Psych 156A/ Ling 150: Acquisition of Language II

Lecture 9

Morphology II

Announcements

Be working on HW2 due: 5/11/10

Pick up midterm and HW1 if you have not done so already

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~blinked	confide~confided	drink~drank (not drinked)
rub~rubbed	hide~hid (not *hided*)	think~thought (not *thinked*)

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~blinked (+ed) [əd]	confide~confided (+ed) [əd]	drink~drank ("ih" --> "ey") [ɪ] --> [e]
rub~rubbed (+ed) [əd]	hide~hid ("i" --> "ih") [aj] --> [ɪ]	think~thought ("ink" --> "ought") [ɪŋk] --> [ɔt]

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

Recap from last time

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…

"Rules, No Words": a closer look at irregular verbs

Irregular verbs tend to have "neighborhoods", where certain verbs seem to follow the same patterns.

Pattern: no change to root form

cut~cut, hurt~hurt, fit~fit, hit~hit, …

Pattern: in [ɪŋ] --> an [eŋ]

drink~drank, shrink~shrank, sink~sank, sing~sang, ring~rang, …

Pattern: final vowel sound --> oo [u]

fly~flew, know~knew, throw~threw, draw~drew,…

"Rules, No Words": a closer look at irregular verbs

Another way to think about irregular past tense patterns is that there are rules for irregular past tense forms (instead of these forms being memorized individually and retrieved from associative memory).

Irregular Rule: no change to root form

cut~cut, hurt~hurt, fit~fit, hit~hit, …

Irregular Rule: in [ɪŋ] --> an [eŋ]

drink~drank, shrink~shrank, sink~sank, sing~sang, ring~rang, …

Irregular Rule: final vowel sound --> oo [u]

fly~flew, know~knew, throw~threw, draw~drew,…

"Rules, No Words": regular and irregular rules

This means that there are two kinds of rules: irregular rules (which generally apply to a specific subset of verbs) and regular rules (which apply to all the rest of the verbs not included in the irregular rules).

Irregular Rule: no change to root form

cut~cut, hurt~hurt, fit~fit, hit~hit, …

Irregular Rule: in [ɪŋ] --> an [eŋ]

drink~drank, shrink~shrank, sink~sank, sing~sang, ring~rang, …

Irregular Rule: final vowel sound --> oo [u]

fly~flew, know~knew, throw~threw, draw~drew,…

More specific: applies to just these verbs

Regular past tense rule: +ed [d], [t], [əd]

Applies to all the other verbs

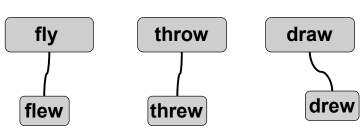
More general

walk, blink, sigh, …

Associative Memory vs. Irregular Rules

What's the difference between retrieving irregular verb forms from associative memory and having an irregular rule that applies to those verbs?

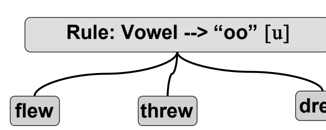
If irregular verb forms are individually memorized and then retrieved from associative memory, then there is not much of a connection between verb forms that don't have similar-sounding root forms. They are learned and retrieved separately, even if they follow a similar pattern to form the past tense.



Associative Memory vs. Irregular Rules

What's the difference between retrieving irregular verb forms from associative memory and having an irregular rule that applies to those verbs?

If irregular verb forms are formed using an irregular rule, then even if the root forms don't sound alike, they are all connected since the same process is used to form the irregular past tense form.

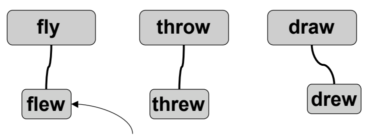


Associative Memory vs. Irregular Rules

How do we know which representation is a more accurate reflection of the knowledge in children's minds?

Associative Memory only (no irregular rules): Irregular past tense performance for any given verb is based largely on how frequently the child hears that verb's past tense form.

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



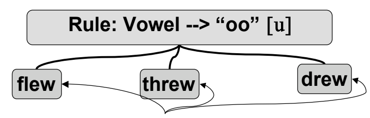
"flew" performance: How often does the child hear "flew"?

Associative Memory vs. Irregular Rules

How do we know which representation is a more accurate reflection of the knowledge in children's minds?

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.

What matters: frequency of that verb's past tense form and frequency of past tense forms that follow the same rule (rule frequency)



"flew" performance: How often does the child hear any of these forms?

Associative Memory vs. Irregular Rules

Predictions of each theory:

Associative Memory only (no irregular rules): what matters is the frequency of that verb's past tense form in the child's input

Prediction: If children encounter two verbs' past tense forms equally often, they should perform the same on each verb

Irregular Rules: what matters is the frequency of that verb's past tense form and the frequency of past tense forms that follow the same rule (rule frequency)

Prediction: If children encounter two verbs' past tense forms equally often, they should perform better on the verb that follows an irregular rule that is often used (which we can gauge by measuring how frequently other verbs that also use that rule are encountered)

Evidence from 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 child-directed speech]

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?

