Heinrich Heine Universität Düsseldorf

Lexical storage and morphological segmentability effects on the production of English derivatives

Simon David Stein
Ingo Plag

DFG Deutsche Forschungsgemeinschaft
FOR2373

Frequency and duration

Frequency and duration

Lexical frequency

How often does a linguistic unit occur in a language?

Acoustic duration

How long do we pronounce linguistic units?

Frequency and duration

Lexical frequency

How often does a linguistic unit occur in a language?

Acoustic duration

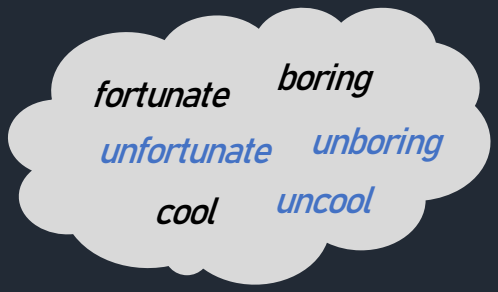
How long do we pronounce linguistic units?

higher → shorter

Storage in the mental lexicon

Storage in the mental lexicon

Whole-word storage



complex words are stored unanalyzed

Caselli et al. 2016, examples from Hay 2007: 40–41

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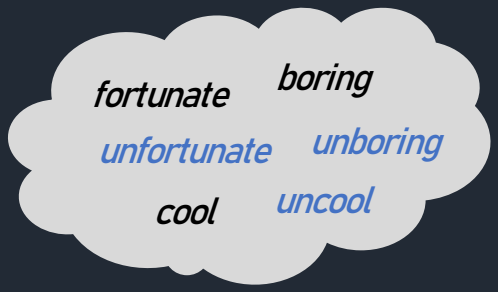

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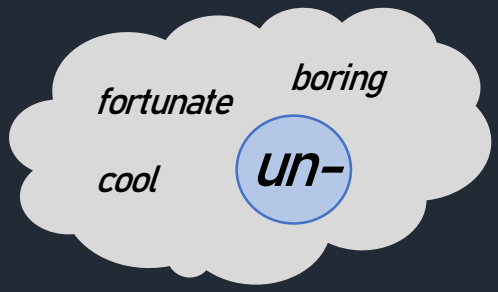

morphemes are stored separately

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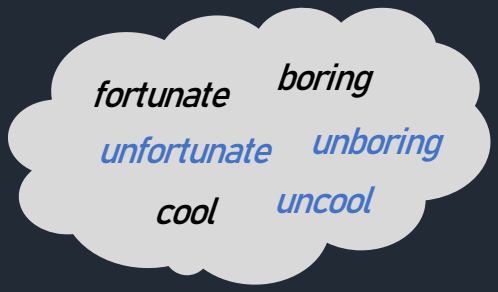

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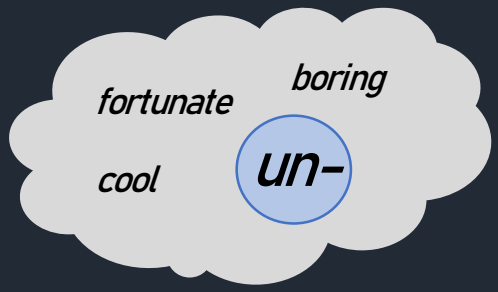

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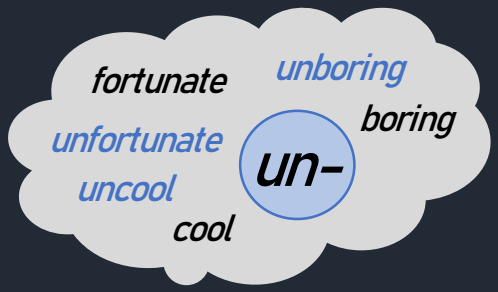

both morphemes and complex words are stored

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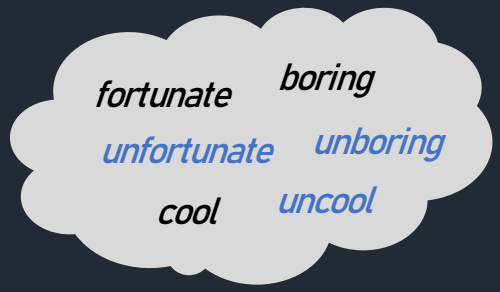

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durations will be shorter the higher the word frequency

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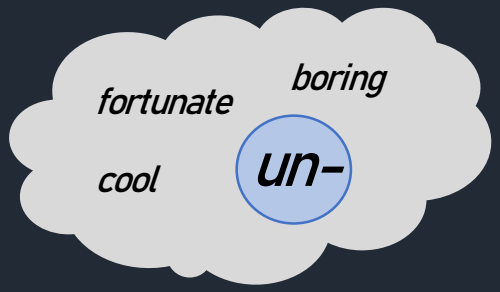

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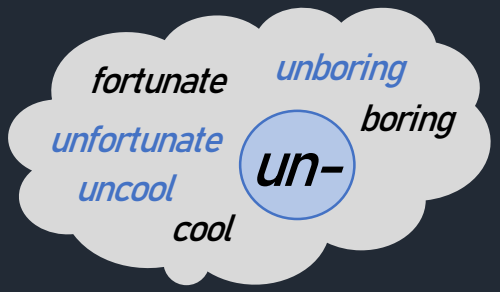

both morphemes and complex words are stored

durations will be shorter the lower the relative frequency

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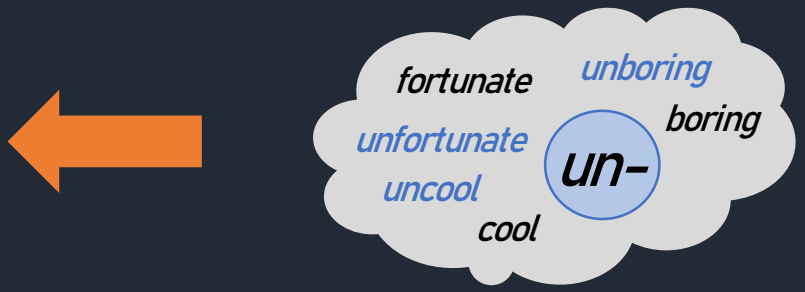
Segmentability

Dual-route models



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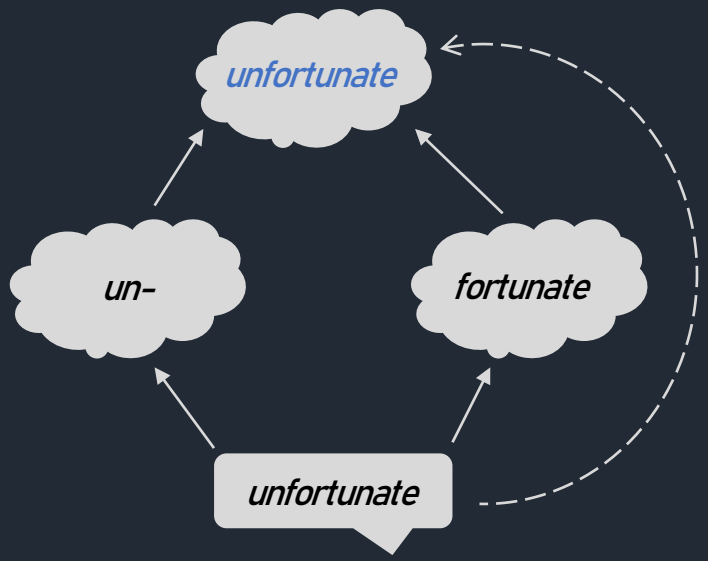

adapted from
Hay 2001: 1045

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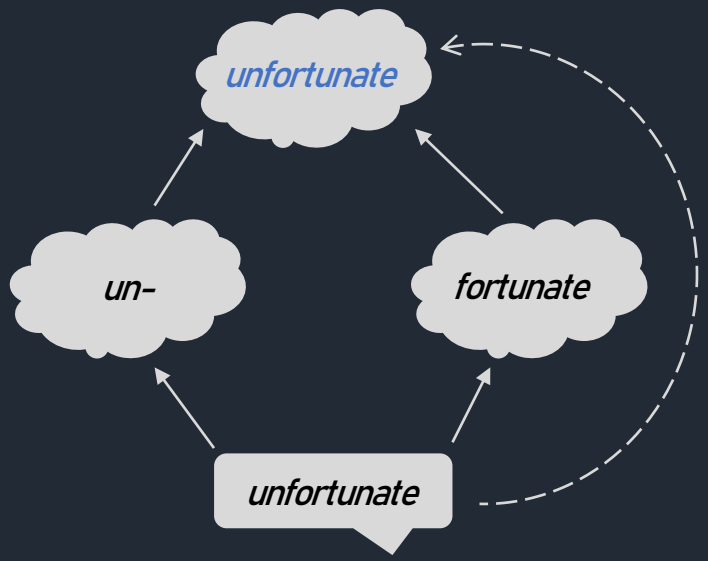

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Dual-route models

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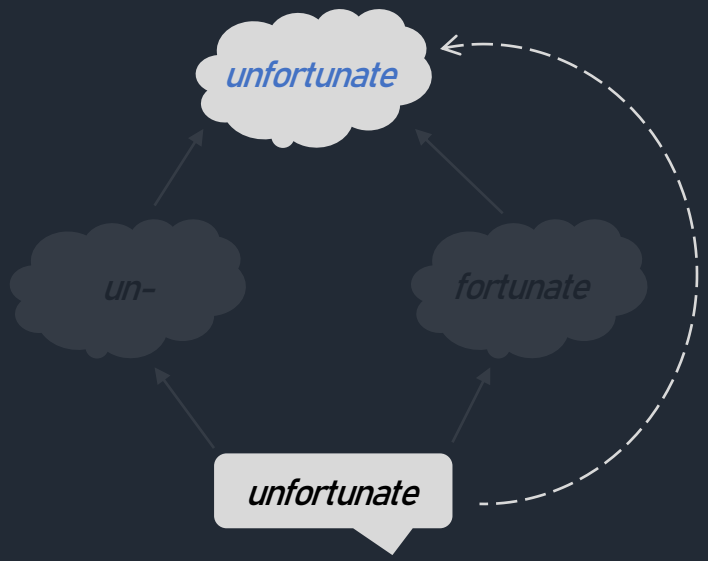
durations will be shorter the lower the relative frequency

