ memory. It should be the case that the more often children hear a word, the easier it is to retrieve from memory.

Implication: The more often children hear irregular past tense forms like “went”, the easier it will become to retrieve those irregular past tense forms even when children already have a regular rule (+ed) they use for many other verbs.

Experimental support for this idea: **Children make more errors on words parents don’t use as frequently** (Marcus et al. 1992). (Presumably, this is because their memory for these verbs is weaker.)

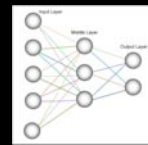
“Words, No Rules”: explaining children’s development

Is it really necessary to have learned rules, or could children (and adults) simply be learning (and using) associative memory to retrieve both regular and irregular patterns?

Pattern: hold~held, walk~walked, go~went

This kind of associative memory can be represented in Parallel Distributed Processing (PDP) computational models, sometimes referred to as **neural nets**. (Rumelhart & McClelland (1986))

Neural nets are very good at learning by analogy, and recognizing similar patterns in the data that is given to them.

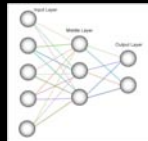


“Words, No Rules”: explaining children’s development

If the regular past tense pattern is really just a bunch of associations we have in our minds between root forms (like “walk”) and past tense forms (like “walked”), do we expect the same learning U-shaped behavior we see in children? Remember, that behavior was explained in the “Words & Rules” theory by children over-applying a regular past tense rule.

Pattern: hold~held, walk~walked, go~went

Rumelhart & McClelland (1986) found that a neural net could produce U-shaped behavior...

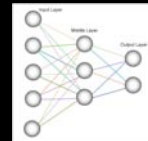


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Pattern: hold~held, walk~walked, go~went

Rumelhart & McClelland (1986) found that a neural net could produce U-shaped behavior...
...but only if it was given input data in a certain way. Specifically, it was first given very frequent irregular verbs (go~went, come~came, be~was) and then given less frequent regular verbs (walk~walked, kiss~kissed).



“Words, No Rules”: explaining children’s development

Implication: Pattern associator models like neural nets, which do not use rules, can produce U-shaped learning behavior.

Caveat: To do that, the models must receive different proportions of irregular verbs in their input at different points in time (high proportion early on, lower proportion later on).

Required Input

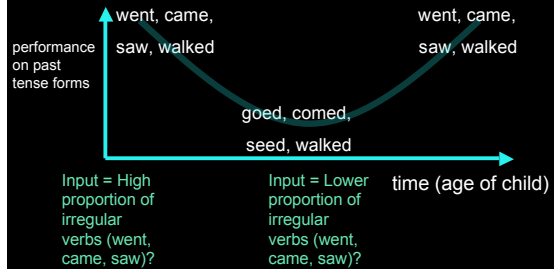
Early: mostly irregular verbs, few regular verbs

Later: some irregular verbs, some regular verbs

“Words, No Rules”: explaining children’s development

Empirical question: Does the proportion of irregular and regular verbs in a child’s input change over time?

Expectation:



“Words, No Rules”: explaining children’s development

Empirical question: Does the proportion of irregular and regular verbs in a child’s input change over time?

Reality: The proportion of irregular verbs in the child’s input does not seem to change over time, or does not change at the right time to produce the U-shaped behavior at the right time in a neural net.

(Pinker 1995)

Implication: Associative memory alone would have difficulty explaining children’s developmental trajectory.

“Words, No Rules”: explaining children’s development

Another prediction: similar patterns should reinforce each other...and reinforce overregularization errors

holded ~ folded ~ scolded ~ ...	drinked ~ blinked
(many regular pattern neighbors)	(few regular pattern neighbors)
= <i>hold</i> overregularized a lot	= <i>drink</i> overregularized rarely

Reality (Pinker 1995): There is no correlation between how often children overregularize a particular verb (like “hold”) and how many regular neighbors (like “fold”, “scold”, etc.) it has.