Evidence from 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 child-directed speech]

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

Evidence from 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 child-directed speech]

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. Children have better performance.

Performance on "draw", "blow", "grow", and "fly": ~35% success
Less "Vowel goes to 'oo' " rule verbs. These verbs have not benefited much, since there are not many other verbs with the same rule. Children have worse performance.

Evidence from Yang (2002): Irregular Rules

Summary of evidence: Even when children encounter irregular past tense verb forms with equal frequency, they do not have similar performance when producing these verb forms. Children are more successful on verb forms that are produced by a rule that has a higher frequency (in this case, the No Change rule) than those that are produced by a rule that has a lower frequency (in this case, the Vowel --> "oo" rule).

Support for the existence of Irregular Rules.

More Evidence from 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

More Evidence from 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

Better performance for less frequent verbs.

More Evidence from 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.

Explaining Yang (2002) evidence

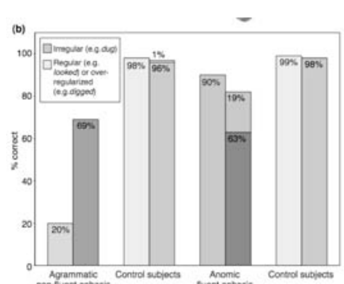
Children's performance can be explained by irregular rule frequency. Children do better on verbs that follow rules with a higher frequency - even if the individual verb form itself is less frequent.

"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 verbs = high rule frequency
rule frequency: > 2500, better performance

"Change to 'aught'" rule: catch~caught
buy, bring, teach, think fewer verbs, but some are frequent = higher rule frequency
rule frequency: > 600, better performance

"Vowel goes to 'oo'" rule: throw~threw, know~knew
draw, blow, fly, withdraw, slay fewer verbs, and most are infrequent = lower rule frequency
rule frequency: < 100, poorer performance

Quick check: How does "Rules, No Words" fit with the neurological evidence we saw before?



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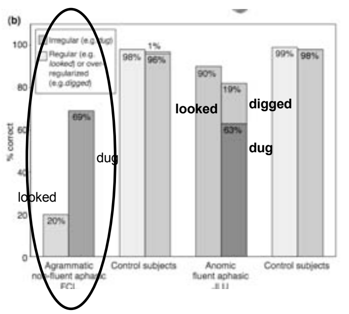


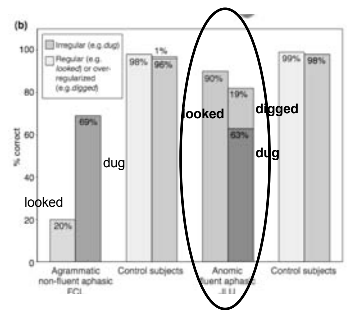
Agrammatic subject:

Prediction: Rule processing is broken, so everything should be broken.

There *is* an overall lower performance trend, with regular verbs being particularly bad.

…however, irregulars are certainly better than chance. Perhaps many of these rules are related to lexical retrieval?

Quick check: How does "Rules, No Words" fit with the neurological evidence we saw before?



Anomic subject:

Prediction: Lexical retrieval is broken, but this shouldn't really affect overall performance much.

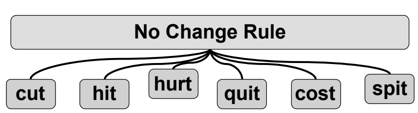
There *is* an overall higher performance trend, with regular verbs being particularly good.

…however, irregulars are certainly worse. Maybe rule application for them is related to lexical retrieval?

Irregular Rules: Recap

Children's performance on irregular past tense verb forms suggests that they produce irregular past tense verb forms with irregular rules. This is because both the individual frequency of a past tense verb form and the frequency of the irregular rule used to produce that verb form seem to influence children's performance.

Using irregular rules is somewhat compatible with neurological evidence, but some explanation is still needed to account for all the observed behavior.



Question:
When do children figure out that they need a rule for certain groups of verbs?

Words To Rules?

Idea: The point of using rules for past tense forms would be that it's easier in some sense -- as opposed to simply remembering each verb and its associated past tense individually.

look	looked		look	
kiss	kissed		kiss	
lurch	lurched	vs.	lurch	+ed
laugh	laughed		laugh	
dance	danced		dance	
harder			easier	

Words To Rules?

Idea: The point of using rules for past tense forms would be that it's easier in some sense -- as opposed to simply remembering each verb and its associated past tense individually.

