

Psych 156A/ Ling 150:
Psychology of Language Learning

Lecture 11
Words & Rules

Quiz 4

20 minutes

Announcements

Homework 3 results: (avg: 17.1 out of 21)

Homework 4 due Thursday (5/8/08)

Words & Rules

Computational Problem: Identifying word *affixes* that signal meaning.
affix examples: prefix (*un-* in *unsolvable*), suffix (*-ed* in *kissed*)

affix = sound sequence smaller than an entire word that is attached to a word in order to indicate some additional meaning

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."

Words & Rules

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

Example: 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)

Words & Rules

Computational Problem: Identifying word *affixes* that signal meaning.
= Identify the rules for altering word forms in order to signal meaning.

Example: 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)	confide~confid ed (+ed)	drink~drank ("ih" --> "ey")
rub~rub bed (+ed)	hide~hid ("aye" --> "ih")	think~thought ("ink" --> "ought")

Past Tense Rule

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

holded = hold + ed

Regular +ed rule is applied to verb that actually obeys an irregular rule 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

Past Tense Rule

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

What this means:

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



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

baked clawed folded
baked /t/ clawed /d/ folded /ed/

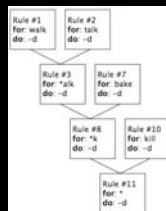
Past Tense Rule

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

How do they figure out that there's a regular rule that applies to a lot of verbs in English?

Yang (2002)

Observation and extraction process



Past Tense Rule

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

How do they figure out that there's a regular rule that applies to a lot of verbs in English?

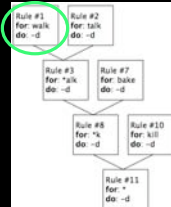
Observation and extraction process

"Ludo **walked** to Sarah."

Pattern: walk --> walked

This pattern works for "walk".

Yang (2002)



Past Tense Rule

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

How do they figure out that there's a regular rule that applies to a lot of verbs in English?

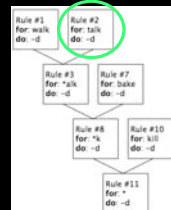
Observation and extraction process

"Hoggle **talked** to Sarah."

Pattern: talk --> talked

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

Yang (2002)



Past Tense Rule

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

How do they figure out that there's a regular rule that applies to a lot of verbs in English?

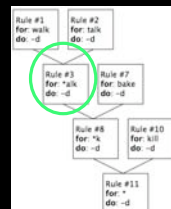
Observation and extraction process

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

Abstraction, based on data:

+ed for words ending with -alk

Yang (2002)



Past Tense Rule

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

How do they figure out that there's a regular rule that applies to a lot of verbs in English?

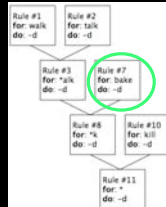
Yang (2002)

Observation and extraction process

"Didymus **bake**d Sarah a cake."

Pattern: bake --> **baked**

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



Past Tense Rule

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

How do they figure out that there's a regular rule that applies to a lot of verbs in English?

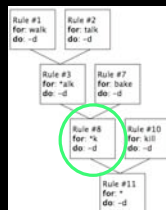
Yang (2002)

Observation and extraction process

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

Abstraction, based on data:

+ed for "-k" words



Past Tense Rule

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

How do they figure out that there's a regular rule that applies to a lot of verbs in English?

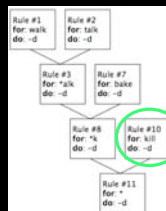
Yang (2002)

Observation and extraction process

"Hoggie would have gladly **killed** the mean fairy."

Pattern: kill --> **killed**

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



Past Tense Rule

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

How do they figure out that there's a regular rule that applies to a lot of verbs in English?

