# Lexical processing

Itamar Kastner

Morphology, UoE 2023-24

Start with an experiment:

`https://www.youtube.com/watch?v=NRTFPPBZGnI`

# Goals

- Discuss one major issue of morphology in the psycholinguistic and neurolinguistic literature.
- Most studies ask whether words decompose into morphemes during language recognition and production.
- Some hypotheses suggest that decomposition varies depending on the "transparency" or "regularity" of the morphology.
- We'll look at evidence that words are decomposed no matter how "opaque" and "irregular".

# Words or Morphemes

## Decomposition vs storage

- **Storage:** we store whole stems.
- **Decomposition:** we store smaller elements (morphemes) and decompose the input.
- A lot of work has been devoted to finding out where the line should be drawn.

# Experimental Paradigms

## Lexical decision

- Response Time $\sim$ frequency + other stuff.
- Error rate (Accuracy) $\sim$ + other stuff.
- The most robust measure we have.
  - What's the computation? Need a theory of the task.
  - For morphology, is it about lookup? Combination of stem and affix?
  - Do we need a theory of storage or of retrieval?

➤ What affects the speed with which we react to ***predictable***?

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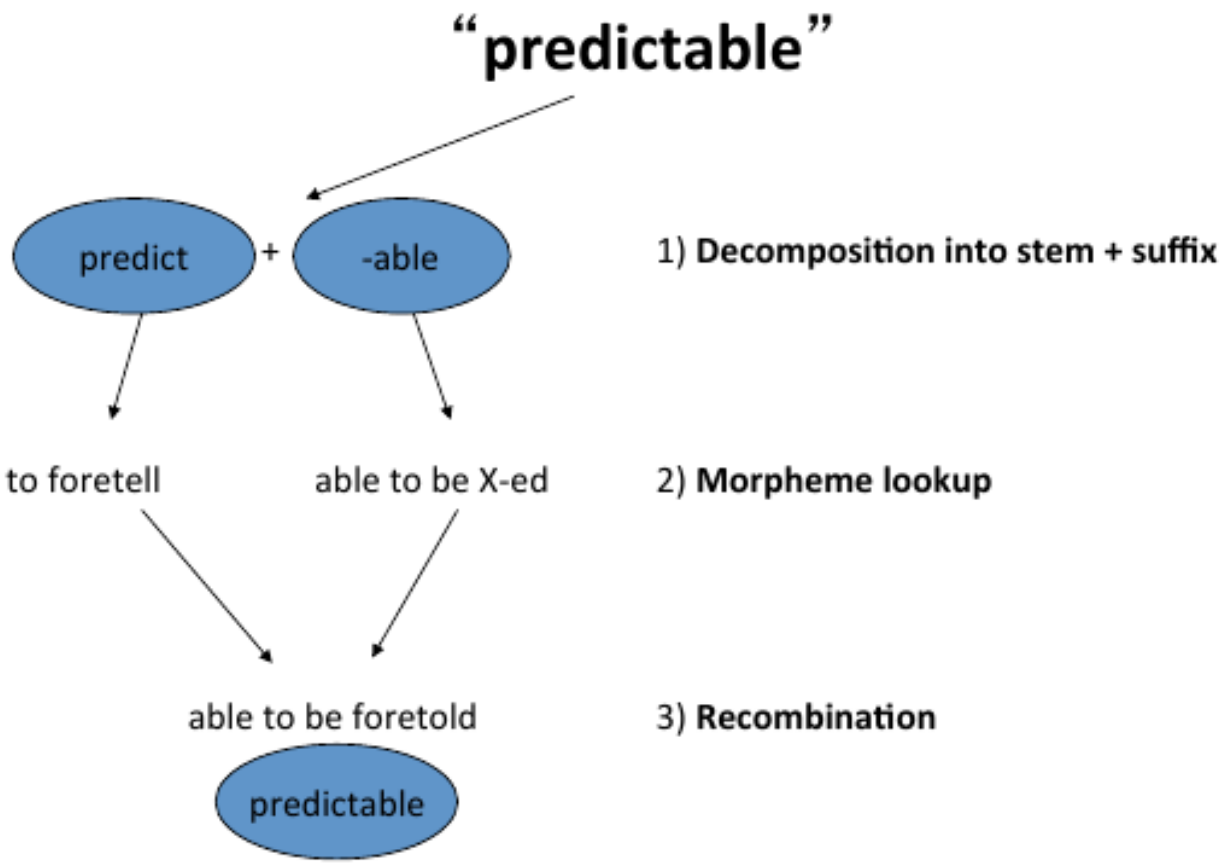
# Affix stripping: Taft (1979)




Decomposition, lookup and recombination can be affected by:

- **Surface** frequency.
- **Base** frequency.
- Their combination.

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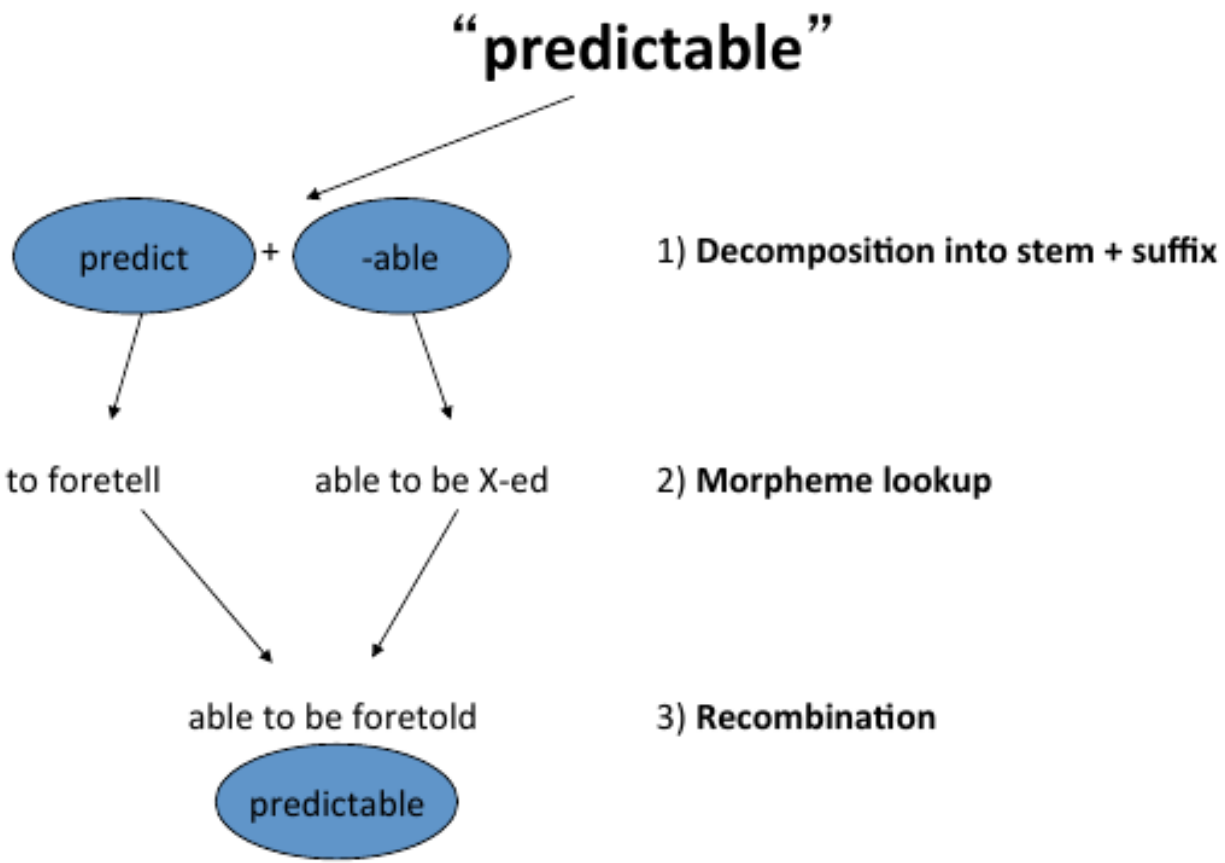


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# Experimental Paradigms

## Priming

- Prime and target.
- Masked priming.
- Identity prime.
- Semantic prime.
- Orthographic prime.