If a particular transformation (rule) occurs a lot (like +ed), it's said to be productive. Productive rules make sense to have because they're used for a lot of different verbs.

Question: What determines if a rule is productive? That is, how does a child decide that a rule is used enough to be worth having?

Productive Rules

Yang (2005): Productivity of a rule depends on some kind of cost-benefit analysis for how many words follow the rule and how many words don't.

Specifically, the child keeps track of how many exceptions there are for a particular rule. If there are too many exceptions, it's easier to just not have a rule.

Rule: *ing --> *ang

Verbs that follow the rule: ring~rang, sing~sang, …

Verbs that don't follow the rule: sting~stung, bring~brought, string~strung, cling~clung, ping~pinged, ding~dinged…

Productive Rules

Important: a rule can be productive while still having exceptions. The big question is simply how many exceptions is too much?

+ed Rule: [any verb] --> [any verb]+ed

Verbs that follow the rule: look~looked, kiss~kissed, laugh~laughed,…
How many?

Verbs that don't follow the rule: sting~stung, bring~brought, drink~drank, ring~rang, keep~kept…
How many?

Productive Rules

Yang (2005): What matters is how long it takes to find the right past tense form.

There are two options when some verbs follow a rule and some items don't.
(1) Store all the exceptions to the rule, and then the rule. If the verb needed isn't among the exceptions, apply the rule.
(2) Just store all the verbs and their past tense forms individually. (Treat all the verbs as exceptions.)

Tolerance Principle: If it takes longer (on average) to find the right past tense form when both the exceptions and the rule are stored (option 1), just store all the verbs separately (option 2).

Productive Rules

Yang (2005): What matters is how long it takes to find the right past tense form.

Note: Exceptions to rule are in order of frequency

Rule: *ing-*ang

If word = *sting* then *stung* (freq 100)
Else if word = *swing* then *swung* (freq 80)
Else if word = *ding* then *dinged* (freq 10)
Else if word = *cling* then *clung* (freq 8)
Else Apply *ing --> *ang

Productive Rules

Yang (2005): What matters is how long it takes to find the right past tense form.

Note: Exceptions to rule are in order of frequency

Rule: *ing-*ang

If word = *sting* then *stung* (freq 100) (Time 1) look here
Else if word = *swing* then *swung* (freq 80) (Time 2) look here
Else if word = *ding* then *dinged* (freq 10)
Else if word = *cling* then *clung* (freq 8)
Else Apply *ing --> *ang

swing?
--> swung

Time units to find: 2

Productive Rules

Yang (2005): What matters is how long it takes to find the right past tense form.

Note: Exceptions to rule are in order of frequency

Rule: *ing-*ang

If word = *sting* then *stung* (freq 100) (Time 1) look here
Else if word = *swing* then *swung* (freq 80) (Time 2) look here
Else if word = *ding* then *dinged* (freq 10) (Time 3) look here
Else if word = *cling* then *clung* (freq 8) (Time 4) look here
Else Apply *ing --> *ang (Time 5) look here

ring?
--> rang

Time units to find: 5 + rule application

Tolerance Principle Prediction

Regular +ed rule can only be productive if it applies to the vast majority of verbs it could apply to (relatively few exceptions), because otherwise it would take too long to get to the rule (have to step through each of these exceptions first).

Regular rule:
Which verb forms should this rule apply to?
  No restrictions on form: kiss, kick, cry, hug, …
  form = [any form]
Transformation: [any form] --> [any form] + ed

There are 150 irregular verbs, which are exceptions to the regular rule because they fit the [any form] context that the regular rule applies to.

Tolerance Principle Prediction

Regular +ed rule
Transformation: [any form] --> [any form] + ed

Verbs that obey this rule: all the regular verbs in English (suppose we let this be 10000, just for demonstration purposes).

Verbs that do not obey this rule: all irregular verbs (150)

Tolerance Principle: a precise mathematical formula that considers the total number of verbs the rule could potentially apply to (regular + irregular verbs) and how many it actually doesn't apply to (irregular verbs)

If Exceptions < Potential/ ln(Potential), then it is faster to have a rule instead of storing all the verb forms individually.

Tolerance Principle Prediction

Regular +ed rule
Transformation: [any form] --> [any form] + ed

Verbs that obey this rule: all the regular verbs in English (suppose we let this be 10000, just for demonstration purposes).

Verbs that do not obey this rule: all irregular verbs (150)

Exceptions = 150
Potential = 10000 + 150 = 10150

Potential/ ln(Potential) = 10150/ ln(10150) = 10150/9.23
=~ 1100

Is 150 < 1100? Yes. Tolerance Principle states that it is faster to have a rule than to store each individual past tense form separately.

Tolerance Principle Prediction

How many regular verbs need to exist in order for it to be faster to have a rule when there are 150 exceptions?