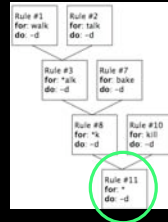
Yang (2002)

Observation and extraction process

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

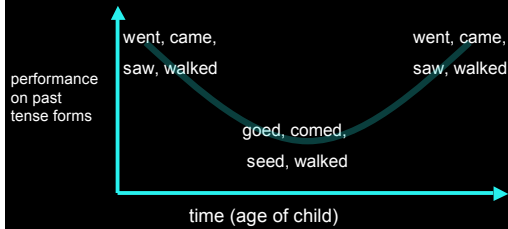
Abstraction, based on data:

+ed for any word



Developmental Trajectory of Past Tense Rule

U-shaped development (often occurs)



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 they overregularize verbs that actually follow irregular rules. (hold~holded (instead of held))

Why do they overregularize?

It's not that children don't realize that the overregularized forms are wrong.



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?"

Overregularization

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)

Overregularization

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

Overregularization

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)

Overregularization

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)

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

Overregularization

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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:

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 rule.

Overregularization

Why do children overregularize?

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

Related idea: 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.

Support for this idea: Children make more errors on words parents don't use as frequently (Marcus et al. 1992).

About Rules

Is it really necessary to have learned rules, or could children (and adults) simply be learning (and using) patterns of association?

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

This kind of pattern association 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.

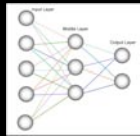


Patterns of Association

If the past tense rule 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 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...



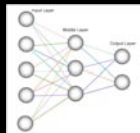
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Pattern: hold~held, walk~walked, go~went

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).

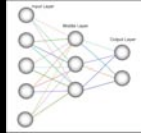


Patterns of Association & U-Shaped Behavior

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

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

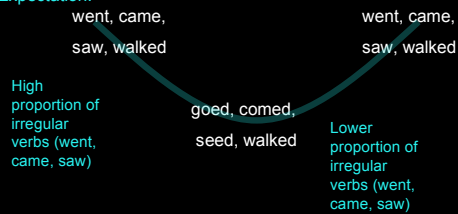
Pattern: hold~held, walk~walked, go~went



Patterns of Association & U-Shaped Behavior

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

Expectation:



Patterns of Association & U-Shaped Behavior

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: Pattern association alone is insufficient to account for children's learning behavior for the English past tense (in particular, the U-shaped learning curve). Children must be learning rules which take advantage of the regularity in the past tense verb forms, not just patterns of associations between verbs and their past tense forms.

More on Pattern Association Learning

Another prediction if learning proceeds by analogy (pattern association); similar patterns should reinforce each other....and reinforce overregularization errors

holded ~ folded ~ scolded ~ ...	drinked ~ blinked
(many regular neighbors)	(few regular neighbors)
= hold overregularized a lot	= drink overregularized infrequently

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 analogy is responsible for children's behavior.

More on Pattern Association Learning

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

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

drink~drank, sink~sank

tell~told, sell~sold, ...

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

...

More on Pattern Association Learning

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

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

sink shrink	show mow
drinked (drank)~ sank ~ shrank ~ ...	went (go)~showed~mowed~...
(more irregular neighbors)	(few irregular neighbors)
= drink overregularized infrequently	= go overregularized more often

More on Pattern Association Learning

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

Pinker (1995) Idea: Pattern association may be taking place for the irregular verbs. Under this view, irregular verb past tense forms are simply memorized. The more rhyming verb forms there are for a word (like "drink" (sink~sank, shrink~shrank)), the easier it will be to retrieve that verb's irregular past tense form...and the less the child will end up relying on the regular rule.

About those irregular past tense forms

Another way to think about irregular past tense forms having neighbors is that are rules for irregular past tense forms, just like for the regular past tense forms.

Regular past tense rule: +ed

Applies to every verb

Irregular past tense rule 1: no change

Applies to: cut~cut, hurt~hurt, fit~fit, ...

Irregular past tense rule 2: ink --> ank

Applies to: drink~drank, sink~sank, shrink~shrank, ...

Irregular past tense rule 3: final vowel sound --> "oo"

Applies to: draw~drew, fly~flew, know~knew, ...

About those irregular past tense forms

Another way to think about irregular past tense forms having neighbors is that are rules for irregular past tense forms, just like for the regular past tense forms.