# Priming Predictions

Does *nation* prime *national*?

## Storage

- Yes!
  - Similar phonology.
  - Similar semantics.

## Decomposition

- Yes!
  - Decompose *national* to *nation+al*.
  - Identity priming for *nation*.

➤ So we need a different technique: **masked** priming.

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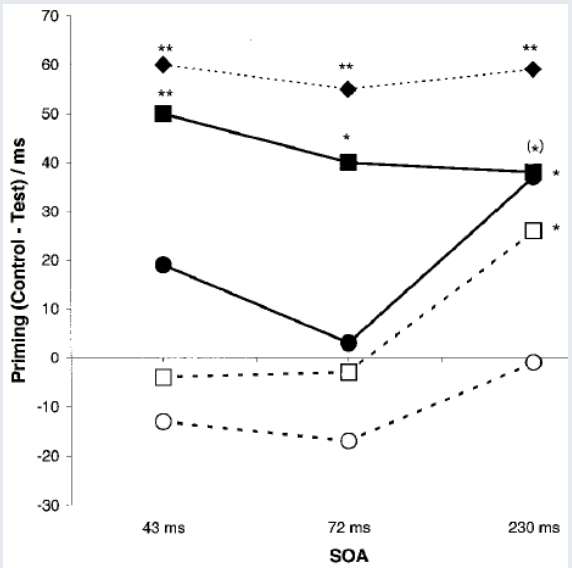
# Behavioral findings: Rastle et al. (2000)

How can we disentangle semantics, phonology and form?

## Methods and results

- Masked priming.
- SOAs: 43ms, 73ms, 230ms.

| | | |
|---|---|---|
| ✓ | **Identity:** | church — CHURCH |
| ✓ | **Morpho + Sem + Form:** | adapter — ADAPTABLE |
| ✗ | Sem + Form: | screech — SCREAM |
| ✗ | Sem: | cello — VIOLIN |
| ✗ | Form: | typhoid — TYPHOON |

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- Morpho ≈ Identity.
- Morpho ≠ Form + Meaning (phonesthemes).

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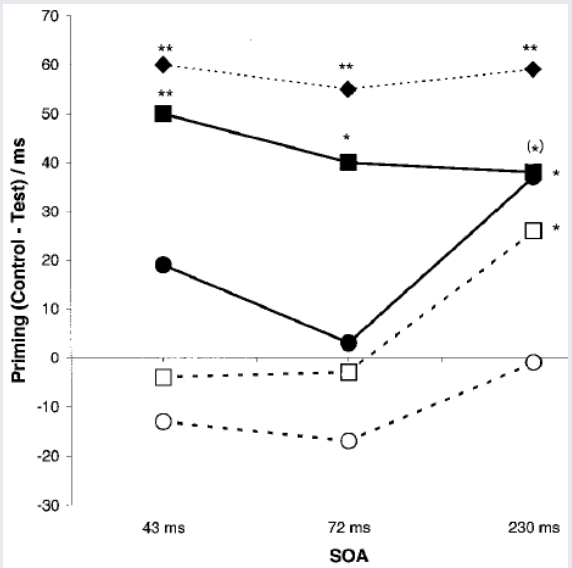


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## Obligatory decomposition

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| ✓ | **Semantic:** | *cleaner* — CLEAN |
| ✓ | **Psuedo-morphological:** | *corner* — CORN |
| ✗ | Form: | *brothel* — BROTH |

- *brother* primes BROTH.
- *brothel* does not prime BROTH.
- Readers identify the **visual form** of the suffix -er.

➤ How far can we stretch this? What about **irregular morphology**?

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# Behavioral findings: Priming for Irregulars?

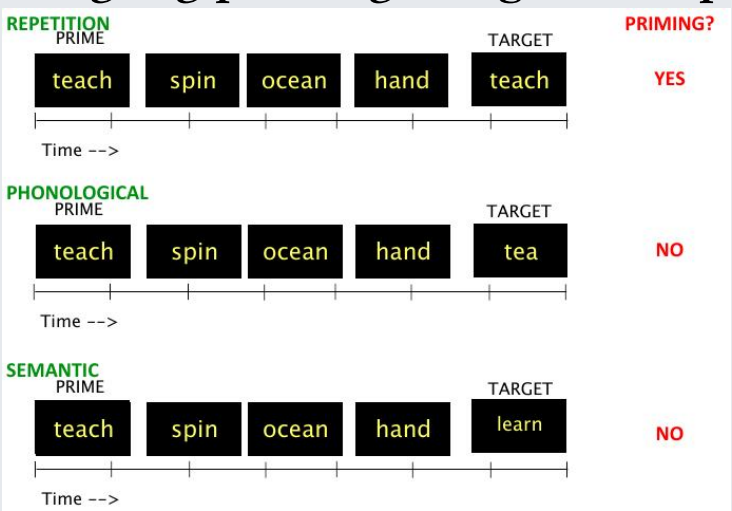
## No: Marslen-Wilson et al (1993)

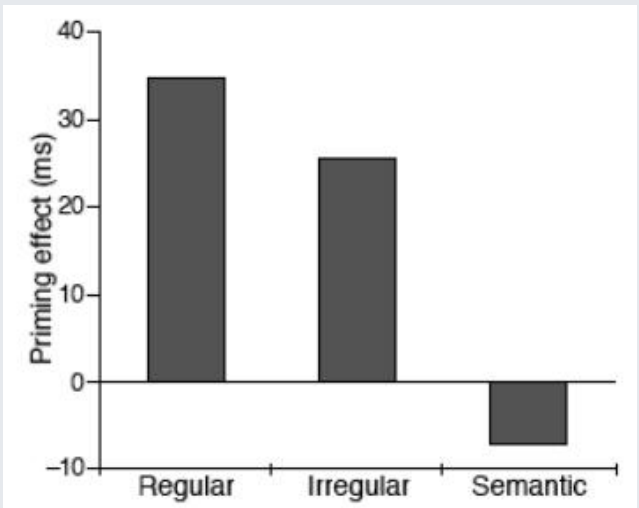
- Cross-modal priming: *taught* does not prime TEACH.

| | Prime (auditory) | Target (visual) | Facilitation (in comparison to unrelated control) |
|---|---|---|---|
| Regular verbs | *walk* | *walk* | Yes |
| | *walked* | *walk* | Yes |
| Irregular verbs | *give* | *give* | Yes |
| | *gave* | *give* | No |

## Yes: Marslen-Wilson and Tyler (1998)

- Long-lag priming: *taught* does prime TEACH.



# Interim Summary

1. Suffixed nouns and adjectives are decomposed.
2. Decomposition is obligatory.
3. Unclear from behavioral methods whether irregular verbs are decomposed.