Word	Frequency	Segmentability	Prediction
fortunate	6000	low	shorter duration
unfortunate	6915		
boring	7483	high	longer duration
unboring	4		

Caselli et al. 2016, examples from Hay 2007: 40–41, frequencies from COCA, Davies 2008

Segmentability



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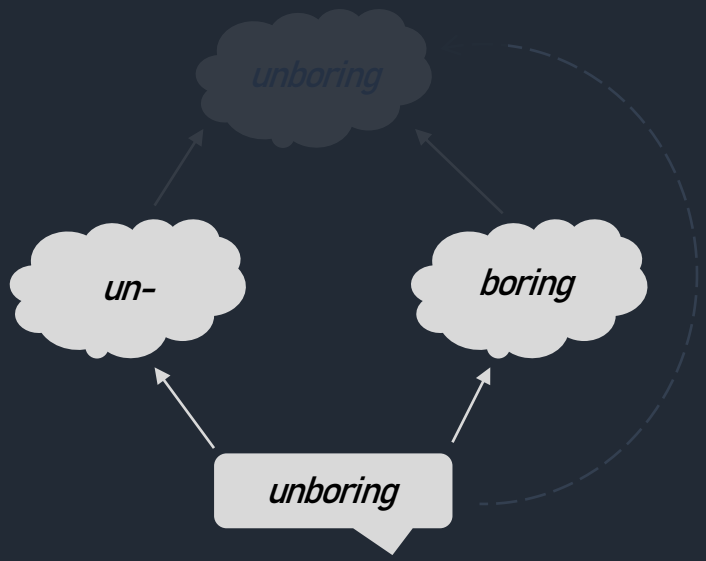

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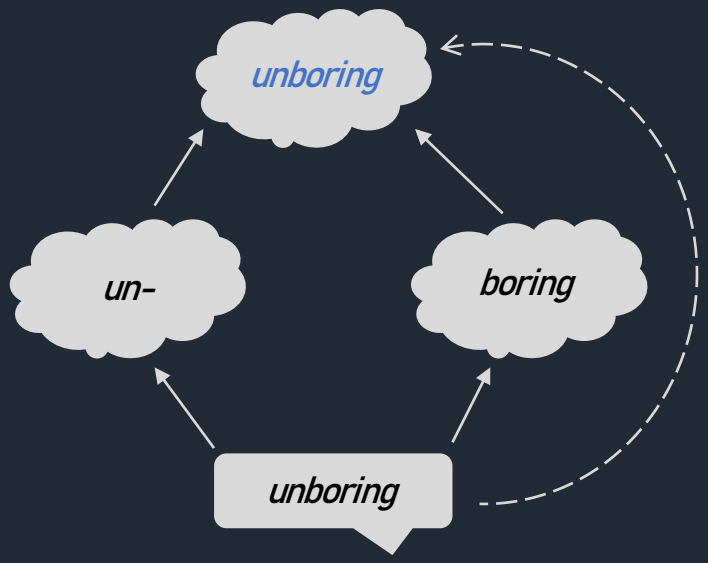

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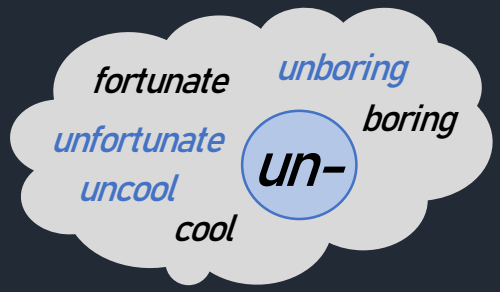

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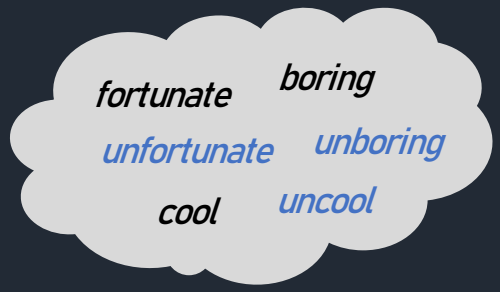

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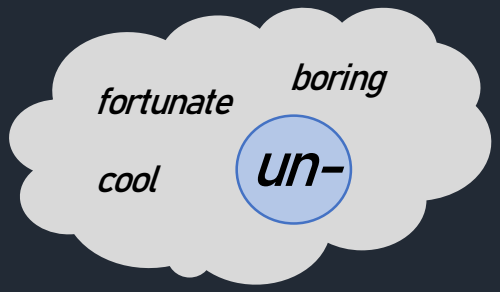

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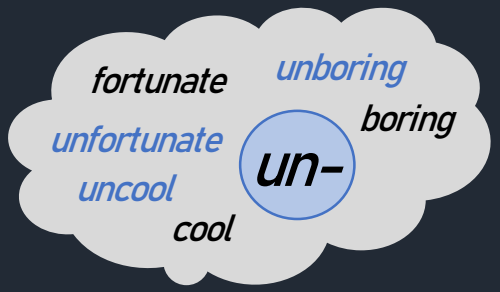

both morphemes and complex words are stored

durations will be shorter the lower the relative frequency

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Previous research

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Caselli et al. 2016

- inflectional suffixes *-ing*, *-ed*, and *-s*
- evidence for both whole-word storage and composition
  - higher base frequency → shorter word duration
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Hay 2003, 2007

- segmentability effects for *un-* and *-ly*

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- segmentability effects for *un-* and *-ly*

Plag and Ben Hedia 2018

- segmentability effects for *un-* and *dis-*
- null effects for negative *in-*, locative *in-*, and *-ly*

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Contradictory evidence:
Why do the frequency measures sometimes show and sometimes not show effects?

Caselli et al. 2016, Hay 2003, 2007, Plag and Ben Hedia 2018

Present study

Present study

Hypothesis 1

Higher word frequency → shorter duration

Present study

Hypothesis 1

Higher word frequency → shorter duration

Hypothesis 2

Higher base frequency → shorter duration

Present study

Hypothesis 1

Higher word frequency → shorter duration

Hypothesis 2

Higher base frequency → shorter duration

Hypothesis 3

Higher relative frequency → longer duration

≈ more segmentability

Present study

Hypothesis 1

Higher word frequency → shorter duration of word, base, and affix

Hypothesis 2

Higher base frequency → shorter duration of word, base, and affix

Hypothesis 3

Higher relative frequency → longer duration of word, base, and affix

≈ more segmentability

Data and measurement

Data and measurement

Data collection

- AudioBNC
- Forced Alignment
- Praat textgrids
- manual cleaning of results

Coleman et al. 2012, Boersma and Weenik 2014

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Affixes N

-ness	363	*pre-*	123
-less	216	*dis-*	689
-wise	289	*un-*	960
-ize	476	*in-*	342
-ation	3979		

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Modeling

- multiple linear regression in R using lm-function
- variable transformations
- trimming of datasets
- backwards exclusion of non-significant variables

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Predictors

- word frequency
- base frequency
- relative frequency

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Covariates

- speech rate
- number of syllables
- biphone probability sum
- bigram frequency

Coleman et al. 2012, Boersma and Weenik 2014, R Core Team 2017, Davies 2008, Vitevitch and Luce 2004

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- separate models for durations and frequencies: 81 models

Coleman et al. 2012, Boersma and Weenik 2014, R Core Team 2017, Davies 2008, Vitevitch and Luce 2004

Frequency and segmentability effects

duration	word	affix	base
affix	-ness		
word frequency			
base frequency			
relative frequency			

p < .001 expected direction

Frequency and segmentability effects

duration	word	affix	base	word	affix	base
affix	-ness			-ize		
word frequency						
base frequency						
relative frequency						

	p < .001	expected direction
	p < .001	unexpected direction

Frequency and segmentability effects

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									

p < .001 expected direction
p < .001 unexpected direction

Frequency and segmentability effects

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
affix	-less								
word frequency									
base frequency									
relative frequency									

p < .001 expected direction
p < .001 unexpected direction

Frequency and segmentability effects

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
affix	-less			pre-					
word frequency									
base frequency									
relative frequency									

p < .001 expected direction

p < .001 unexpected direction

Frequency and segmentability effects

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
affix	-less			pre-			-wise		
word frequency									
base frequency									
relative frequency									

