Lexical processing

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Morphology, UoE 2022-23

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.
- Error rate $\sim$ frequency.
- The strongest, most robust measure we have.
- Though we still don't understand it completely:
  - 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?

Priming

- Prime and target.
- Masked priming.
- Identity prime.
- Semantic prime.
- Form prime?

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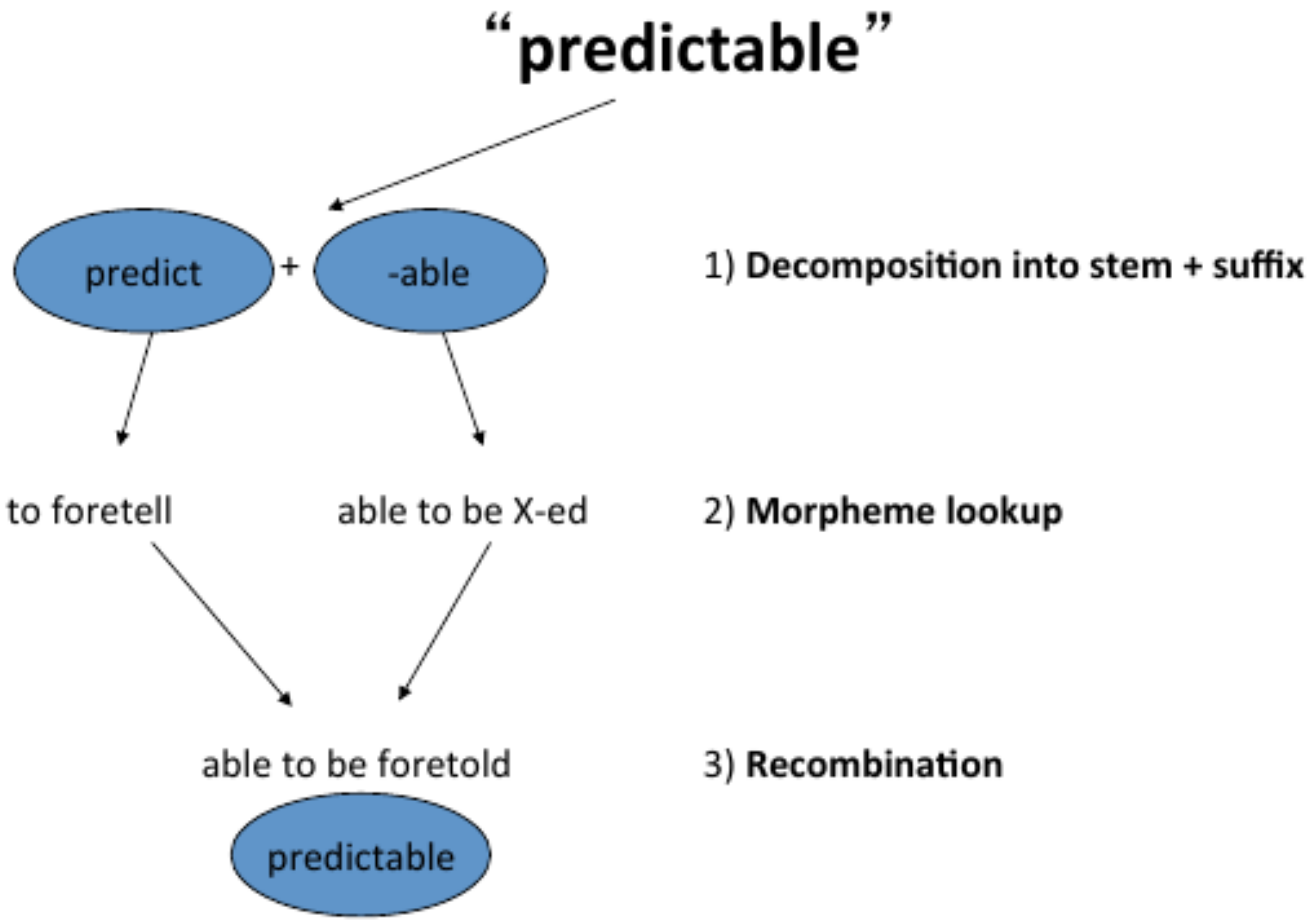
Affix stripping: Taft (1979)



Decomposition, lookup and recombination can be affected by:

- **Surface** frequency.
- **Base** frequency.