# MEG background

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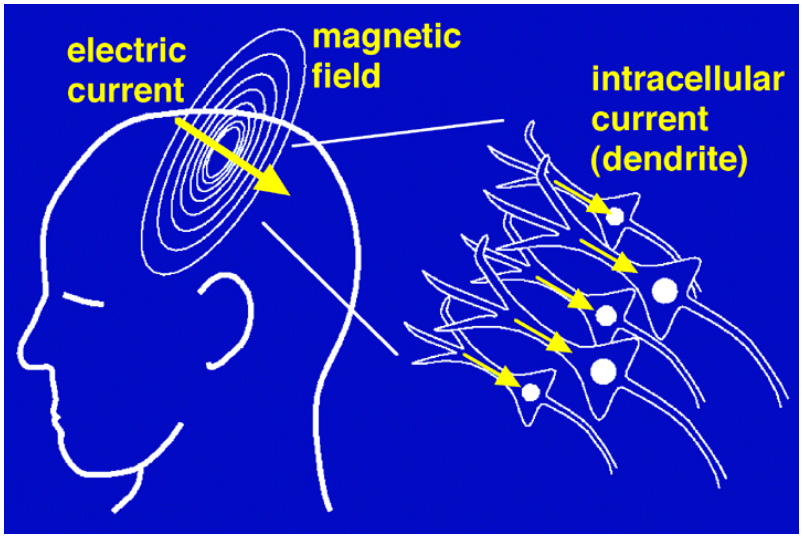
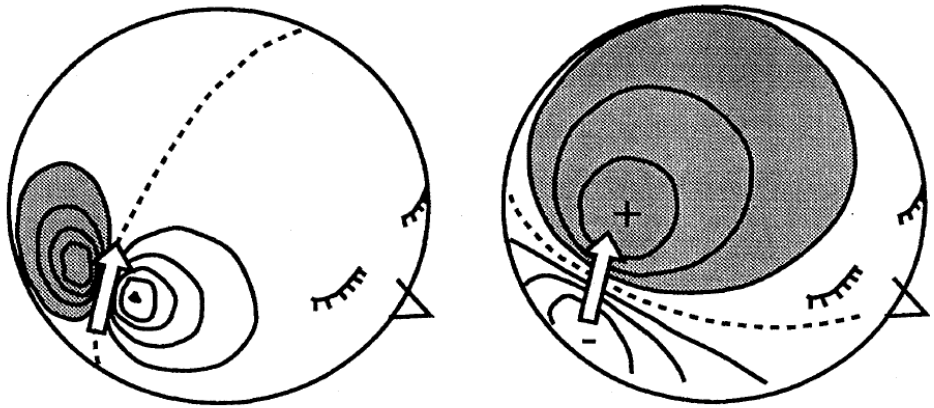
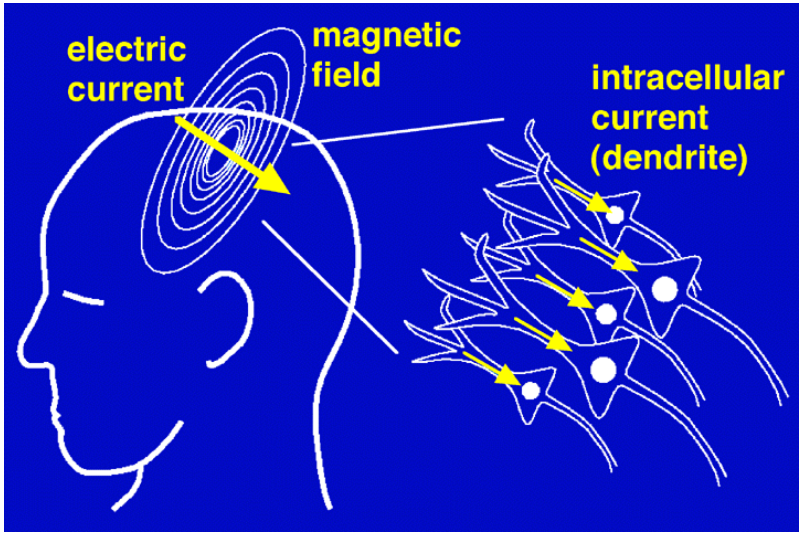
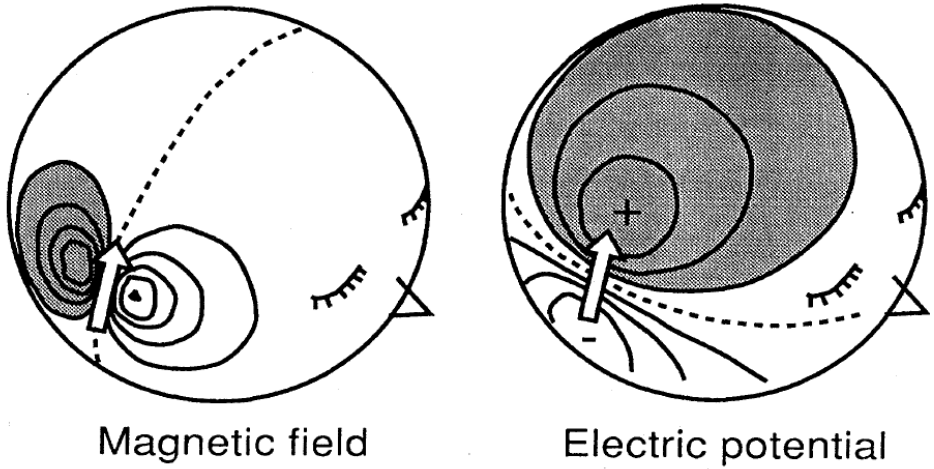


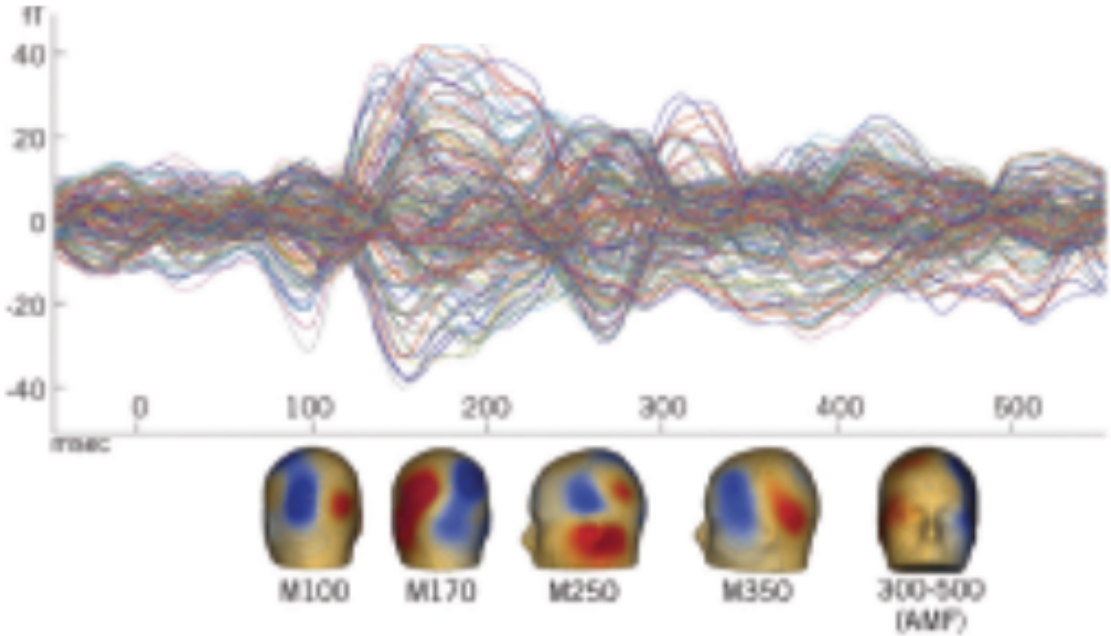



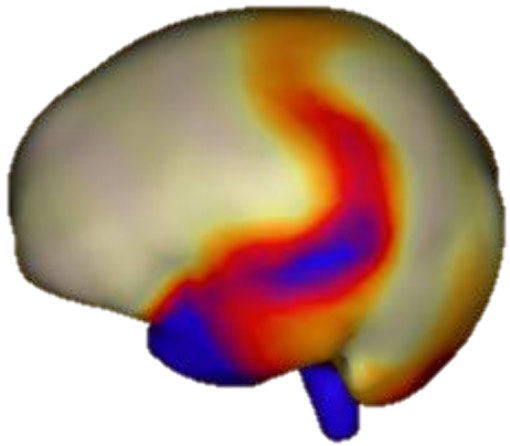

Magnetic field Electric potential

# MEG background



# MEG background: Priming in Irregular Verbs

## Stockall and Marantz (2006)

- Overt priming using **MEG**.