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base frequency									
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word frequency									
base frequency									
relative frequency									
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base frequency									
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base frequency									
relative frequency									
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	$p < .001$	expected direction
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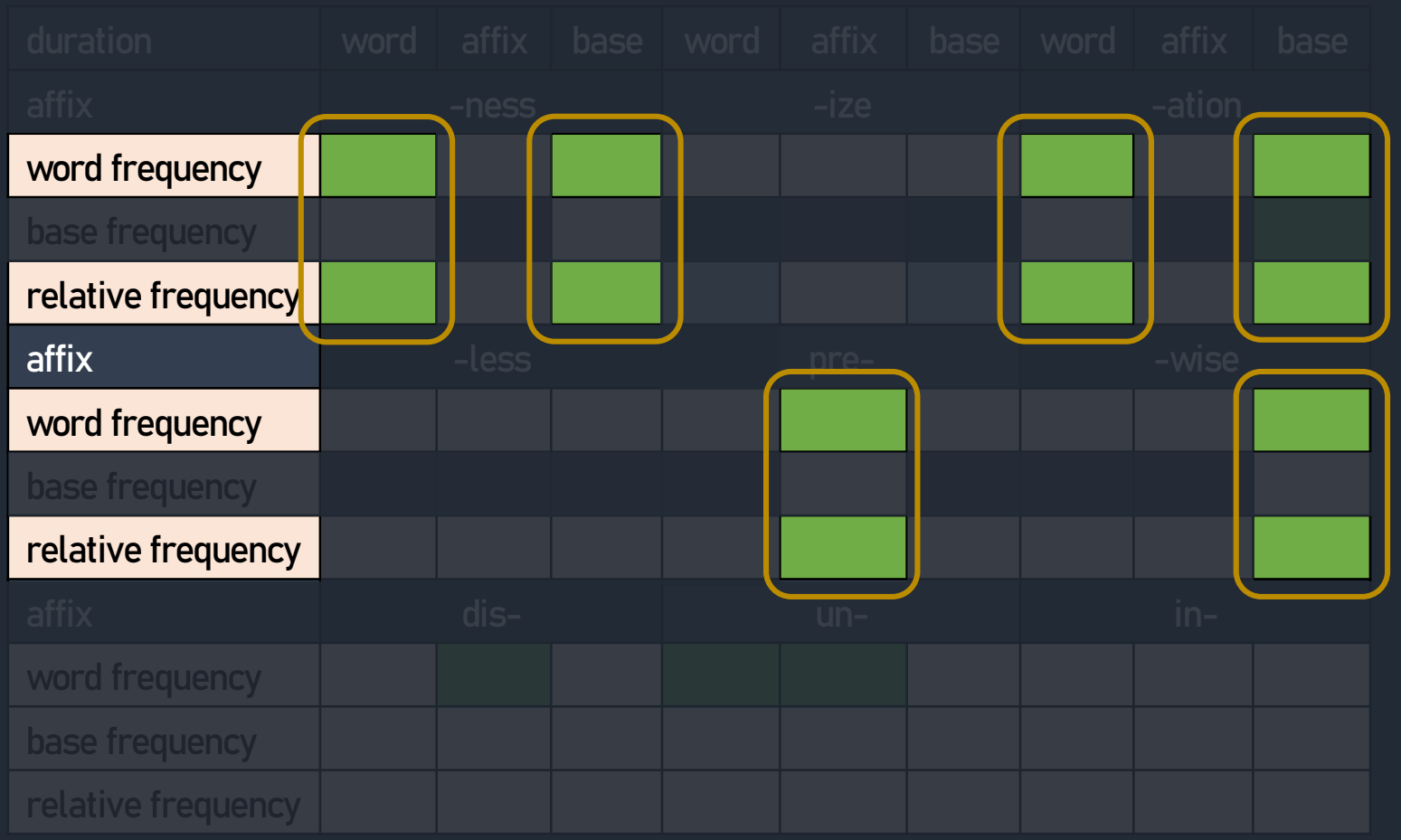
Frequency and segmentability effects



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Are the differences related to ...

Prefixes vs. suffixes

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
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base frequency									
relative frequency									
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word frequency									
base frequency									
relative frequency									

p < .001 expected direction

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Are the differences related to ... the type of affix?

Prefixes vs. suffixes

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
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word frequency									
base frequency									
relative frequency									
affix	dis-			un-			in-		
word frequency									
base frequency									
relative frequency									

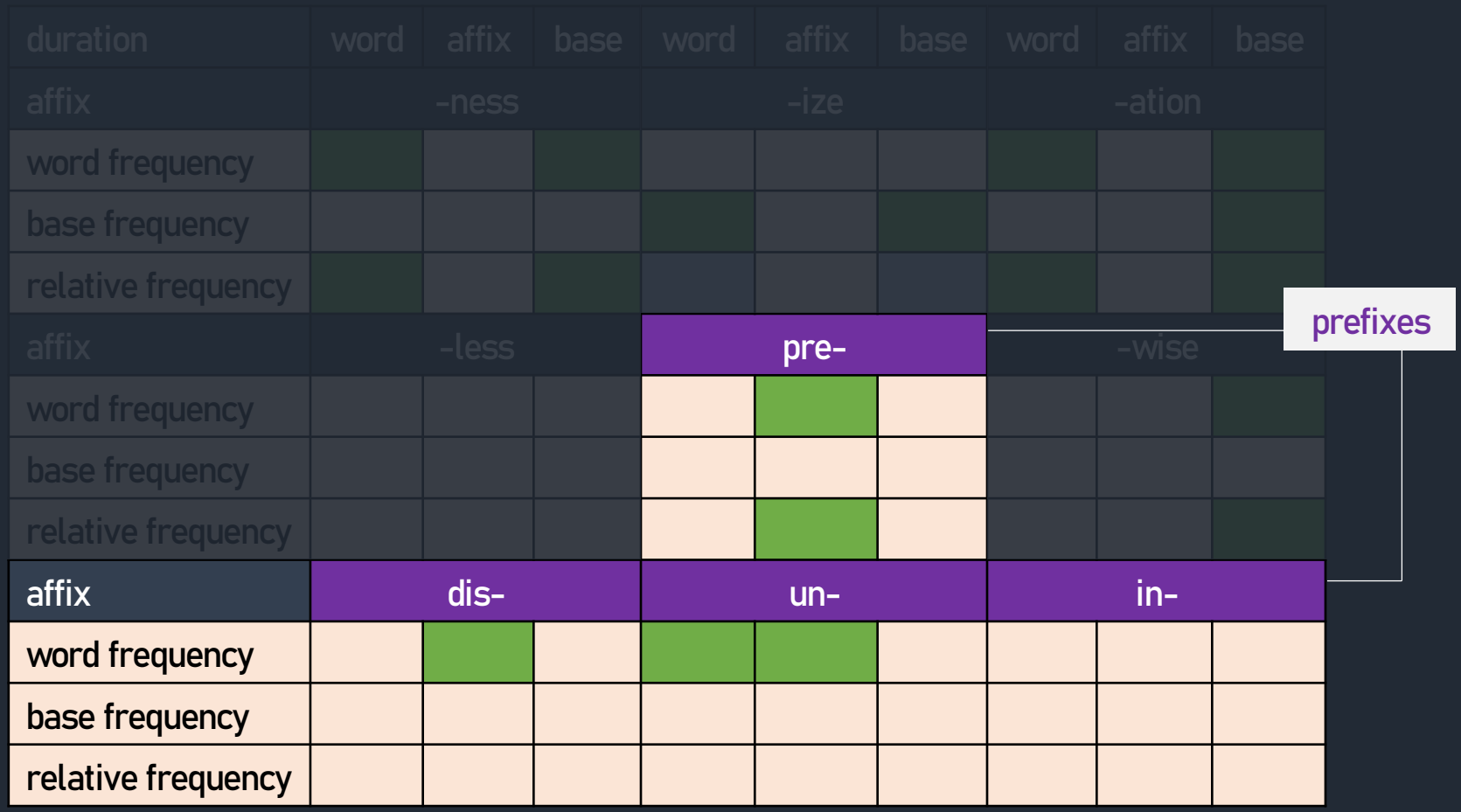
suffixes

p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ... the type of affix? ✗

Prefixes vs. suffixes



p < .001 expected direction

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Are the differences related to ... the type of affix? ✗

Affix length

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word frequency									
base frequency									
relative frequency									
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base frequency									
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word frequency									
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base frequency									
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affix	dis-			un-			in-		
word frequency									
base frequency									
relative frequency									

around 100–150 ms

p < .001 expected direction

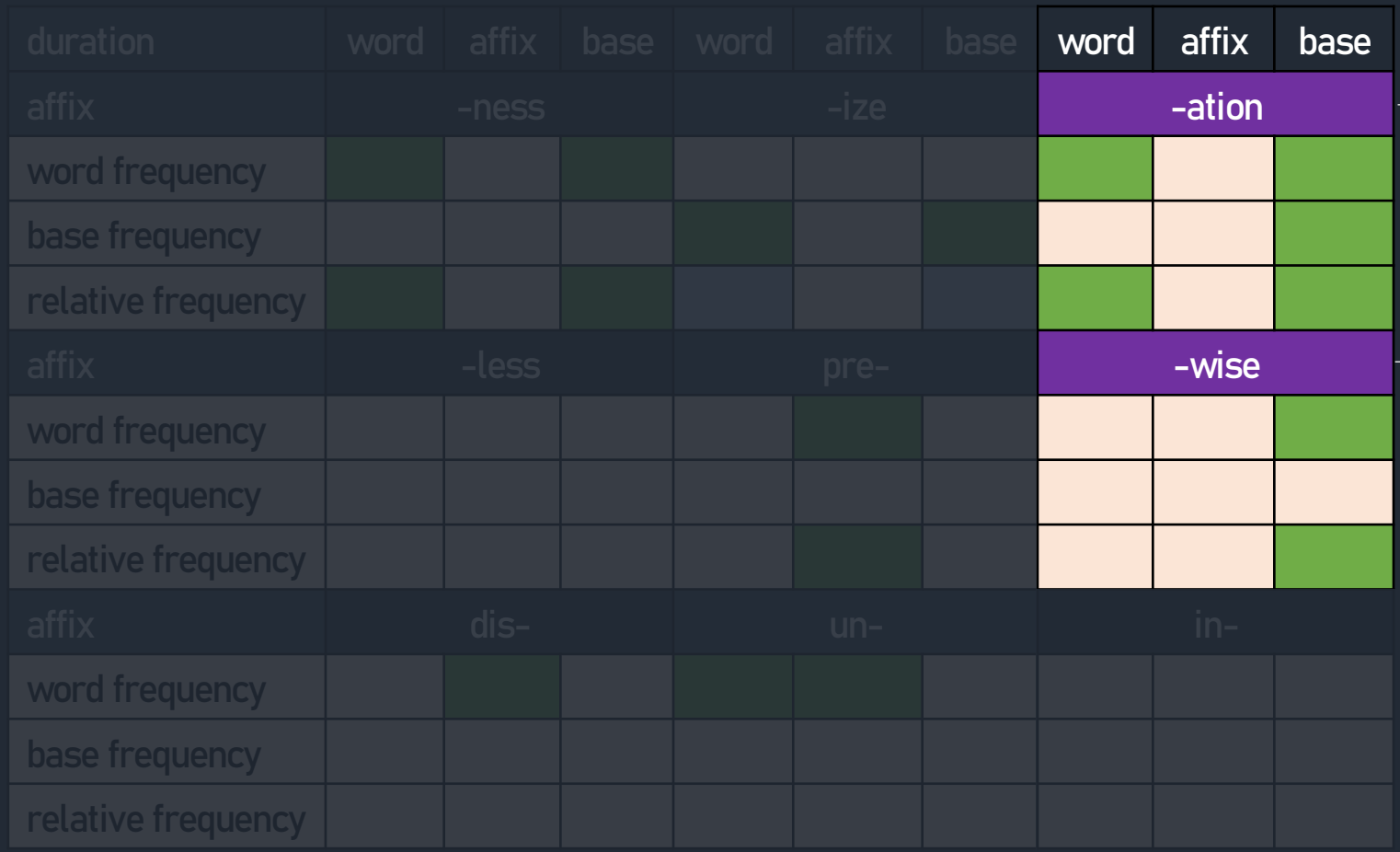
p < .001 unexpected direction

Are the differences related to ...

the type of affix? ✗

the affix length?