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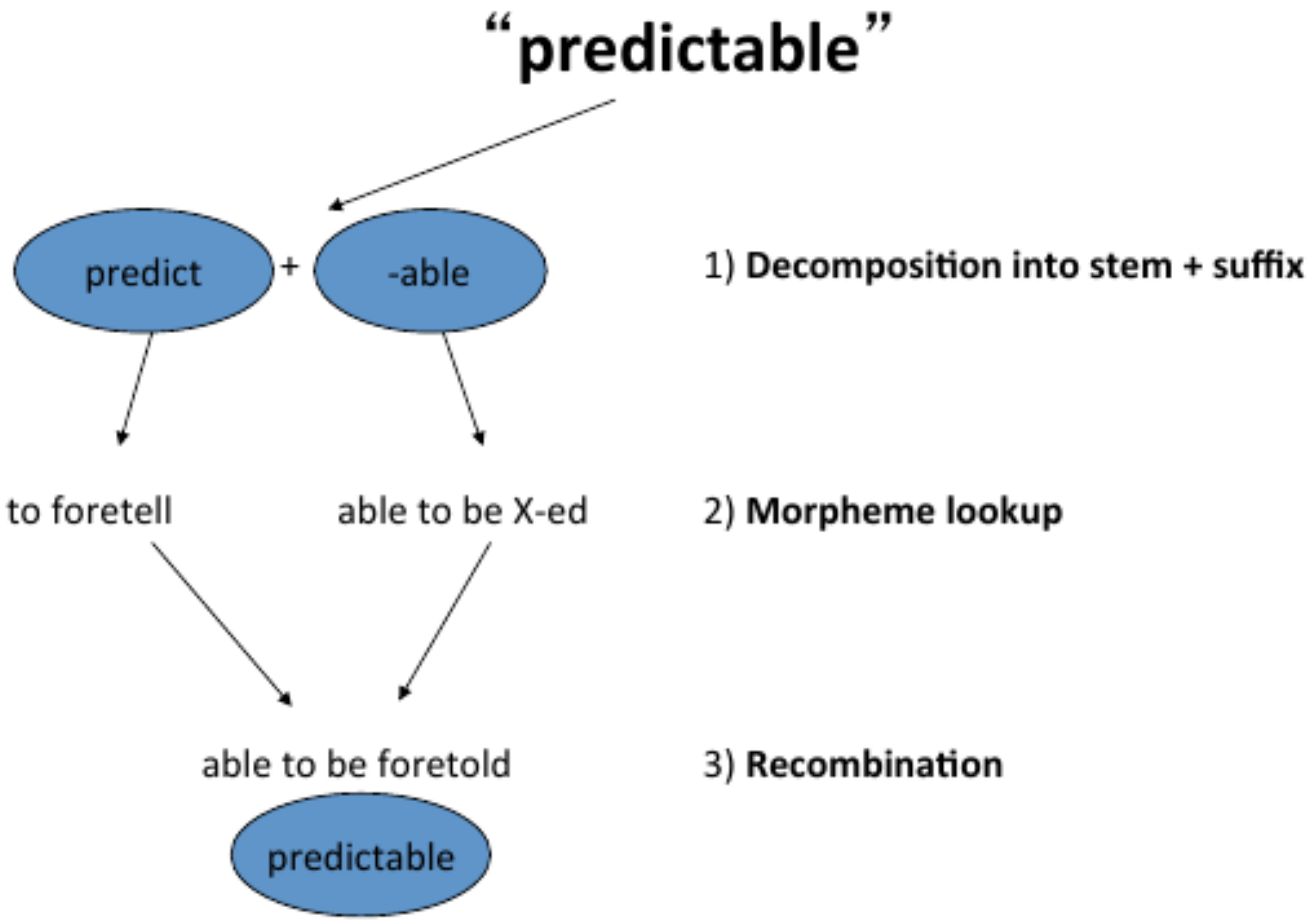

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Priming Predictions

Does *nation* prime *national*?

Storage

- Yes!
  - Similar phonology.
  - Similar semantics.

Decomposition

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

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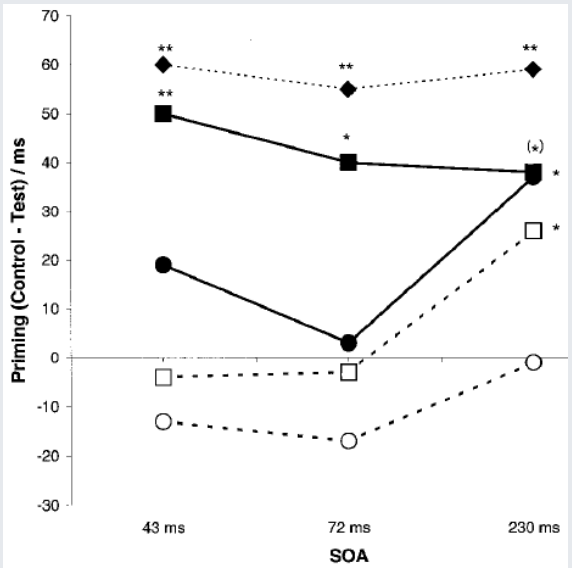
Behavioral findings: Rastle et al. (2000)

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



- Stimuli are **obligatorily** (automatically) decomposed into stem and affix.
- Morpho ≈ Identity.
- Morpho ≠ Form + Meaning (phonesthemes).

➤ What about things that only look like affixes?