| Condition | MEG | | | RT | | |
|---|---|---|---|---|---|---|
| | Rel.*(SD)* | Unrel.*(SD)* | Dif. | Rel.*(SD)* | Unrel.*(SD)* | Dif. |
| **Identity** | 323.2*(31.3)* | 354.9*(26.2)* | −31.7* | 603.4*(138)* | 665.9*(171.1)* | −62.5** |
| **Hi-O Irr** (eg. *gave–give*) | 347.6*(25.6)* | 374.1*(48.2)* | −26.5* | 586.9*(124.3)* | 605.6*(142)* | −18.7* |
| **Lo-O Irr** (eg. *taught–teach*) | 338.7*(57.4)* | 371.1*(41.8)* | −32.4* | 619.5*(184.4)* | 606.5*(151.9)* | 13 |
| **Ortho-O** (eg. *stiff–staff*) | 343.1*(28.9)* | 359.2*(26.9)* | −16.1 | 664.7*(192.6)* | 637.1*(162.5)* | 27.6* |

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# Interim Summary

1. Suffixed nouns and adjectives are decomposed.
2. Decomposition is obligatory.
3. Irregular verbs are decomposed.
4. Can we predict how much?

Which stem is -*able* more likely to appear after?

*formidable* *taxable*

# Transition probabilities

- *taxable*, *taxing*, *taxes*, *taxation*, ...
- *formidable*, ...?

## Transition probabilities

- **Transition probability**: the probability of having *-able* after *tax* or *formid*.
- *tax-able*, *formid-able*.
- Contrast with orthographic *axab*, *idab*.

## M170

- Transition Probability: the **probability** of an affix given its stem.
- TP(formidable) > TP(taxable).
- **M170**, a neural response originating at the fusiform gyrus, is sensitive to TP.

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## M170

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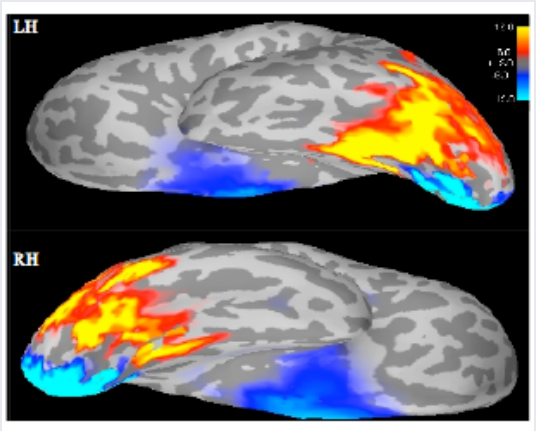
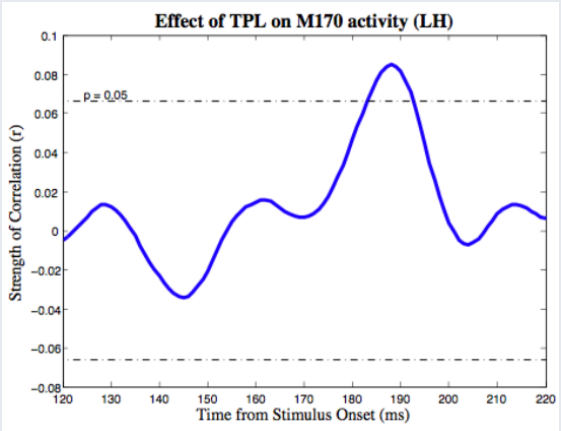
# Transition probabilities: M170

## M170 effect (Solomyak and Marantz 2009)

- Materials: words suffixed with *-able*, *-ate*, *ic*, ...
- Transition probability modulates activation in the Visual Word Form Area.



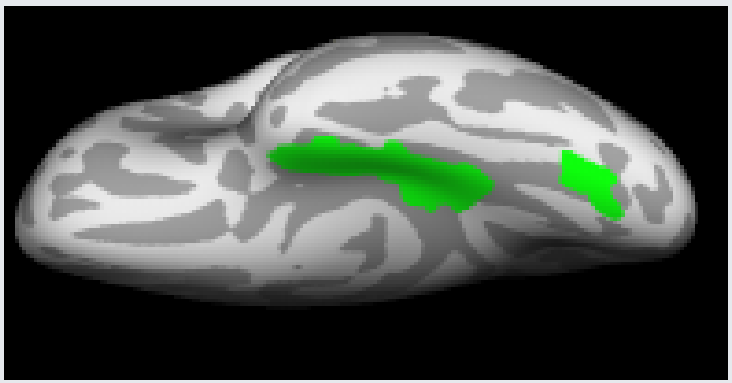

- Neural correlate of decomposition.
- TP(*formidable*) > TP(*taxable*)
- M170(formidable) > M170(taxable). (Solomyak and Marantz 2010)

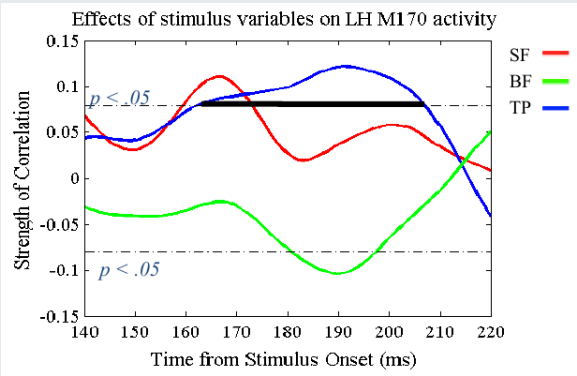
➤ What about the *brother* items?

# Transition probabilities: M170

## Psuedo-affixes show M170 effects

- Even with pseudo-affixes. (Lewis et al. 2011)
- *Brother*, *lotion*, *ration*, *magic*, *barber*, *final*, ...





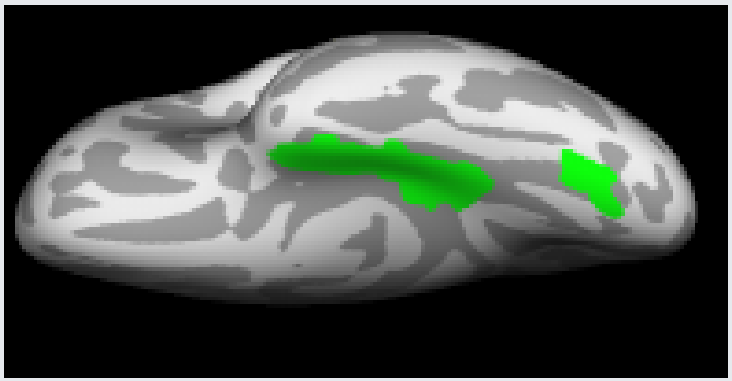

➤ Converging behavioral and MEG evidence for obligatory decomposition.