Affix length



around 250–300 ms

p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ...

the type of affix? ✗

the affix length? ✗

Manual resegmentation

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
affix	-less			pre-			-wise		
word frequency									
base frequency									
relative frequency									
affix	dis-			un-			in-		
word frequency									
base frequency									
relative frequency									

p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ...

the type of affix? ×

the affix length? ×

the segmentation?

Manual resegmentation

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
affix	-less			pre-			-wise		
word frequency									
base frequency									
relative frequency									
affix	dis-			un-			in-		
word frequency									
base frequency									
relative frequency									

p < .001	expected direction	Are the differences related to …	the type of affix? ✗
p < .001	unexpected direction		the affix length? ✗
p < .01	weaker effect		the segmentation? ✗

Type of prosodic integration

Type of prosodic integration

The prosodic hierarchy

- U — Phonological utterance
- IP — Intonation phrase
- ϕ — Phonological phrase
- ω — Prosodic word
- Σ — Foot
- σ — Syllable

Hildebrandt 2015, Raffelsiefen 1999, 2007

Type of prosodic integration

The prosodic hierarchy

- U — Phonological utterance
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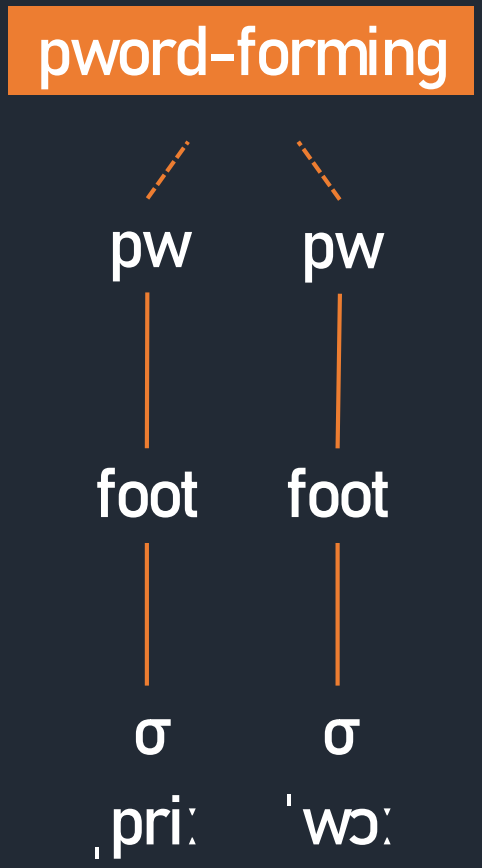
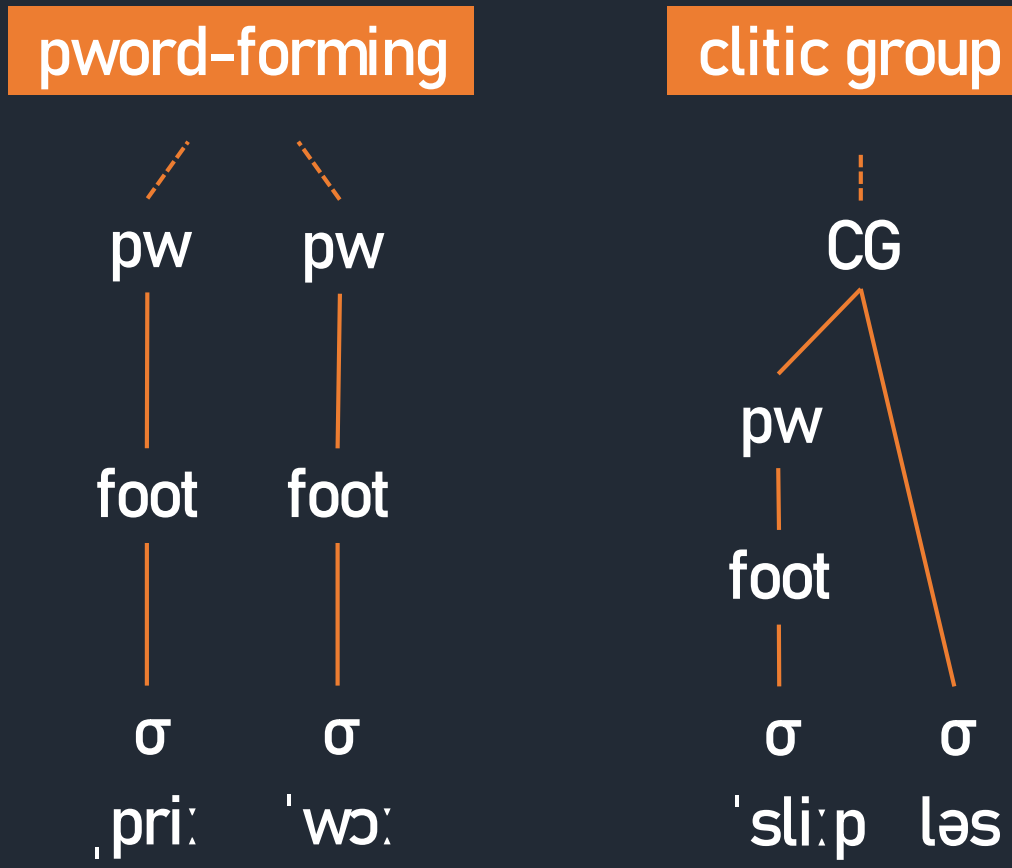
Hildebrandt 2015, Raffelsiefen 1999, 2007