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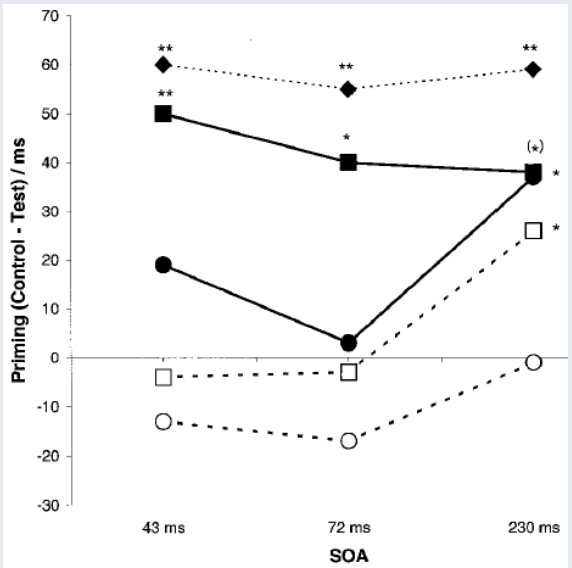

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Behavioral findings: Rastle et al. (2004)

Obligatory decomposition

✓	**Semantic:**	*clean**er*** — CLEAN
✓	**Psuedo-morphological:**	*corn**er*** — CORN
✗	Form:	*brothel* — BROTH

- *broth**er*** 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**?

Behavioral findings: Rastle et al. (2004)

Obligatory decomposition

✓	**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**?

Behavioral findings: Priming for Irregulars?

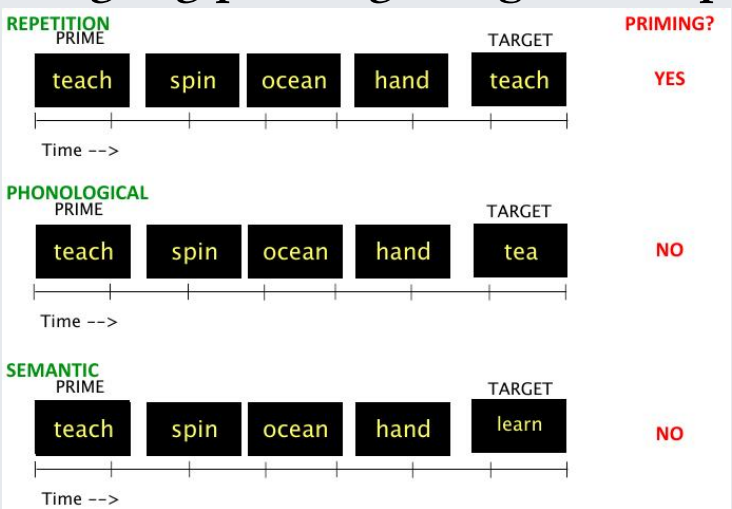
No: Marslen-Wilson et al (1993)

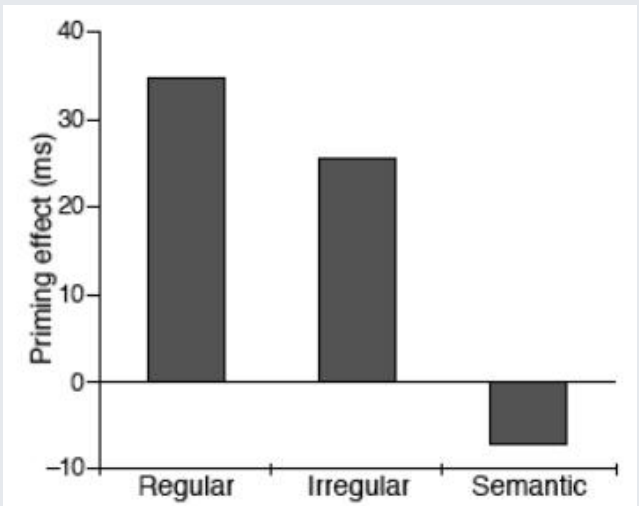
- Cross-modal priming: *taught* does not prime TEACH.

	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: 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*

- **Finding**: Priming for irregulars, including *taught* priming TEACH.
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2. Decomposition is obligatory.
3. Irregular verbs are decomposed.
4. Can we predict how much?

Where is -*able* more frequent?