Regular past tense rule: +ed

Applies to every verb

More general

walk, blink, sigh, ...

Irregular past tense rule 1: no change

Applies to: cut~cut, hurt~hurt, fit~fit, ...

More specific:

applies to just these verbs

Irregular past tense rule 2: ink --> ank

Applies to: drink~drank, sink~sank, shrink~shrank, ...

Irregular past tense rule 3: final vowel sound --> "oo"

Applies to: draw~drew, fly~flew, know~knew, ...

Irregular rules

How do we know if humans really abstract across irregular verbs with neighboring (rhyming) past tense forms and store rules unconsciously in their minds the way we think they do for the regular past tense?

Competing idea 1

No Irregular Rules: Irregular past tense performance for any given verb is based on **how frequently the child hears that past tense form**. There may be some benefit to performance if the verb form has neighboring irregular words ("drink" benefits from "sink" and "shrink").

What matters: frequency of that verb's past tense form in the child's input

Irregular rules

How do we know if humans really abstract across irregular verbs with neighboring (rhyming) past tense forms and store rules unconsciously in their minds the way we think they do for the regular past tense?

Competing idea 1

No Irregular Rules

What matters: frequency of verb's past tense form in the child's input

Prediction for children's behavior: Children should perform the same on verb past tense forms they encounter equally often.

Irregular rules

How do we know if humans really abstract across irregular verbs with neighboring (rhyming) past tense forms and store rules unconsciously in their minds the way we think they do for the regular past tense?

Competing idea 2

Irregular Rules: Irregular past tense performance for any given verb is based on **how frequently the child hears that past tense form and how often the child hears any irregular verbs that follow the same past tense rule** (ex: draw~drew follows the same rule as fly~flew, grow~grew, know~knew, so "draw" benefits from the past tense forms of these verbs, too).

What matters: frequency of individual verb past tense form, frequency of neighboring (sometimes rhyming) past tense forms [rule frequency]

Irregular rules

How do we know if humans really abstract across irregular verbs with neighboring (rhyming) past tense forms and store rules unconsciously in their minds the way we think they do for the regular past tense?

Competing idea 2

Irregular Rules

What matters: frequency of individual verb past tense form, frequency of neighboring (sometimes rhyming) past tense forms [rule frequency]

Prediction for children's behavior: For verb past tense forms that children hear equally often, they should perform better on verbs that belong to an irregular rule class whose members appear more frequently.

Irregular rules

How do we know if humans really abstract across irregular verbs with neighboring (rhyming) past tense forms and store rules unconsciously in their minds the way we think they do for the regular past tense?

Competing ideas

No Irregular Rules

Prediction for children's behavior: Children should be the same on verb past tense forms they encounter equally often.

Irregular Rules

Prediction for children's behavior: For verb past tense forms that children hear equally often, they should perform better on verbs that belong to an irregular rule class whose members appear more frequently.

Yang (2002): Irregular Rules

Evidence from CHILDES database

Children encounter "hurt" and "cut" as often as "draw", "blow", "grow", and "fly" [20 times in a given corpus of a child's experience]

Results:

Performance on "hurt" and "cut": ~80% success at correct irregular form

Performance on "draw", "blow", "grow", and "fly": ~35% success

Different performance for same frequency verbs!

Why?

Yang (2002): Irregular Rules

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Children encounter "hurt" and "cut" as often as "draw", "blow", "grow", and "fly" [20 times in a given corpus of a child's experience]

Results:

Performance on "hurt" and "cut": ~80% success at correct irregular form

"No change" rule: hurt~hurt, cut~cut

Other verbs with same rule: hit, quit, split, slit, spit, bid, rid, forbid, spread, wed, let, set, upset, wet, shut, put, burst, cast, cost, thrust many!

rule frequency: > 2500

Performance on "draw", "blow", "grow", and "fly": ~35% success

"Vowel goes to 'oo" rule: draw~drew, blow~blew, grow~grew, fly~flew

Other verbs with same rule: know, throw, withdraw, slay less!

rule frequency: < 100

Yang (2002): Irregular Rules

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Children encounter "hurt" and "cut" as often as "draw", "blow", "grow", and "fly" [20 times in a given corpus of a child's experience]

Results:

Performance on "hurt" and "cut": ~80% success at correct irregular form

Many "No Change" rule verbs. These verbs have benefited from children encountering the other verbs with the same rule. Better performance.