Type of prosodic integration



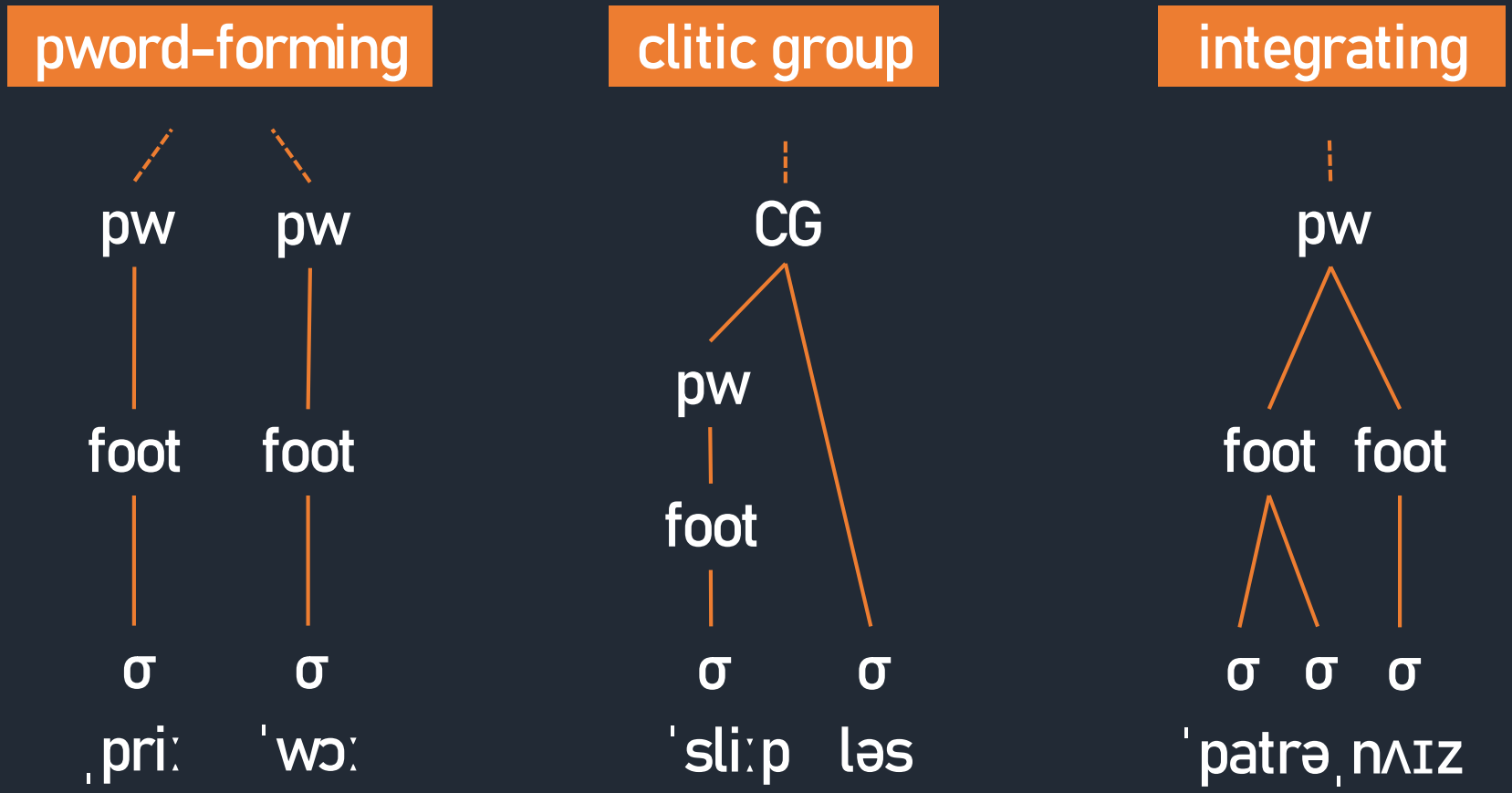
following Raffelsiefen 1999

Type of prosodic integration



following Raffelsiefen 1999

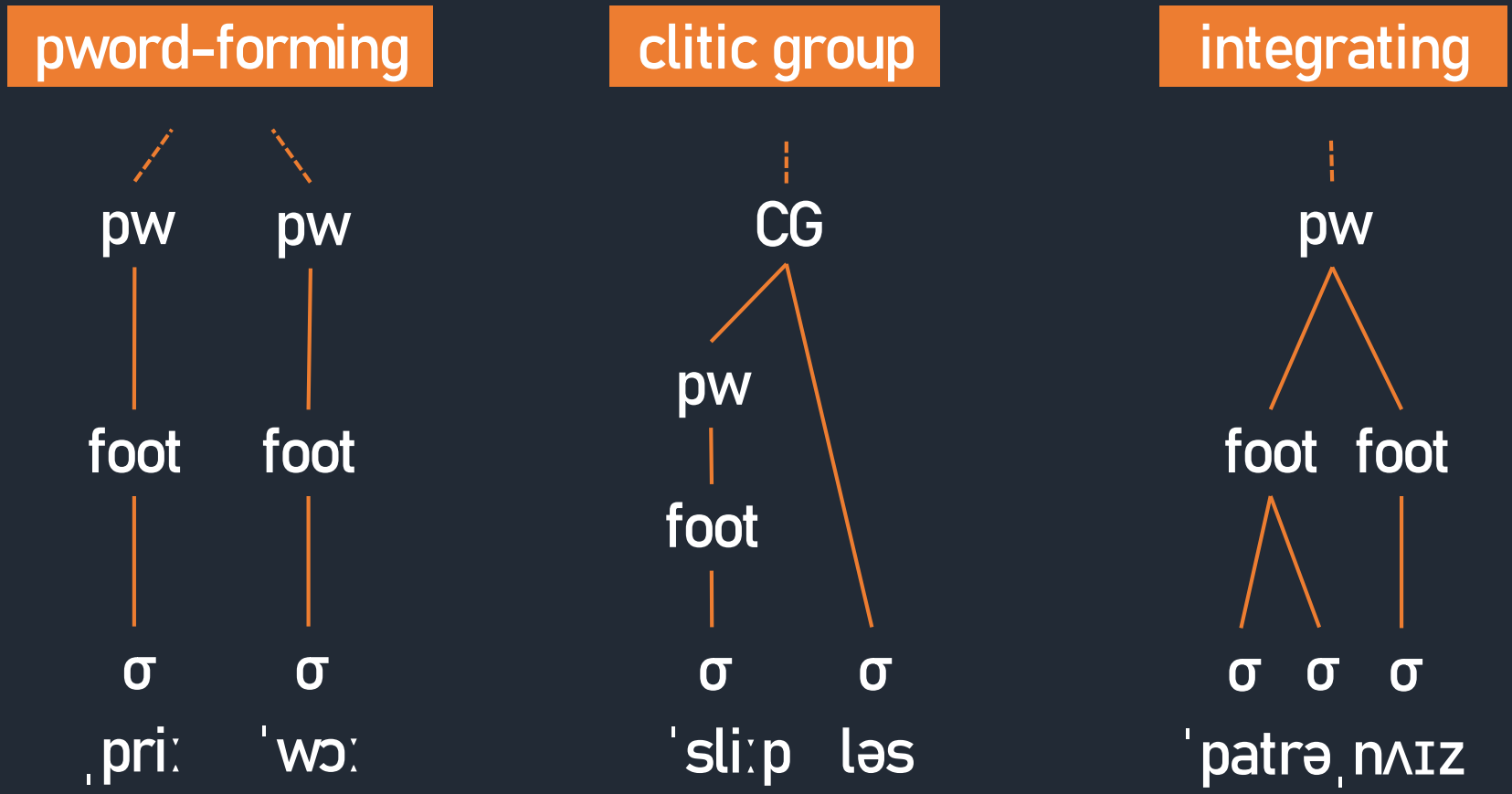
Type of prosodic integration



following Raffelsiefen 1999

Type of prosodic integration

more integration



following Raffelsiefen 1999

Type of prosodic integration

duration longer — duration shorter

pword-forming

clitic group

integrating

following Raffelsiefen 1999

Type of prosodic integration

duration longer — unclear — duration shorter

pword-forming

clitic group

integrating

following Raffelsiefen 1999

Type of prosodic integration

duration longer — unclear — duration shorter

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Type of prosodic integration

duration longer — unclear — duration shorter

pword-forming

clitic group

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following Raffelsiefen 1999

Type of prosodic integration

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
affix	-less			pre-			-wise		
word frequency									
base frequency									
relative frequency									
affix	dis-			un-			in-		
word frequency									
base frequency									
relative frequency									

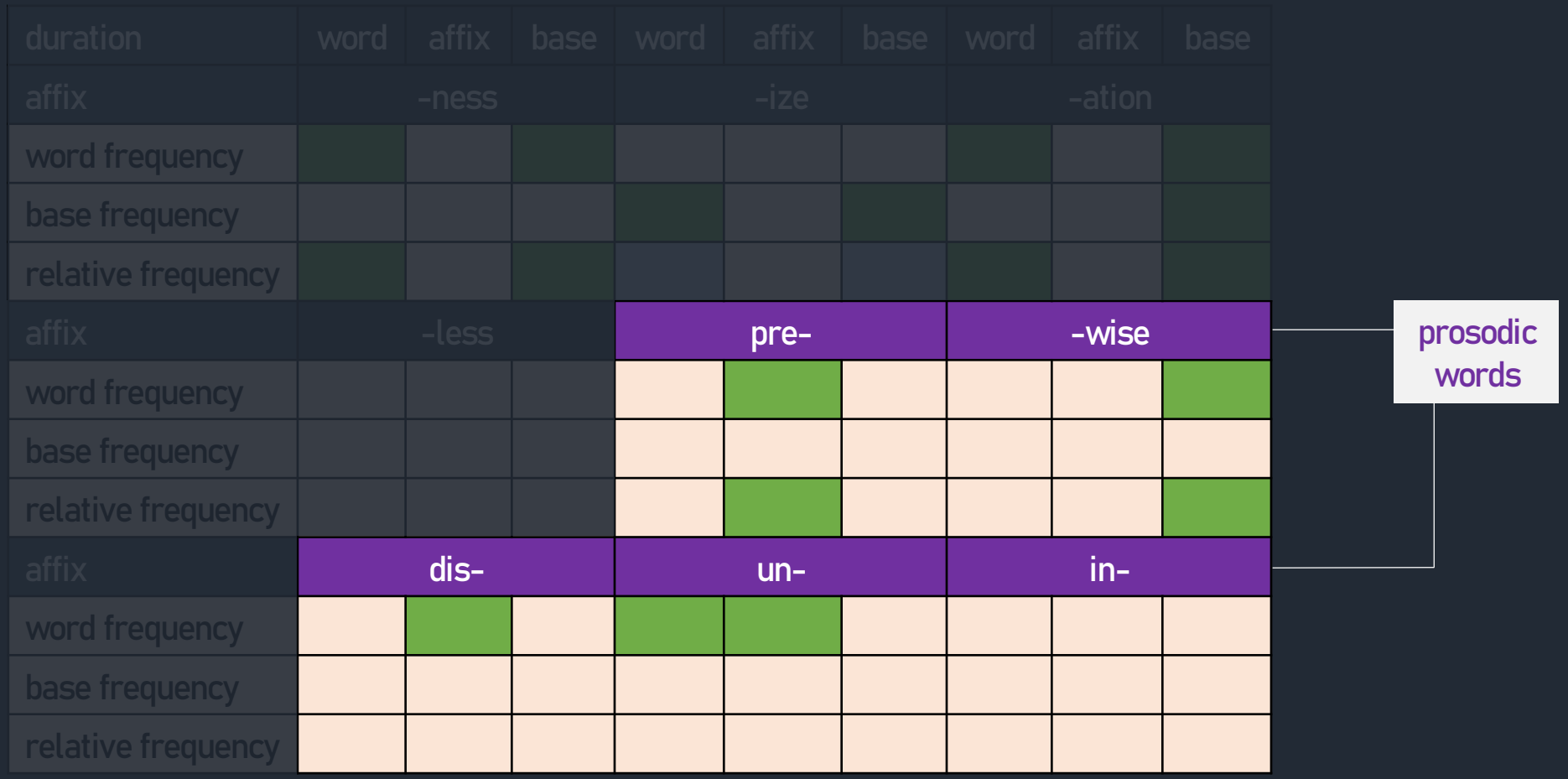
p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ...

- the type of affix? ×
- the affix length? ×
- the segmentation? ×
- prosodic structure?

Type of prosodic integration



p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ...