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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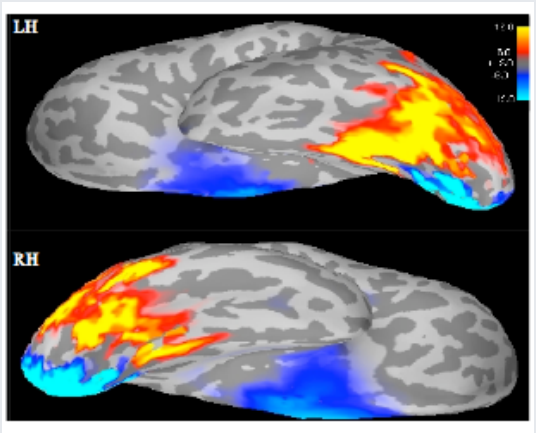
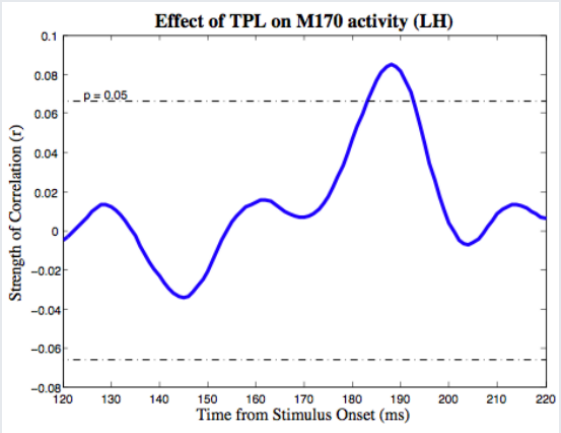
Transition probabilities: M170

M170 effect (Solomyak and Marantz 2009)

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





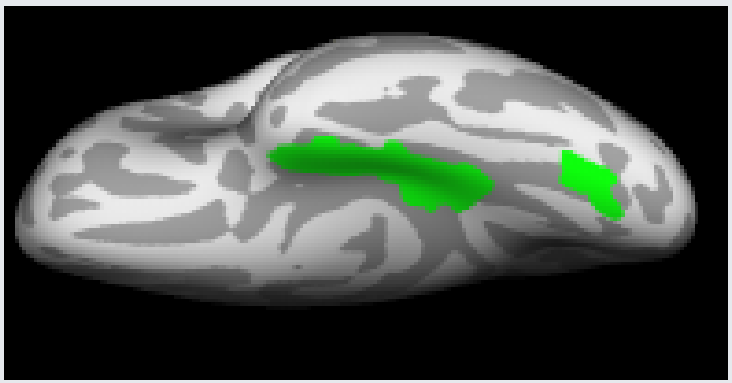
- Neural correlate of decomposition.
- TP(*formidable*) > TP(*taxable*)
- M170(formidable) > M170(taxable). (Solomyak and Marantz 2010)

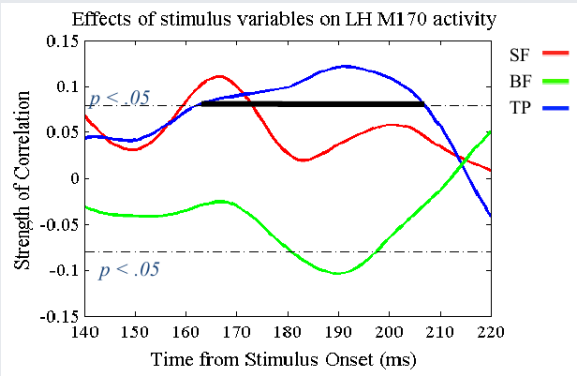
➤ What about the *brother* items?

Transition probabilities: M170

Psuedo-affixes show M170 effects

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





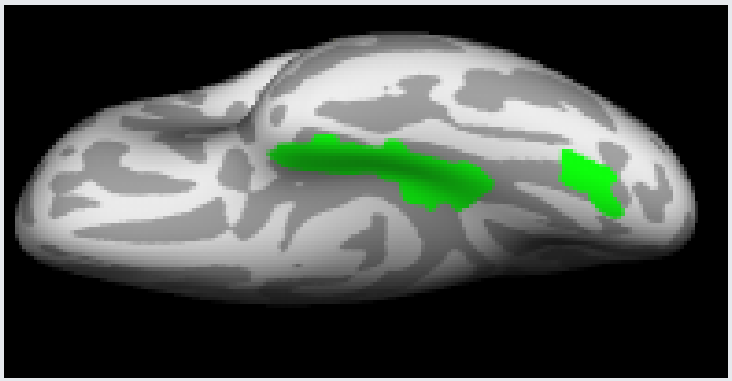
➤ Converging behavioral and MEG evidence for obligatory decomposition.

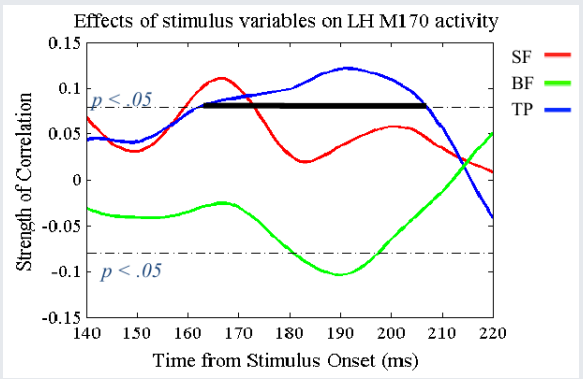
Transition probabilities: M170 and M350

We can even isolate different lexical statistic measures.