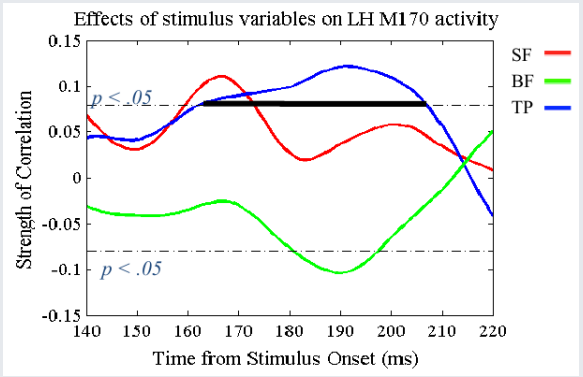
# Transition probabilities: M170 and M350

We can even isolate different lexical statistic measures.

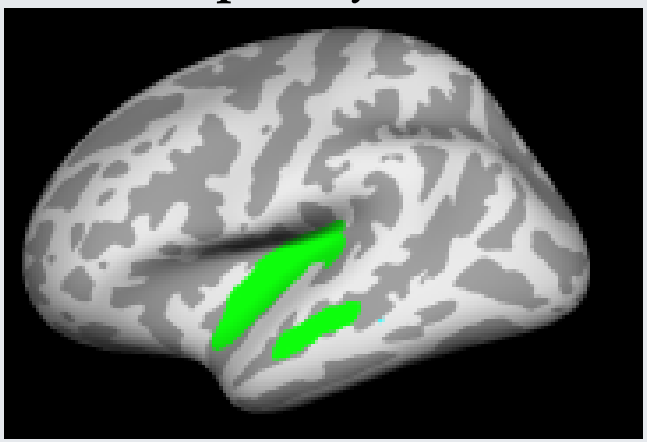
## Lewis et al (2011)

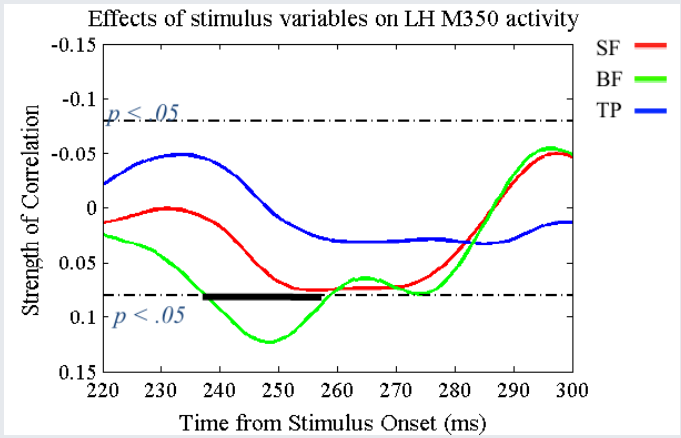
- *Lotion*, *ration*, *magic*, *barber*, *final*, ...
- TP in M170: M170(formidable) > M170(taxable)






- Base frequency in M350: M350(taxable) > M350(formidable)





# Regularity in Irregulars

Back now to irregular verbs:

1. We have evidence that they are decomposed.
2. We have measures for neural correlates of decomposition.
3. We need measures for irregular verbs.

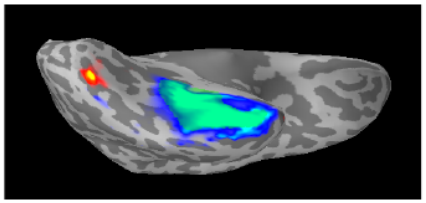
## Albright and Hayes (2003)

- Past tense nonce words.
  - *blafe: blafed / bleft?*
  - *bredge: bredged / broge?*
  - *chake: chaked / chook?*
  - *fleep: fleeped / flept?*

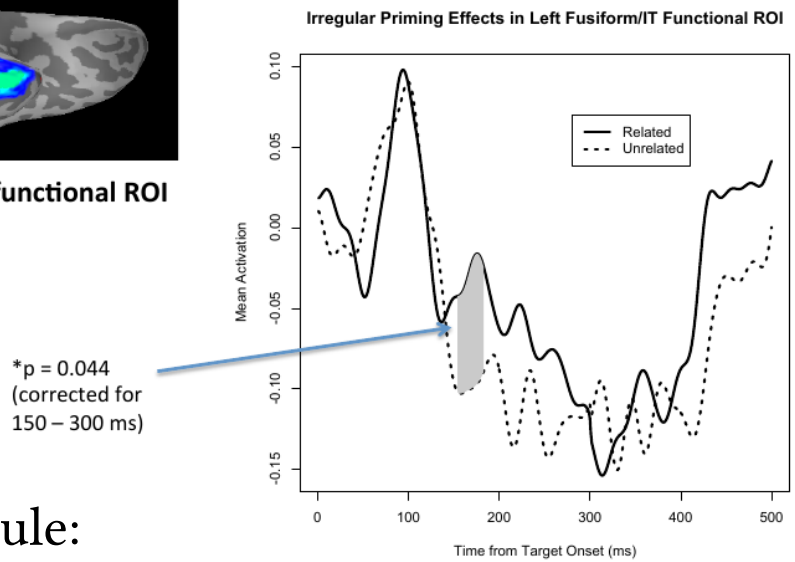
| | AlbrightScore | Related Forms |
|---|---|---|
| **bleed-bled** | **0.71** | breed-bred, lead-led, read-read |
| **smite-smote** | **0.21** | write-wrote |
| **ask-asked** | **0.97** | walk-walked, park-parked, mark-marked, talk-talked, ... |

# Tying it all together

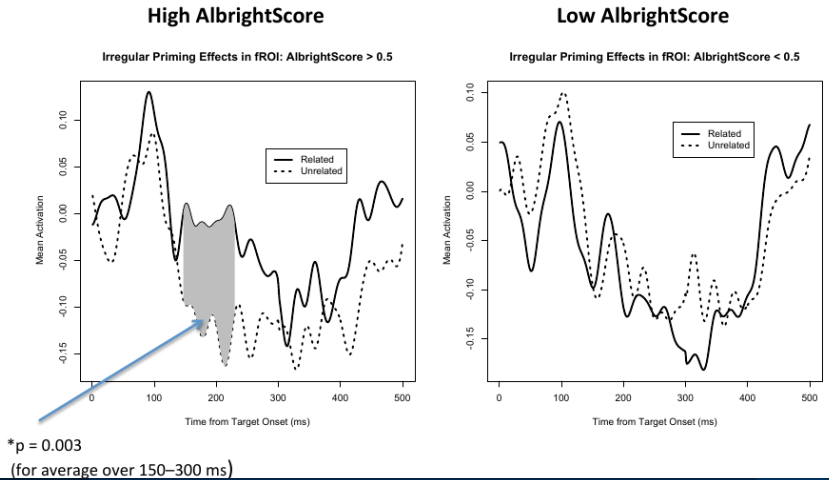
**Return to irregular verbs:** does *taught* prime TEACH in masked priming?
Fruchter et al. (2013): **yes**. Priming found in M170 (and M350).