Verbs that do not obey this rule: all irregular verbs (150)
Verbs that obey this rule: ???? (let's call this x)

Exceptions = 150
Potential = x + 150

What is the threshold at which it's better to have a rule with 150 exceptions?
Exceptions = Potential/ ln(Potential)
150 = (x + 150)/ ln(x + 150)

x =~ 890

[Check: (890 + 150)/ ln(890 + 150) = 1040/ ln(1040) =~ 150]

Tolerance Principle Prediction

How many regular verbs need to exist in order for it to be faster to have a rule when there are 150 exceptions?

Verbs that do not obey this rule: all irregular verbs (150)
Verbs that obey this rule: 890

Implication: If there are at least 890 regular verbs (ones that follow this rule), then it is faster to store the rule and the 150 exceptions than to store all the verb past tense forms separately.

Since there are many more regular verbs than this in the language, the Tolerance Principle predicts that people will use a rule to produce the regular past tense form of verbs (which seems to be true, given neurological evidence).

Tolerance Principle in Child Learning

1) Child identifies possible rule.
   Ex: (*ing --> *ang)

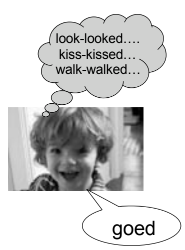
2) Child (unconsciously) checks current vocabulary with Tolerance Principle to see if it's better to store a rule + exceptions, or just store everything individually.

3) Child repeats with each new word type encountered. (Productivity of rules can change, based on how many exceptions the child is aware of at any given time.)

Productivity Predictions

Depending on the verbs they have encountered, children may believe certain rules are productive while other rules are not.

Prediction for English regular +ed rule:
Children who have this rule should know many more regular verbs than irregular verbs, in order for it to be faster for them to have a rule. (This seems to be true - children who overregularize (and thus have the rule) seem to know many more regular verbs than irregular verbs.)



Explaining Yang (2002) evidence

Children's performance can be explained by irregular rule frequency. Children do better on verbs that follow rules with a higher frequency - even if the individual verb form itself is less frequent.

"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 verbs = high rule frequency
rule frequency: > 2500, better performance

"Change to 'aught'" rule: catch~caught
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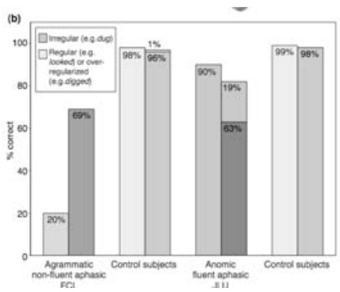
Re-check: How does “Rules, No Words” fit with the neurological evidence we saw before?



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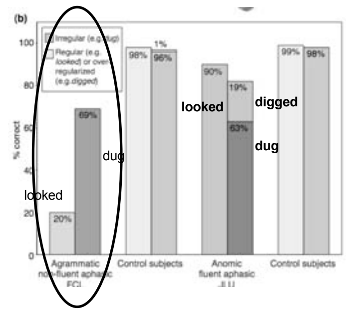


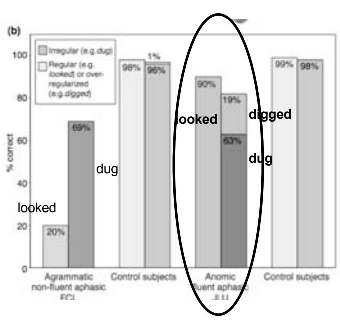
Agrammatic subject:

Prediction: Rule processing is broken, so everything should be broken.

There *is* an overall lower performance trend, with regular verbs being particularly bad.

…however, irregulars are certainly better than chance. Perhaps many of these rules are not productive and so the words are stored individually.

Quick check: How does “Rules, No Words” fit with the neurological evidence we saw before?



Anomic subject:

Prediction: Lexical retrieval is broken, but this shouldn’t really affect overall performance much.

There *is* an overall higher performance trend, with regular verbs being particularly good.

…however, irregulars are certainly worse. Some of these are likely unproductive irregular rules, and so the words are stored in lexical memory.

Summary: Storing Rules vs. Words

It makes sense from a processing standpoint for children to store rules if these rules are used a lot - that is, if they are productive rules. Otherwise, it will be easier to simply store individual words and their associated past tense forms.

One way children might decide if a rule should be stored is based on how many verbs follow the rule vs. how many verbs do not follow the rule. The important thing is to store the knowledge in such a way as to make it faster to find a given past tense form.

The “Rules, No Words” model, while it uses irregular verbs to account for productive irregular rules, may in fact still store some “words” in associative memory if the rules these words belong to are not productive. This would make this model compatible with the observed neruological evidence (and perhaps we should rename it the “Rules, and a Few Words” model)

Questions?

Be working on HW2 and review questions for morphology