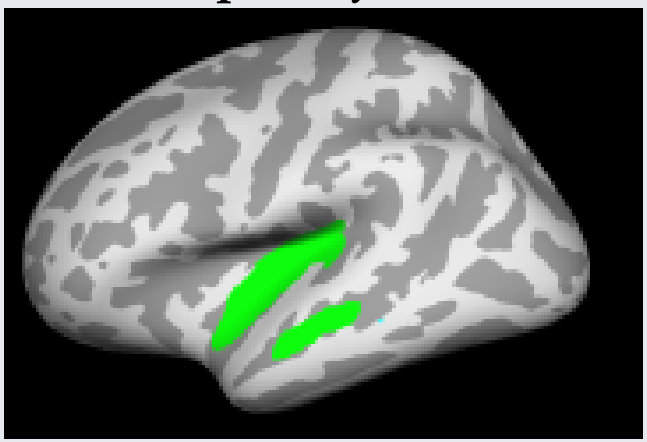
Lewis et al (2011)

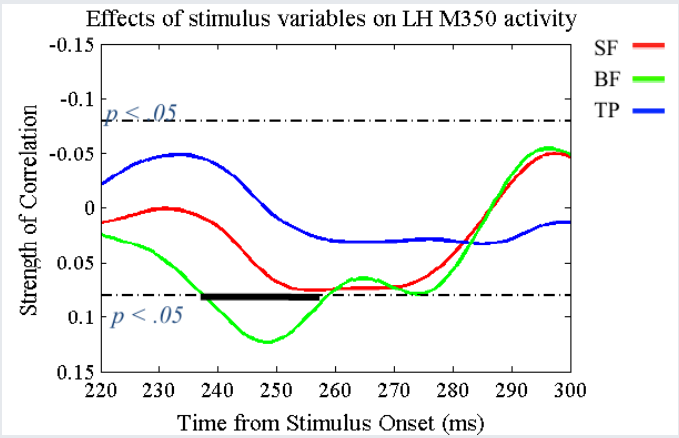
- *Lotion*, *ration*, *magic*, *barber*, *final*, ...
- TP in M170: M170(formidable) > M170(taxable)





- 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.

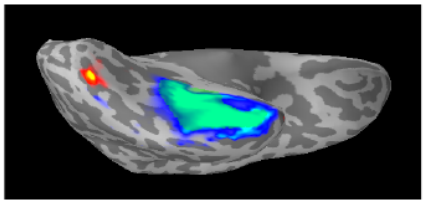
Albright and Hayes (2003)

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

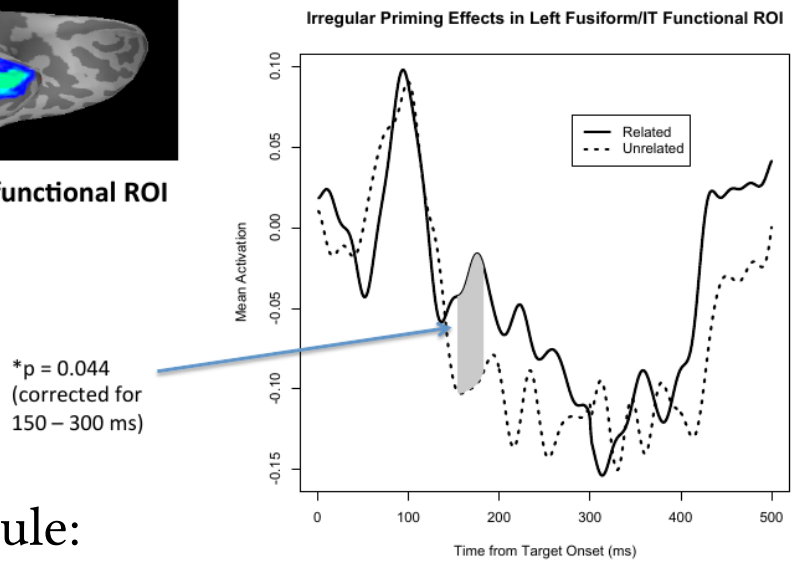
	AlbrightScore	Related Forms
bleed-bled	**0.71**	breed-bred, lead-led, read-read
smite-smote	**0.21**	write-wrote
ask-asked	**0.97**	walk-walked, park-parked, mark-marked, talk-talked, ...