Left Fusiform/IT functional ROI




**Correlated** with strength of rule:



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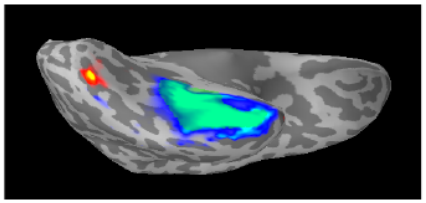

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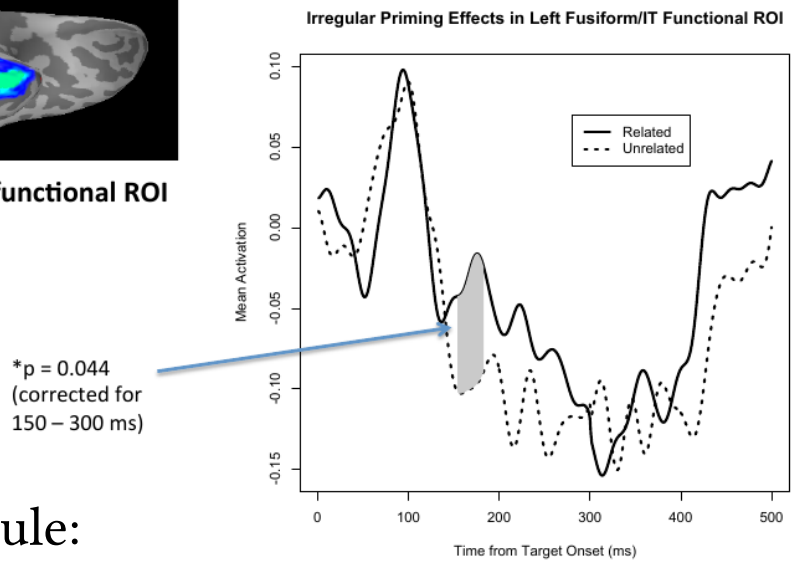


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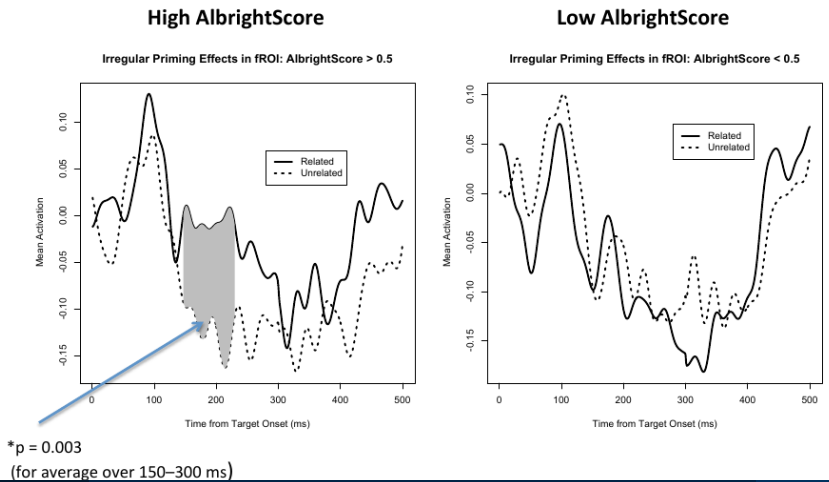

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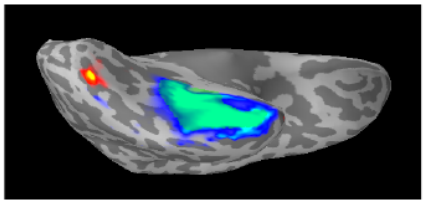

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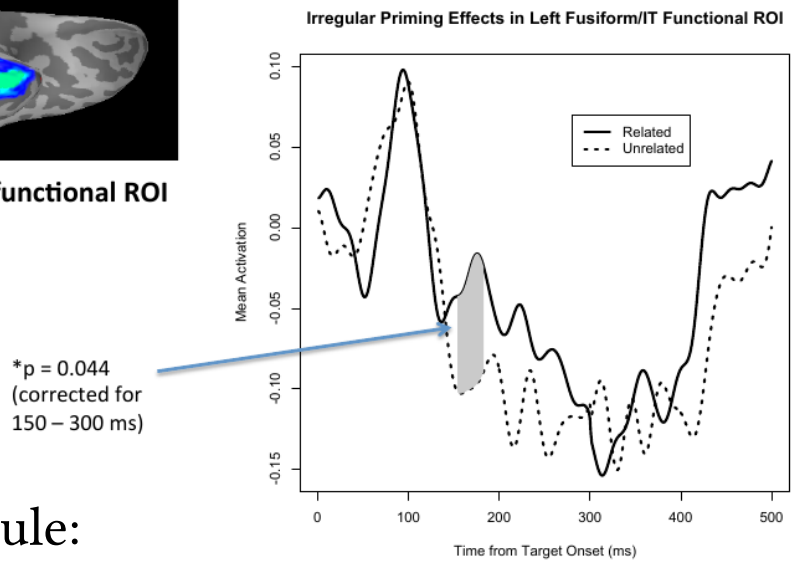
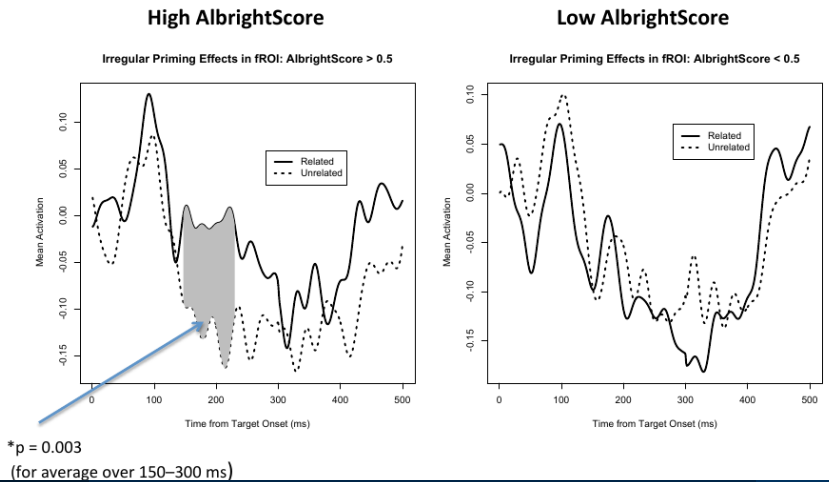