Implication: More than just associative memory is responsible for children’s behavior.

Associative memory for irregulars

However...what about the irregular verbs (like "drink" and "tell")?
Would analogy (and associative memory) work to explain children's behavior on these verbs?

Irregulars fall into families of rhyming forms ("neighborhoods"):

drink~drank, sink~sank

tell~told, sell~sold, ...

keep~kept, sleep~slept, weep~wept, ...

...

Associative memory for irregulars

Pinker (1995): There *is* a relation between how often a verb is overregularized and the number of rhyming neighbors. Specifically, the more rhyming **irregular** neighbors a word has, the less that verb will be overregularized

drink rhymes with *sink*, *shrink*, *think* which are irregular (*sank*, *shrank*, *thought*) --> *drink* should be overregularized rarely

go rhymes with *blow*, which is irregular, but few other irregular verbs --> *go* should be overregularized more often

"Words & Rules": Associative memory for irregular patterns

Pinker (1995) Idea: Pattern association may be taking place for the irregular verbs. Under this view, irregular verb past tense forms are simply memorized, and then retrieved from associative memory when needed. The more rhyming irregular verb forms there are for a word (like *drink* has *sink~sank*, *shrink~shrank*, and *think-thought*), the easier it will be to retrieve that verb's irregular past tense form because of the structure of associative memory...and the less the child will end up falling back on the regular rule.

"Words & Rules": process

Idea (Pinker (1995), Pinker & Ullman (2002))

Producing a past tense form is a process:

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“Words & Rules”: process

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VERB + ed (apply regular rule)

Lexicon:
Looking up a
word in
associative
memory

“Words & Rules”: process

Idea (Pinker (1995), Pinker & Ullman (2002))

Producing a past tense form is a process:

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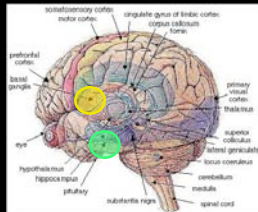
Grammar:
Apply a rule,
usually
combinatorial in
nature
(ex: combine
root with +ed)

Words & Rules: Neurological Basis

Declarative/Procedural Hypothesis (Pinker & Ullman 2002):

lexical/irregular, hippocampus & medial lobe structures =
declarative

grammatical/regular, basal ganglia & frontal cortex =
procedural



Declarative/Procedural Hypothesis Predictions

1) Separable memory

Irregulars - psychological, linguistic, **neuropsychological traces of lexical memory**

Regulars - psychological, linguistic, **neuropsychological traces of grammatical processing**

2) “Elsewhere” rule for +ed

When memory fails for irregulars, use +ed rule for past tense.

Neurological Evidence: Declarative/Procedural Hypothesis

Studies on patients with brain lesions

agrammatism

Agrammatism: problems with grammar of language (rules & combinatorial processes)

Prediction: These patients do worse on regular +ed rule than irregulars.



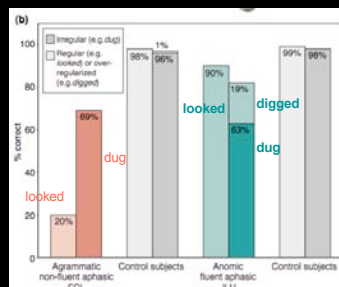
anomia

Anomia: problems with remembering words (lexical access in associative memory)

Prediction: These patients do worse on irregulars than +ed rule.