Tying it all together

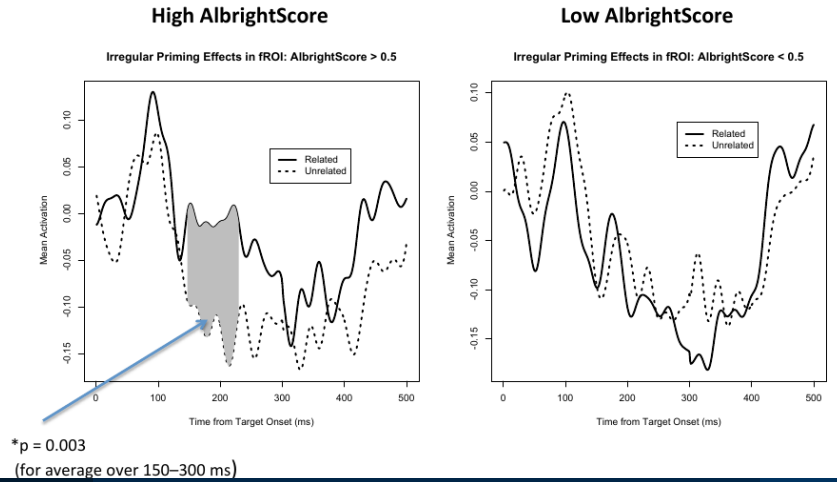
Return to irregular verbs: does *taught* prime TEACH in masked priming?
Fruchter et al. (2013): **yes**. Priming found in M170 (and M350).



Left Fusiform/IT functional ROI



Correlated with strength of rule:



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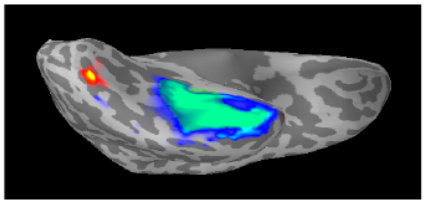

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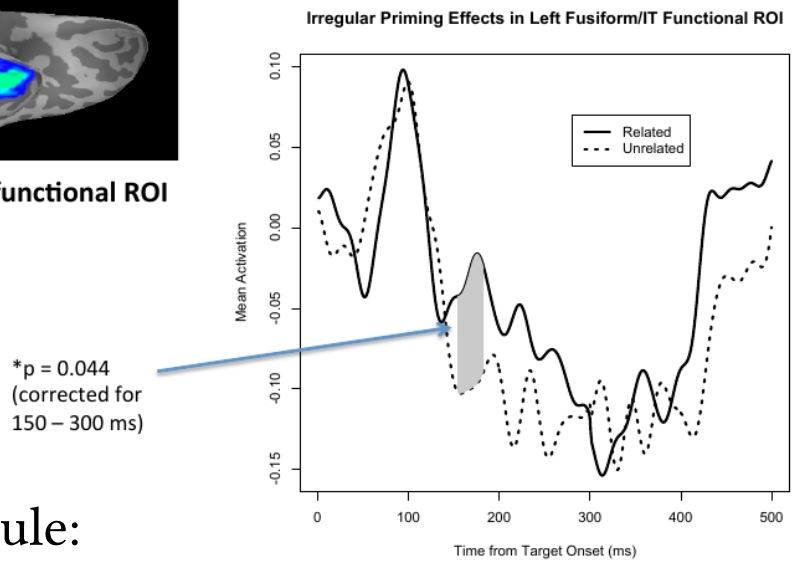

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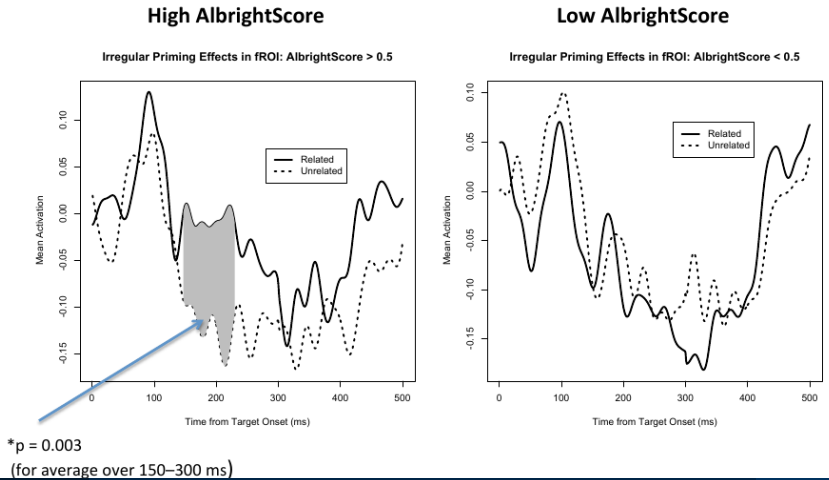

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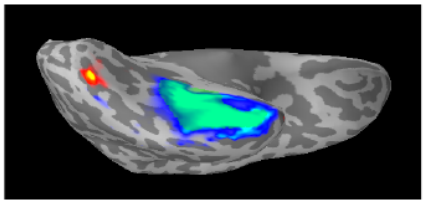