**Correlated** with strength of rule:



# Infixation in Tagalog

## Obligatory decomposition

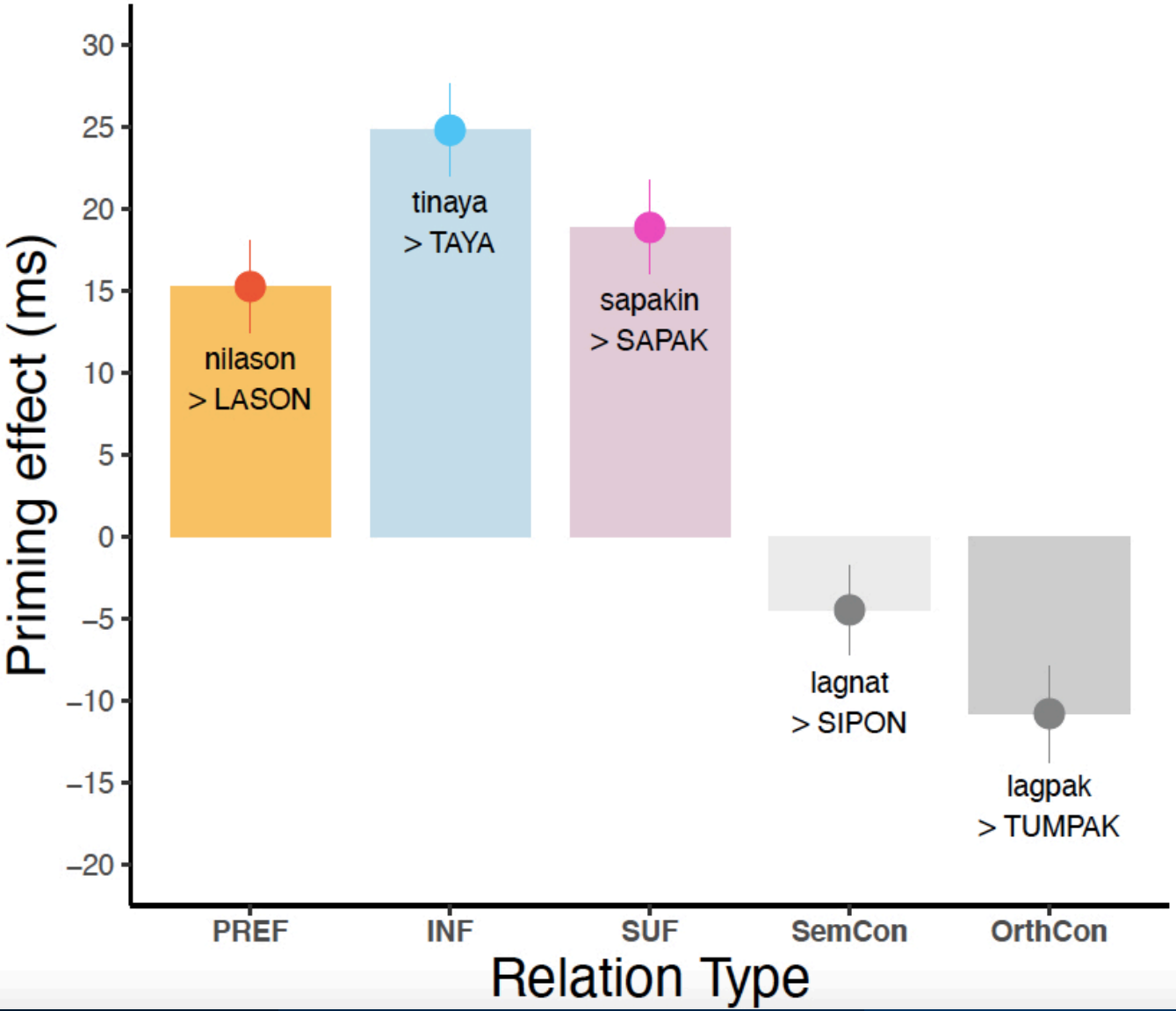
1. Complex forms (stem+affix) are decomposed.
2. We seem to encode what affixes our language has.
3. What if the affix is an infix?

Tagalog has prefixes, suffixes and infixes (Cayado 2023; Cayado et al. 2023):

| Condition | Target | Related Prime | Unrelated Prime |
|---|---|---|---|
| INF | TAWAG 'call' | tinawag 'called' | sumbong 'complain' |
| PREF | LUNOD 'drown' | nilunod 'drowned' | seryoso 'serious' |
| SUF | BASAG 'to break' | basagin 'to break' | alangan 'uncertain' |
| SemCon | SIPON 'cold' | lagnat 'fever' | bantay 'guard' |
| OrthCon | TUMPAK 'correct' | sapak 'punch' | unggoy 'monkey' |

# Infixation in Tagalog

… and all are decomposed in masked priming: (Cayado 2023)



# Infixation in Tagalog

Tagalog infixation and pseudo-infixation: where should we get priming?

(Wray et al. 2022; Cayado 2023)

| | | | | |
|---|---|---|---|---|
| a. | *subok* | 'try' | *sinubok* | 'tried' |
| b. | *gulat* | 'surprise' | *ginulat* | 'shocked someone' |
| c. | **noŋ* | — | *ninoŋ* | 'godfather' |
| d. | **mistro* | — | *ministro* | 'ministry' |

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➤ See Wray et al. (2022) for discussion of the M170 in Tagalog infixes, pseudo-infixes and reduplication.

# Nonconcatenative morphology

We've seen converging evidence that morphologically complex forms are decomposed into constituent morphemes.

There's a wealth of work on processing Semitic.

(Frost et al. 1997, 2000; Deutsch et al. 1998, 2000, 2003, 2005; Deutsch and Meir 2011; Velan et al. 2005; Bick et al. 2008, 2010; Boudelaa and Marslen-Wilson 2005, 2011; Boudelaa et al. 2010; Twist 2006; Ussishkin and Twist 2009; Ussishkin et al. 2011; Schluter 2013; Ussishkin et al. 2015; Moscoso del Prado Martín et al. 2005; Gwilliams and Marantz 2015; Farhy et al. 2018)

Main findings: robust root priming and some template priming.

What does this look like? How abstract can the representation of these morphemes be?

# Nonconcatenative morphology

Work by Deutsch, Frost and colleagues:

| | | | | |
|---|---|---|---|---|
| ✓ | **Root priming:** | התלבש | — | הלביש |
| | | *hitlabeʃ* | | *helbiʃ* |
| | | ‘got dressed’ | | ‘dressed someone up’ |
| ✓ | **Template priming:** | הסריט | — | הספיק |
| | | ***he**sri**t*** | | ***he**spi**k*** |
| | | ‘filmed’ | | ‘sufficed’ |
| ✗ | **Pattern priming:** | תקליט | — | תרגיל |
| | | ***ta**kli**t*** | | *TARGIL* |
| | | ‘record’ | | ‘exercise’ |
| ? | **Abstract template** | צלל | — | רחץ |
| | | ʦ*alal* | | *raxa*ʦ |
| | | ‘dove’ | | ‘washed’ |

Three characters aren’t enough to **identify the verb/template**:

1. basar בשר
2. halax הלך
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**What we know:**

1. Affixes are obligatorily decomposed.
2. M170 tracks decomposition.
3. Roots are primed.
4. Templates are primed (sometimes).

## Hypotheses

A Visual word decomposition only tracks overt forms/morphemes.

B Visual word decomposition tracks abstract morphemes as well.

## Methods (Kastner et al. 2018)

- Visual lexical decision using MEG.
- Masked priming, SOA = 33ms.
- N = 21 native speakers of Hebrew.
- 42 verbal targets in *XaYaZ*, matched with primes.