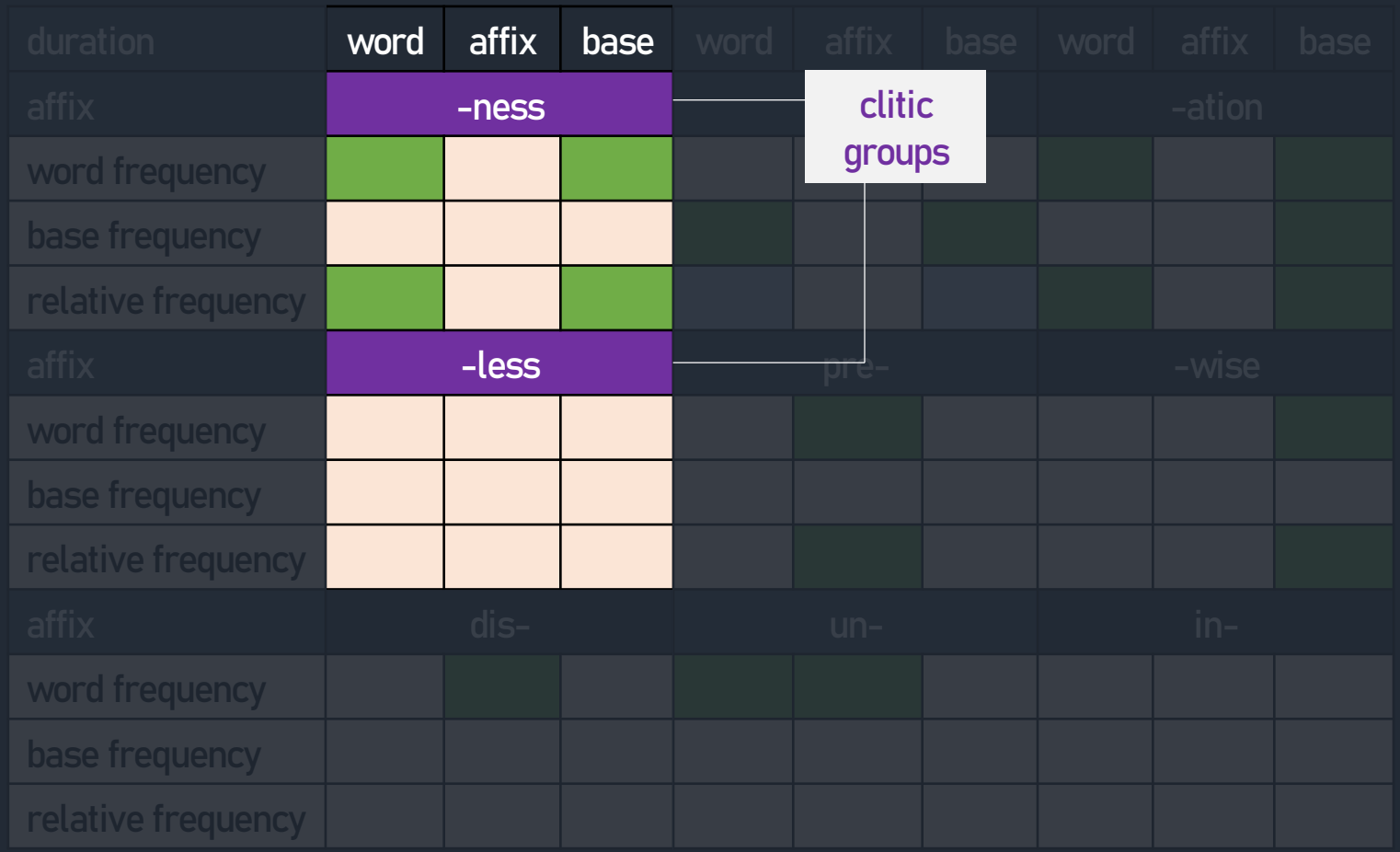
the type of affix? ✗

the affix length? ✗

the segmentation? ✗

prosodic structure?

Type of prosodic integration



p < .001 expected direction

p < .001 unexpected direction

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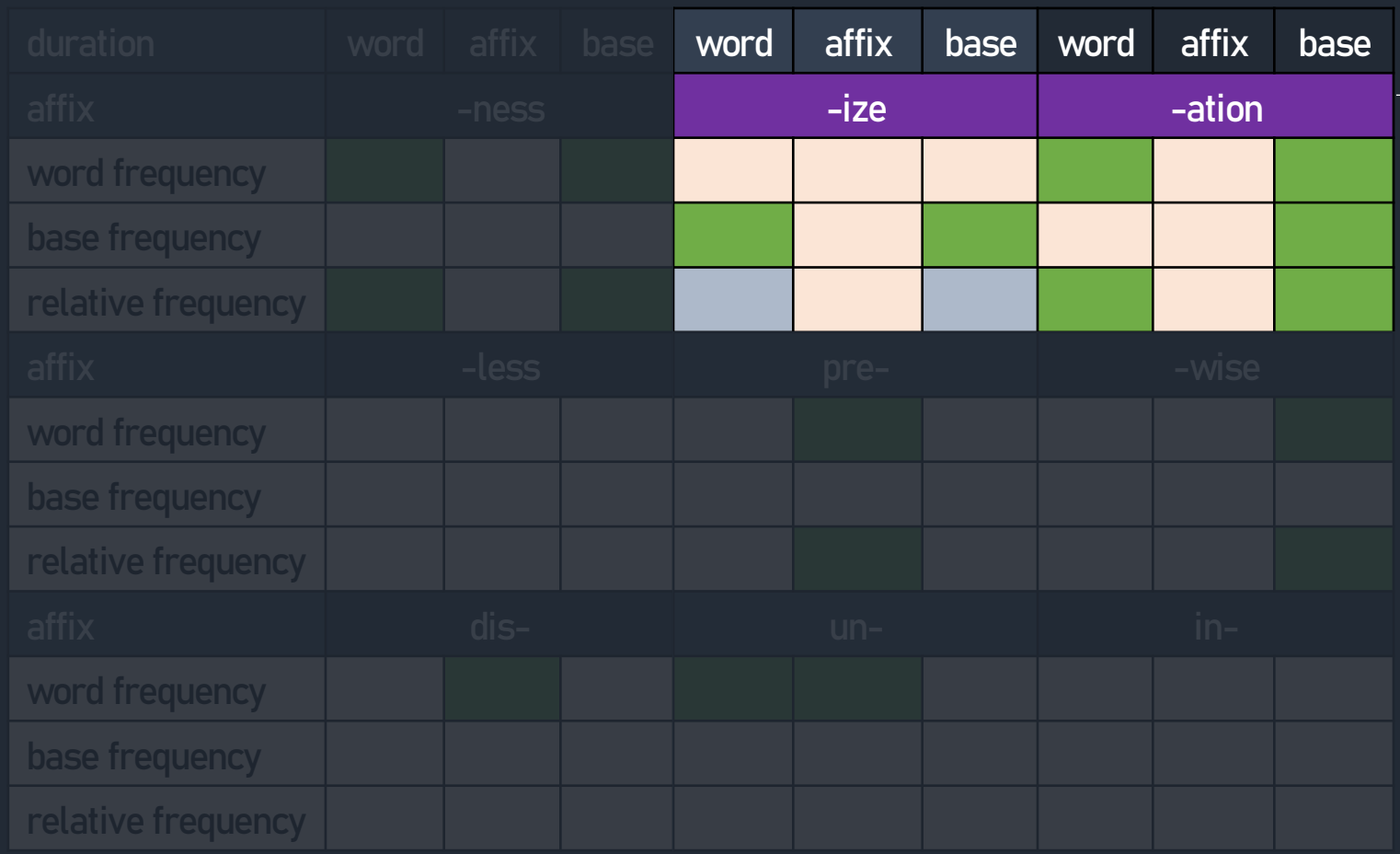
Type of prosodic integration



p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ...

the type of affix? ✗

the affix length? ✗

the segmentation? ✗

prosodic structure?

Type of prosodic integration

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
affix	-less			pre-			-wise		
word frequency									
base frequency									
relative frequency									
affix	dis-			un-			in-		
word frequency									
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relative frequency									

integrating

p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ...

- the type of affix? ✗
- the affix length? ✗
- the segmentation? ✗
- prosodic structure? ✗

Type of prosodic integration

Meta-model including all affixes

- Additional predictor: type of prosodic integration
- Additional covariate: number of timing slots
- N = 7441

Type of prosodic integration

Meta-model including all affixes

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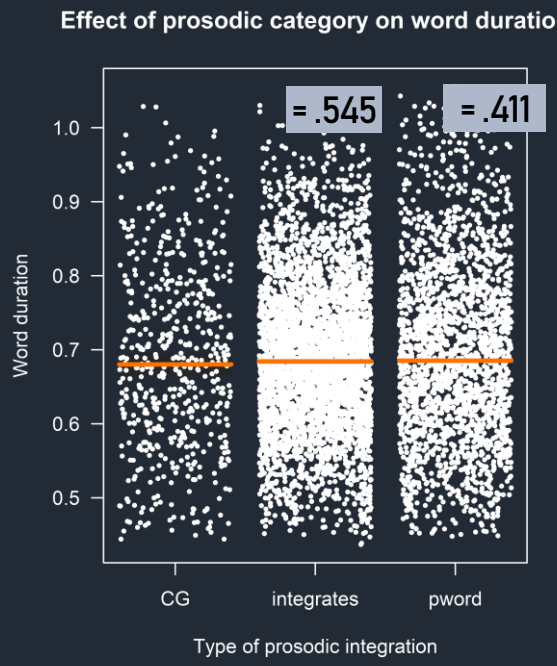

Type of prosodic integration

Meta-model including all affixes

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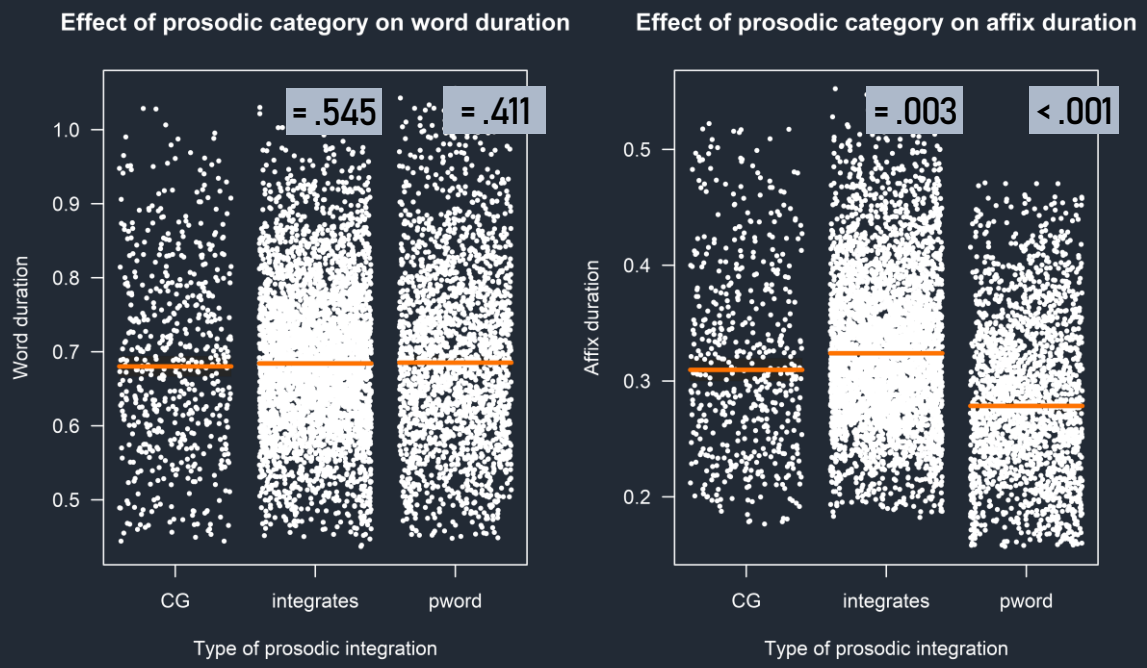