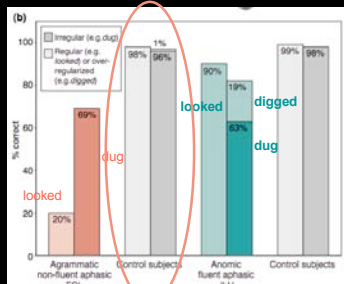
Neurological Evidence: Declarative/Procedural Hypothesis

Pinker & Ullman (2002)



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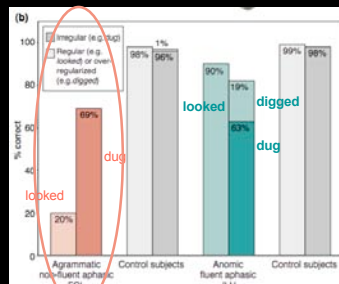


Control subjects:

At ceiling performance (near 100%) for producing the correct past tense for both irregular verbs (dig~dug) and regular verbs (look~looked).

Neurological Evidence: Declarative/Procedural Hypothesis

Pinker & Ullman (2002)



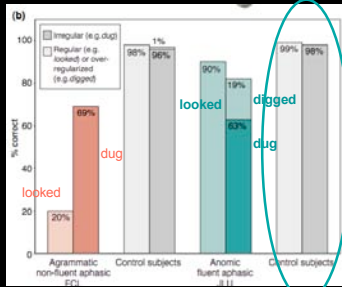
Agrammaticic subject:

Poor performance comparatively, but much worse on producing the correct past tense form for regular verbs and no overregularizations for irregular verbs.

Worse at rules & combinatorial processes

Neurological Evidence: Declarative/Procedural Hypothesis

Pinker & Ullman (2002)

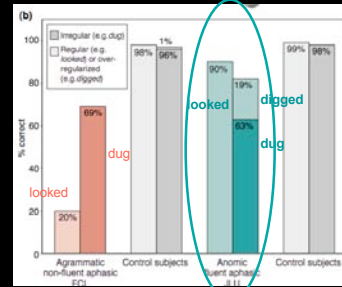


Control subjects:

At ceiling (near 100% performance) for producing both regular and irregular past tense forms.

Neurological Evidence: Declarative/Procedural Hypothesis

Pinker & Ullman (2002)



Anomic subject:

Not so bad comparatively (over 80% production), but better at regular verbs (look-looked) than irregular verbs (dig-dug). Also, produced many overregularizations (dig-digged) [19%].

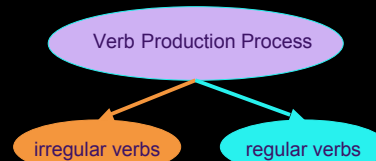
Good at rules, not so good at irregulars.

Double dissociation for regular and irregular verbs

There seems to be a **double dissociation** between performance on regular verbs and performance on irregular verbs. We can find patients who are good at regulars, but poor at irregulars. We can also find patients who are good at irregulars, but poor at regulars. This makes it unlikely that a single underlying process is responsible for producing both verb types. Why?

Double dissociation for regular and irregular verbs

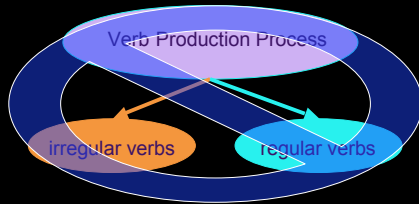
Suppose there was only one process responsible for producing both regular and irregular verbs.



We would expect people to either be good at both verb types (normal people) or bad at both verb types (people with brain damage to the area responsible). But it would be impossible for people to be good at one and bad at the other since both verb types are produced by the same process.

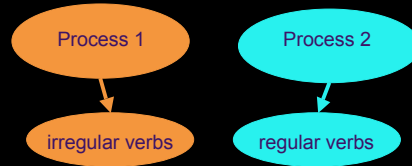
Double dissociation for regular and irregular verbs

If we find double dissociation behavior, it means there must be a separate process responsible for producing each verb type.