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## Materials

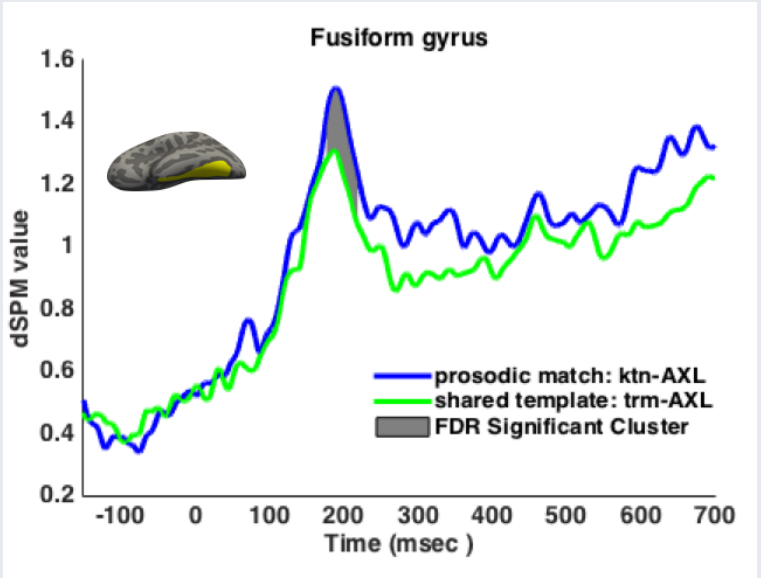
| | Shared Template | | | Shared Root | | |
|---|---|---|---|---|---|---|
| | Ortho | Phono | Gloss | Ortho | Phono | Gloss |
| **Related** | צלל | tsalal | 'dove' | התרחץ | hitraxets | 'washed himself' |
| **Unrelated** | בשר | basar | 'meat' | התלבש | hitlabeʃ | 'dressed up' |
| **Target** | רחץ | | raxats | | washed (transitive) | |

- All strings were unambiguous.
- Unrelated Shared Template prime ('meat'): adjectives and nouns.
- Ssyntactic category cannot be known from the orthography or phonology alone.

## Results

### Shared template

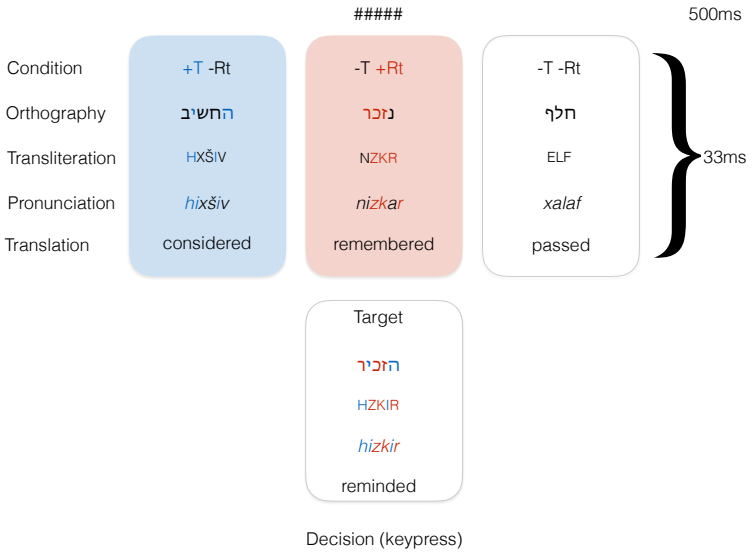
- Significant effect of Relatedness.
- $p < 0.01$.
- 177-219ms.
- **Novel result:** verbs in *XaYaZ* prime other verbs in *XaYaZ*.



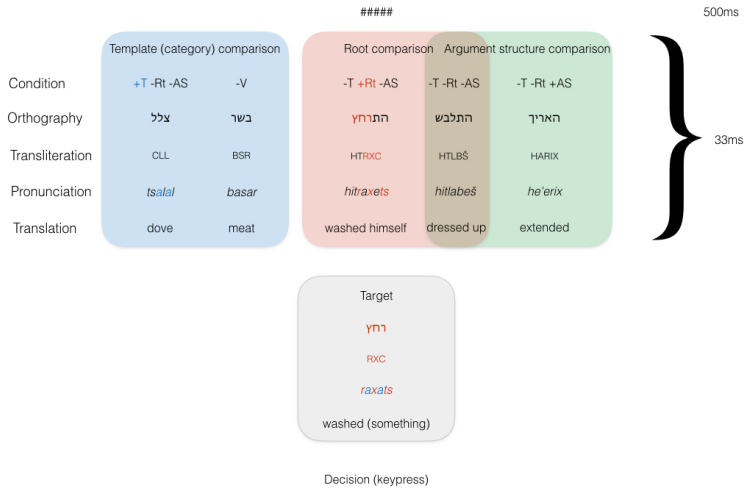

1. Replicated findings for root and template priming in *heXYiZ* (not shown).
2. No root priming in this template, as noted in the behavioral literature before (remains mysterious).

# Full experimental design

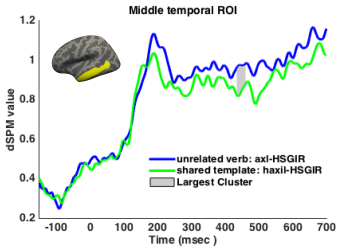
## Experiment 1: *heXYiZ*



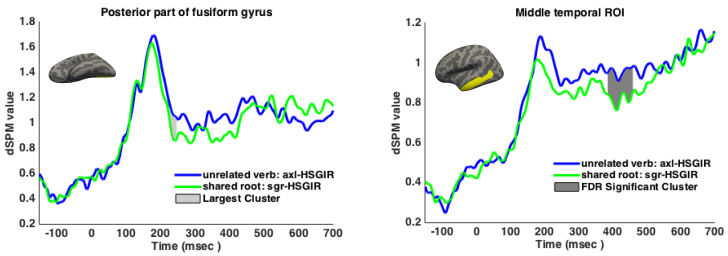

## Experiment 2: *XaYaZ*




### Shared Template




### Shared Root

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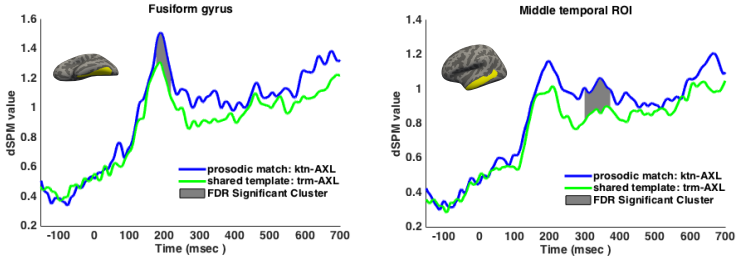

# Nonconcatenative morphology

## Discussion

**Implications:**

- If a Hebrew string XYZ can be immediately parsed into [$\sqrt{\text{XYZ}}$ v], it is.
- Abstract v may then be primed again, even if it is covert.

$\Rightarrow$ Support for Hypothesis B: readers recognize abstract morphemes too.

**In general:**

- In line with the literature on form-based masked priming.
- Provides an explanation for masked priming results beyond matching of overt forms.

$\Rightarrow$ Beyond "priming morphemes": experimental findings only make sense given a theory of the task (a linking theory).

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# Additional references

- Work in this general approach:
  - Prefix/particle priming: Creemers et al. (2020)
  - Plural affix priming: Davies and Embick (2019)
  - Auditory priming: Schluter (2013); Ussishkin et al. (2015)
  - Rhyme auditory priming: Bacovcin et al. (2017)
  - Argument structure: Gwilliams and Marantz (2018); Neophytou et al. (2018)
  - Nouns vs verbs: King et al. (To appear)
  - Insights from Tagalog (infixation, reduplication): Wray et al. (2022); Cayado (2023); Cayado et al. (2023)
- One alternative view: Baayen et al. (2011, 2015); Marantz (2013)
- Word processing in a syntactic context: Luke and Christianson (2011)
- Overviews: Crepaldi (2023); Stockall and Gwilliams (submitted)

# Goals, revisited

- Discuss one major issue of morphology in the psycholinguistic and neurolinguistic literature.
- Most studies ask whether words decompose into morphemes during language recognition and production.
- Some hypotheses suggest that decomposition varies depending on the "transparency" or "regularity" of the morphology.
- We looked at evidence that words are decomposed no matter how "opaque" and "irregular".
- Even when the morphemes are complex or abstract, e.g. infixes in Tagalog and verbalizers in Hebrew.

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