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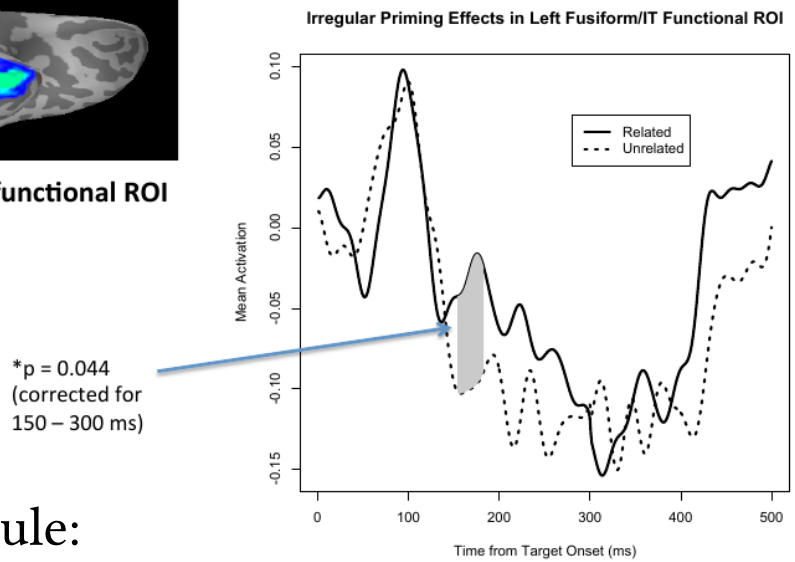

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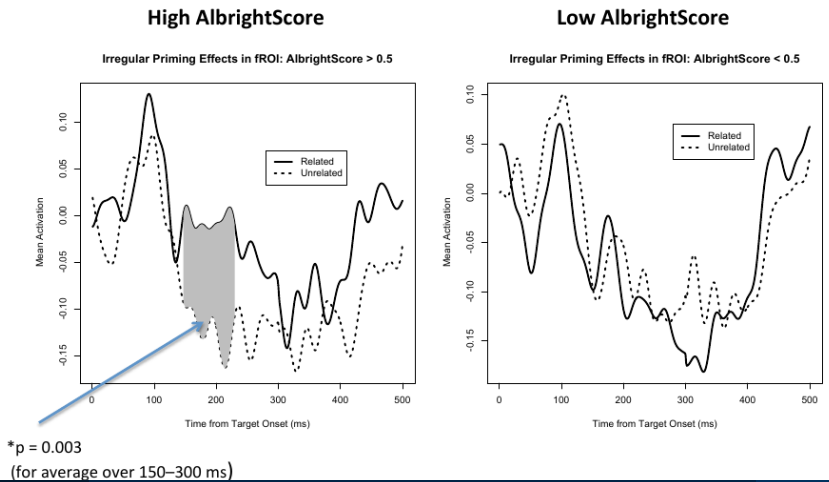

Nonconcatenative morphology

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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Work by Deutsch, Frost and colleagues:

✓	**Root priming:**	התלבש	—	**הלביש**
		hitlabeʃ		***helbiʃ***
		‘got dressed’		‘dressed someone up’
✓	**Template priming:**	הסריט	—	**הספיק**
		***he**srit*		***he**spik*
		‘filmed’		‘sufficed’
✗	**Pattern priming:**	תקליט	—	**תרגיל**
		***ta**klit*		*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
3. katan קטן

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

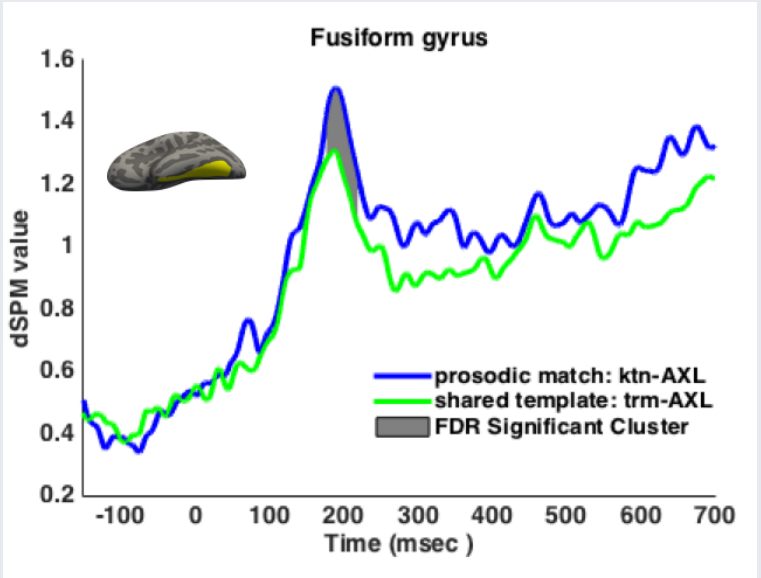
	Shared Template			Shared Root		
	Ortho	Phono	Gloss	Ortho	Phono	Gloss
Related	צלל	tsalal	'dove'	התרחץ	hitraxets	'washed himself'
Unrelated	בשר	basar	'meat'	התלבש	hitlabeʃ	'dressed up'
Target	רחץ		raxats		washed (transitive)	