Type of prosodic integration

Meta-model including all affixes

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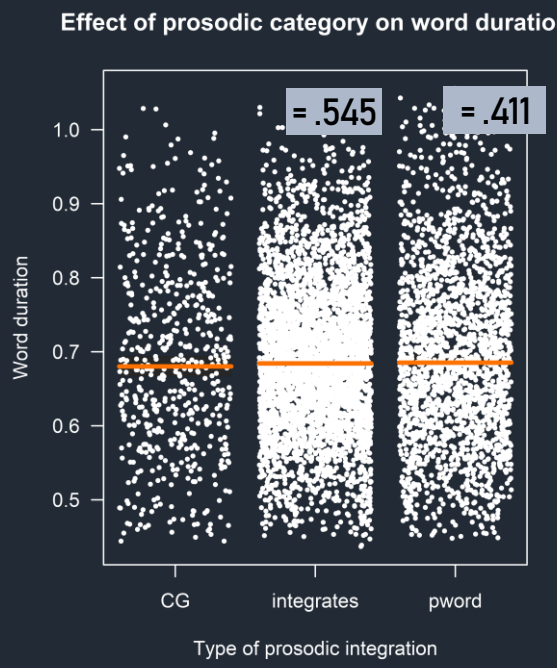
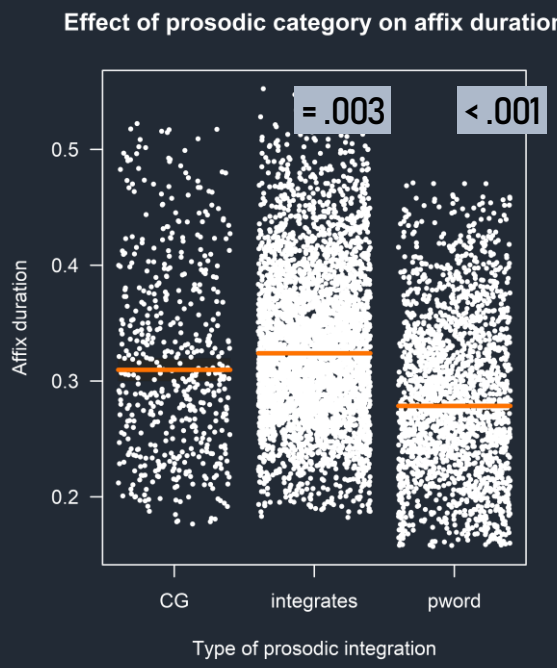
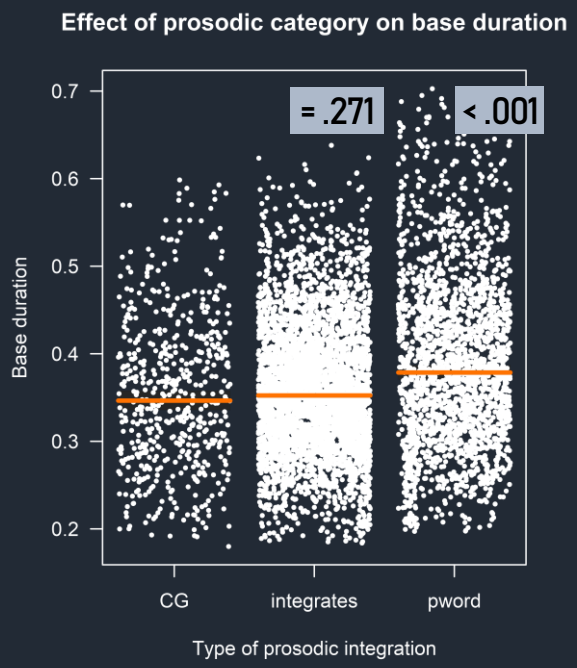


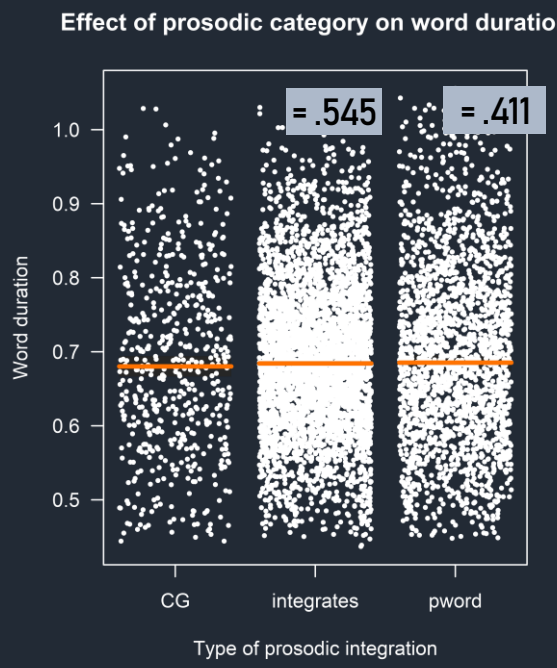


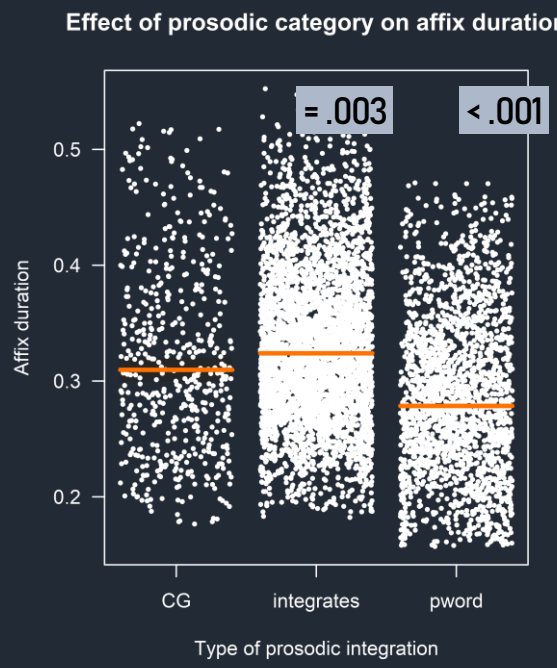


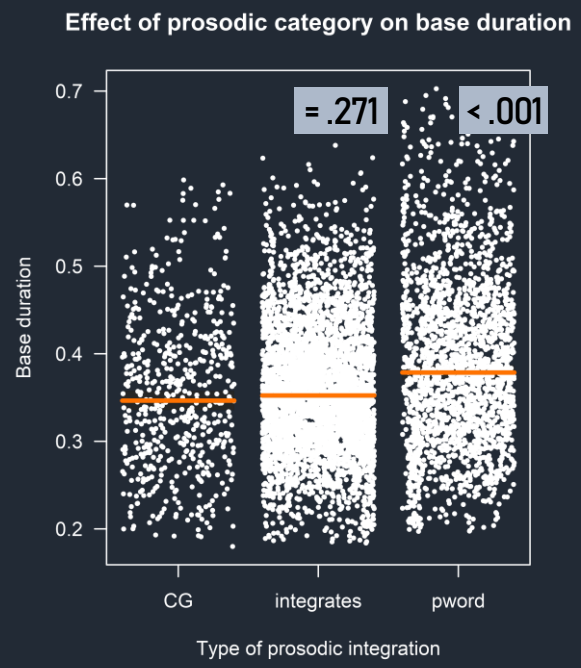
Type of prosodic integration

Meta-model including all affixes

- Additional predictor: type of prosodic integration
- Additional covariate: number of timing slots
- N = 7441
- This does not support the predictions of pword integration.







Summary

Summary

In sum, we have a mixed picture.

- Some results are in line with Caselli et al. 2016:
  - All three frequency measures can independently predict duration.
  - This is evidence for both types of storage in the mental lexicon, as well as for segmentability effects.

Summary

In sum, we have a mixed picture.

- Some results are in line with Caselli et al. 2016:
  - All three frequency measures can independently predict duration.
  - This is evidence for both types of storage in the mental lexicon, as well as for segmentability effects.

- However, there are also null effects, which require explanation.
  - So far, we cannot attribute the differences to:
    - the domain of durational measurement (word, affix, base)
    - the type of affix (prefix, suffix)
    - the prosodic category (pword, clitic group, integrating).

Discussion

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Our findings imply that …

- morphological structure can at least partly influence the phonetic output.

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- morphological structure can at least partly influence the phonetic output.
- models that prohibit post-lexical access of morphological information (e.g. Kiparsky 1982, Levelt et al. 1999, Bermúdez-Otero 2018) should be revised.

Kiparsky 1982, Levelt et al. 1999, Bermúdez-Otero 2018

Discussion

Our findings imply that …

- morphological structure can at least partly influence the phonetic output.
- models that prohibit post-lexical access of morphological information (e.g. Kiparsky 1982, Levelt et al. 1999, Bermúdez-Otero 2018) should be revised.
- we need to investigate further factors that might cause frequency effects to surface or to not surface.

Kiparsky 1982, Levelt et al. 1999, Bermúdez-Otero 2018

Thank you for listening.

Thank you for listening.