Performance on "draw", "blow", "grow", and "fly": ~35% success

Less "Vowel goes to 'oo" rule verbs. These verbs have not benefited, since there are not many other verbs with the same rule. Worse performance.

Yang (2002): Irregular Rules

Evidence from CHILDES database

Implication: Children seem to benefit from rule use frequencies of verbs ("cut" and "hurt" benefit from the higher frequency of "no change" rule verbs).

Support for the existence of Irregular Rules.

Another Test for Irregular rules

How do we know if humans really abstract across irregular verbs with neighboring (sometimes rhyming) past tense forms and store rules unconsciously in their minds the way we think they do for the regular past tense?

Competing ideas

No Irregular Rules

Prediction for children's behavior: Children should perform better on verbs they hear more frequently.

Irregular Rules

Prediction for children's behavior: Children could perform better on verbs they hear less frequently if those verbs follow an irregular past tense rule that many other verbs follow.

Yang (2002): Irregular Rules

Evidence from CHILDES database

How often children encounter certain verbs in a given corpus:

"hurt", "cut": 20 times

"caught": 36 times

"threw": 31 times

"knew": 58 times

Performance on "hurt" and "cut": ~80% success

Performance on "caught": ~96% success

Performance on "threw": ~49% success

Performance on "knew": ~49% success

Yang (2002): Irregular Rules

Evidence from CHILDES database

How often children encounter certain verbs in a given corpus:

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Performance on "hurt" and "cut": ~80% success

Performance on "caught": ~96% success

Performance on "threw": ~49% success

Performance on "knew": ~49% success

Better performance for less frequent verbs.

Yang (2002): Irregular Rules

Evidence from CHILDES database

How often children encounter certain verbs in a given corpus:

"hurt", "cut": 20 times

"caught": 36 times

"threw": 31 times

"knew": 58 times

Performance on "hurt" and "cut": ~80% success

Performance on "caught": ~96% success

Performance on "threw": ~49% success

Performance on "knew": ~49% success

Different performance for equally frequent verbs.

Yang (2002): Irregular Rules

Evidence from CHILDES database

Irregular rule members:

"No Change" rule: hurt~hurt, cut~cut

hit, quit, split, slit, spit, bid, rid, forbid, spread, wed, let, set, upset, wet, shut, put, burst, cast, cost, thrust many!

rule frequency: > 2500

"Change to 'aught'" rule: catch~caught

buy, bring, teach, think less, but very frequent verb forms!

rule frequency: > 600

"Vowel goes to 'oo'" rule: throw~threw, know~knew

draw, blow, fly, withdraw, slay less!

rule frequency: < 100

Yang (2002): Irregular Rules

Evidence from CHILDES database

Irregular rule members:

"No Change" rule: hurt~hurt, cut~cut ~80% success

hit, quit, split, slit, spit, bid, rid, forbid, spread, wed, let, set, upset, wet, shut, put, burst, cast, cost, thrust many! > 2500

"Change to 'aught'" rule: catch~caught ~96% success

buy, bring, teach, think less, but very frequent verb forms! > 600

"Vowel goes to 'oo'" rule: throw~threw, know~knew ~49% success

draw, blow, fly, withdraw, slay less! < 100

Implication: Irregular past tense verb forms benefit if the child encounters many other verbs that use the same rule. The frequency of the rule influences the child's performance.

Rules for Words

When learning how to form the past tense, children behave as if they are extracting a regular past tense rule.

When children over-apply the regular past tense rule, overregularization errors appear. This often leads to a U-shaped learning trajectory on their performance with the past tense forms of verbs.

There is evidence for children extracting irregular rules as well, based on their performance with the past tense forms of irregular verbs.

Questions?