- 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

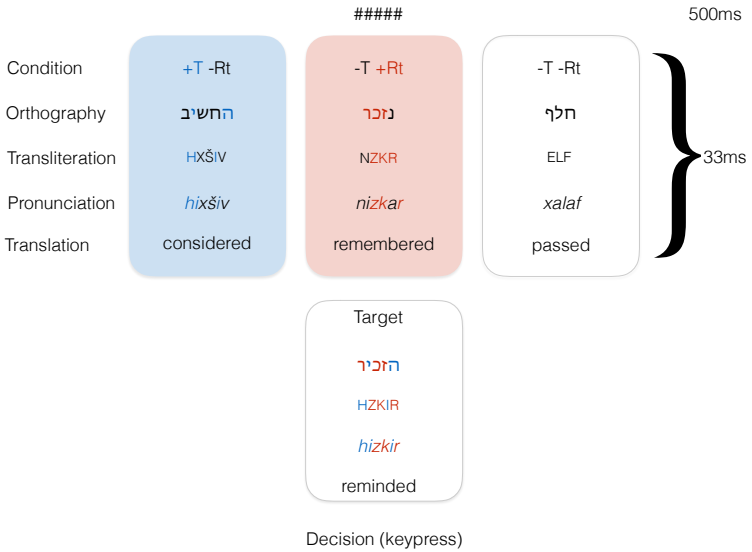
- Significant effect of Relatedness.
- $p < 0.01$.
- 177-219ms.
- **Novel result:** verbs in *XaYaZ* prime other verbs in *XaYaZ*.



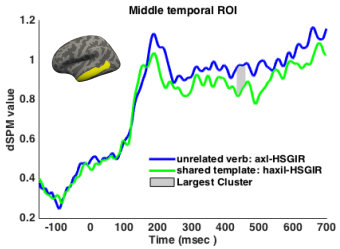
1. Replicated findings for root and template priming in *heXYiZ* (not shown).
2. No root priming in this template, as noted in the behavioral literature before (remains mysterious).

Full experimental design

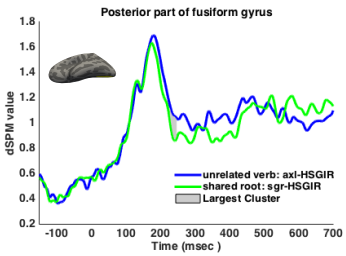
Experiment 1: *heXYiZ*

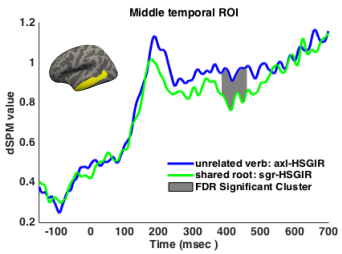


Shared Template

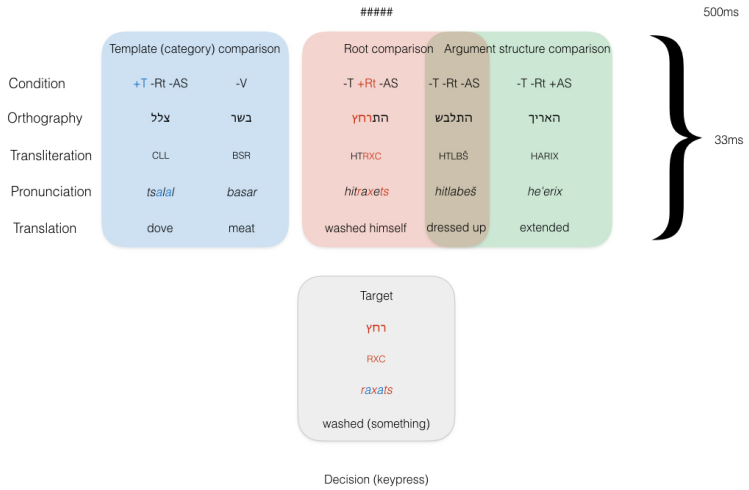


Shared Root

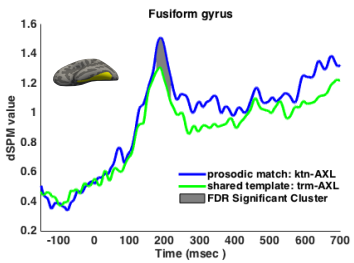


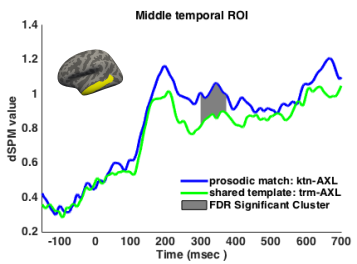


Experiment 2: *XaYaZ*



Shared Template





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)
- 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 abstract, e.g. a verbalizer in Hebrew.

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