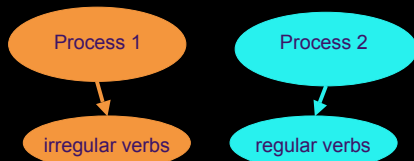
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Double dissociation for regular and irregular verbs

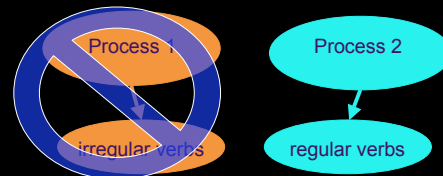
If we find double dissociation behavior, it means there must be a separate process responsible for producing each verb type.



Then, it is possible for someone to be good at one while being bad at the other since it is possible to damage the area responsible for one process while leaving the area responsible for the other process intact.

Double dissociation for regular and irregular verbs

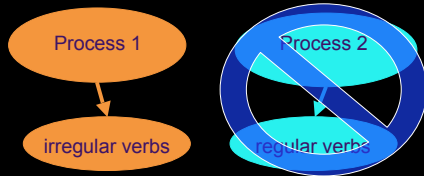
If we find double dissociation behavior, it means there must be a separate process responsible for producing each verb type.



Anomic patient: damage to lexicon retrieval and associative memory; regular verbs and grammar are okay

Double dissociation for regular and irregular verbs

If we find double dissociation behavior, it means there must be a separate process responsible for producing each verb type.



Agrammatic patient: damage to grammatical and combinatorial processes; irregular verbs and lexicon retrieval are okay

Declarative/Procedural Hypothesis: Neurological Support

Since we find double dissociation behavior in patients with different brain lesions, this lends support to the idea that the past tense of regular and irregular verbs may be generated differently. Regular verbs may be making use of more rule-like brain structures and irregular verbs may be making use of more associative-memory-like structures.

More Neurological Evidence: Declarative/Procedural Hypothesis

More results: Patients with Alzheimer's Disease, Parkinson's Disease, Huntington's Disease

- 1) Alzheimer's: **impaired lexical knowledge** (can't remember words) & **impaired irregular verbs**
- 2) Parkinson's: **impaired grammatical knowledge** (can't use rules of language) & **impaired regular verbs**
- 3) Huntington's: **unsuppressed basal ganglion** (~grammatical brain structure) & **overuse of -ed rule** (*dugged, walkeded*)

"Words, No Rules": Can neural networks capture this neurological evidence?

Because neural networks can be mapped to brains, networks can have "lesions" in them the same way that brains do, by **selectively removing a section** of a functional network.



“Words, No Rules”: Can neural networks capture this neurological evidence?

However, it is hard to get the double dissociation pattern observed in human patients. No matter where a neural network is lesioned, the network’s performance on irregulars (dig~dug) suffers more than its performance on regulars (look~looked). It always behaves like an anomic patient, not like an agrammatic patient. (Note: this is only true for networks that do not separate the way regular verbs are processed/retrieved from the way irregular verbs are processed/retrieved.)

Point: There must be something additional besides this kind of associative memory in human brains.

“Words, No Rules”: An additional issue with novel verbs

Human Behavior (both adult and child): the ability to generate an appropriate past tense ending for a novel word (like “wug”)

wug~wugged (regular past tense rule)

Neural network behavior: Unless the network has specifically built in a section that applies the regular past tense pattern, it will not generate appropriate past tense forms for words it has never encountered before.

Example: Network is trained on English verbs, but never has seen “mail”. When forced to generate a past tense form, it produces “membled” (something humans would never do).

Recap

Several theories attempt to explain how children (and adults) represent knowledge of morphology in their minds. One example of morphology is the English past tense.

The “Words & Rules” theory claims that regular and irregular verbs are produced by two different processes, that are controlled by two different pieces of the brain. This theory can explain children’s developmental trajectory as well as adult neurological evidence.

The “Words, No Rules” theory claims that both regular and irregular verbs are processed in associative memory. However, this theory requires special input conditions in order to match children’s developmental trajectory. In addition, it does not seem able to account for some adult neurological evidence.

Stay tuned for the “Rules, No Words” theory...

Questions?