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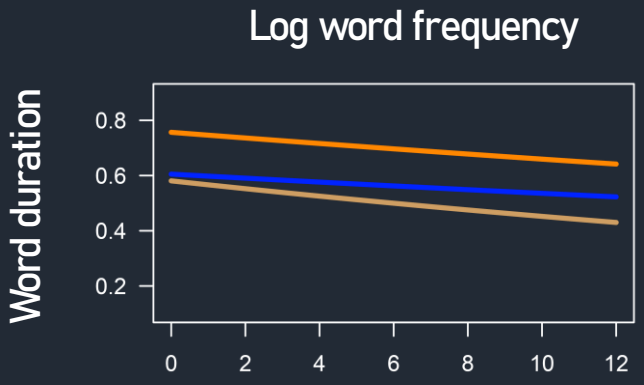
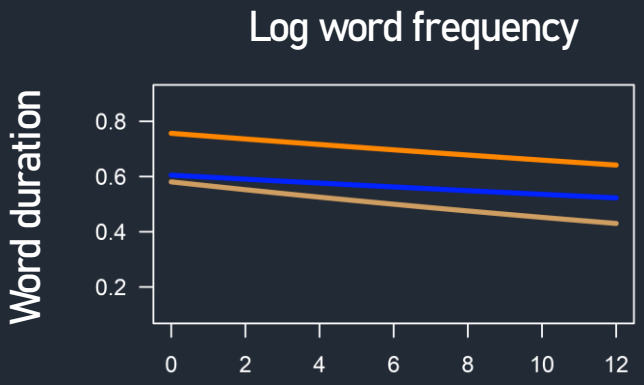
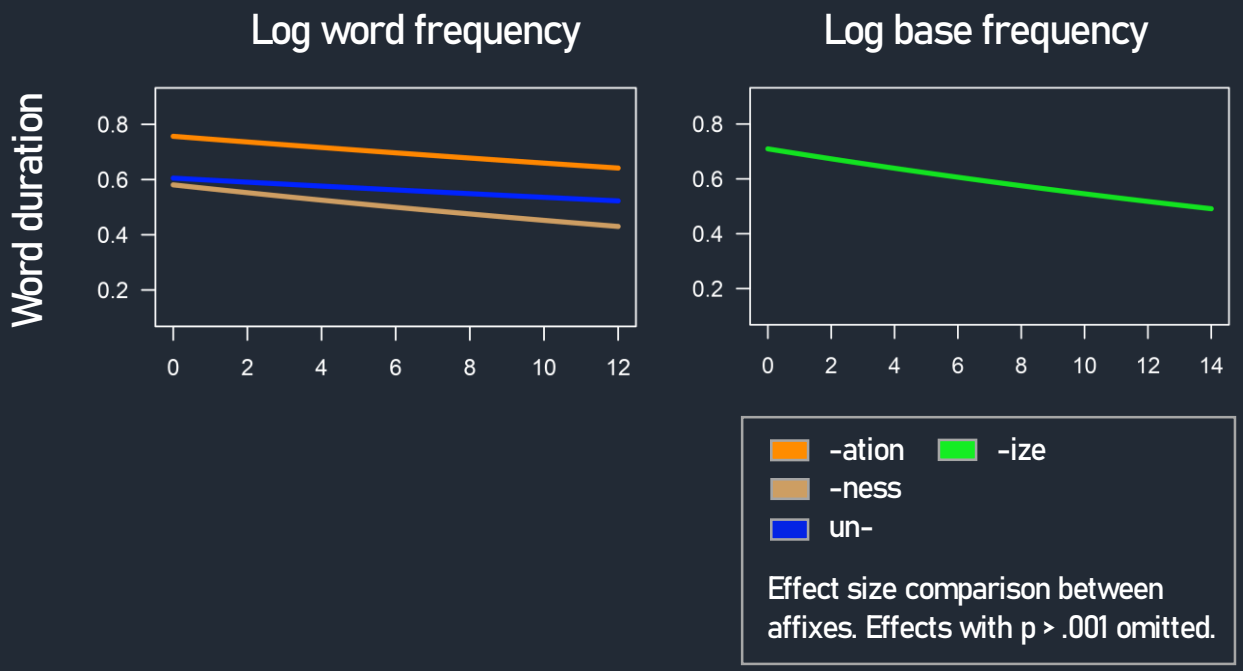
Appendix

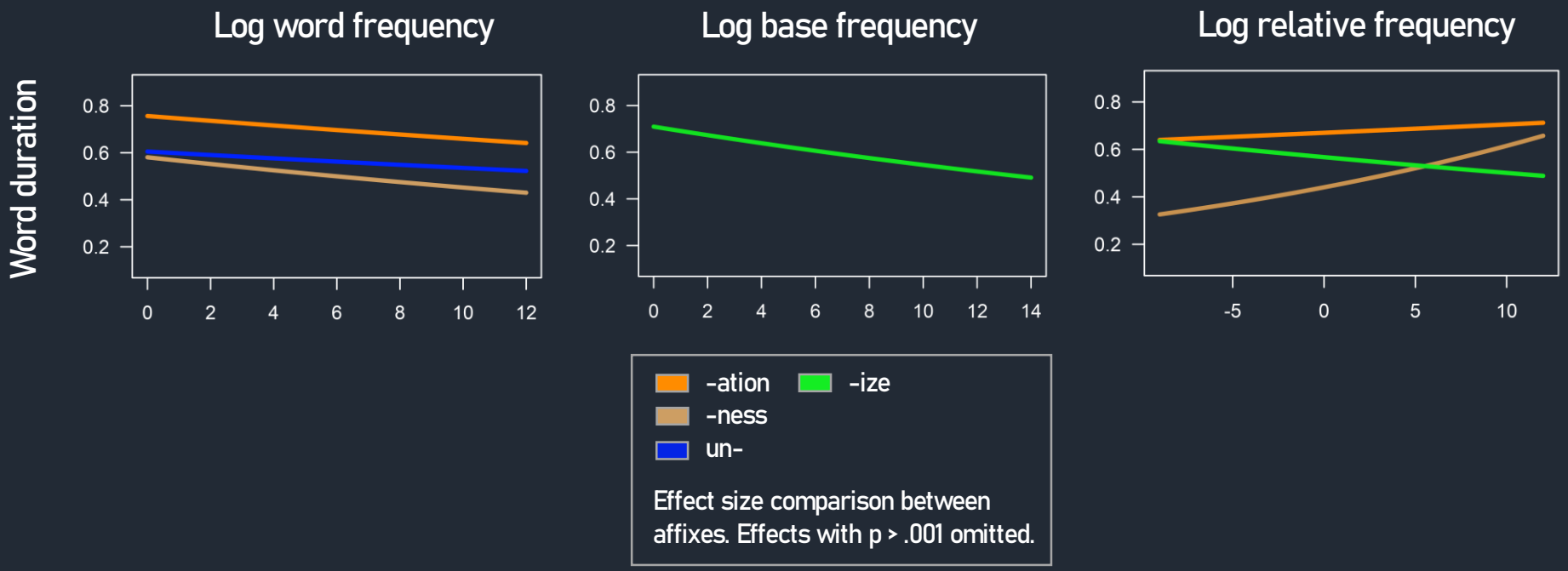

Log word frequency
Word duration
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12



-ation
-ness
un-

Effect size comparison between affixes. Effects with p > .001 omitted.


Log word frequency
Log base frequency
Word duration
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
-ation
-ness
un-
-ize
Effect size comparison between affixes. Effects with p > .001 omitted.

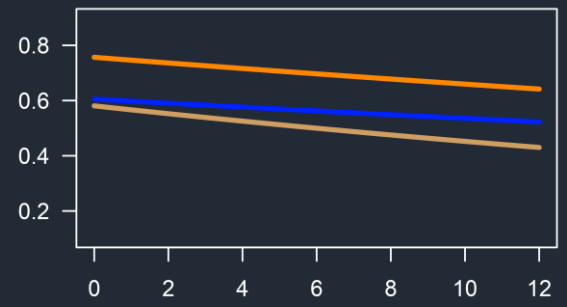

Log word frequency
Log base frequency
Log relative frequency
Word duration
0.8
0.6
0.4
0.2
0 2 4 6 8 10 12
0 2 4 6 8 10 12 14
-5 0 5 10
-ation
-ness
un-
-ize
Effect size comparison between affixes. Effects with p > .001 omitted.

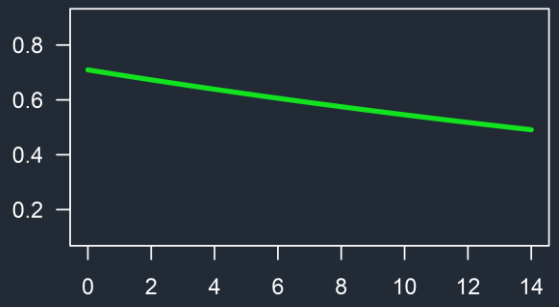
Log word frequency

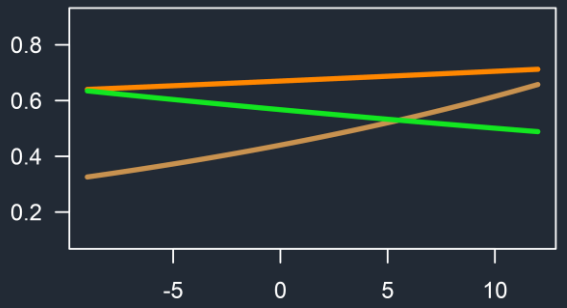
Log base frequency

Log relative frequency

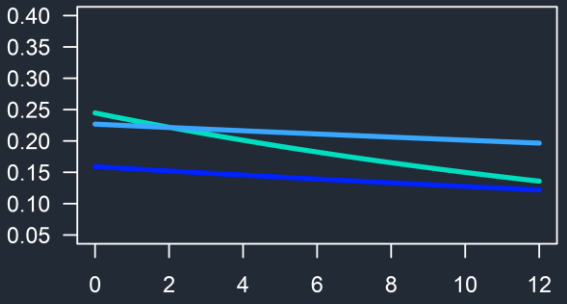
Word duration





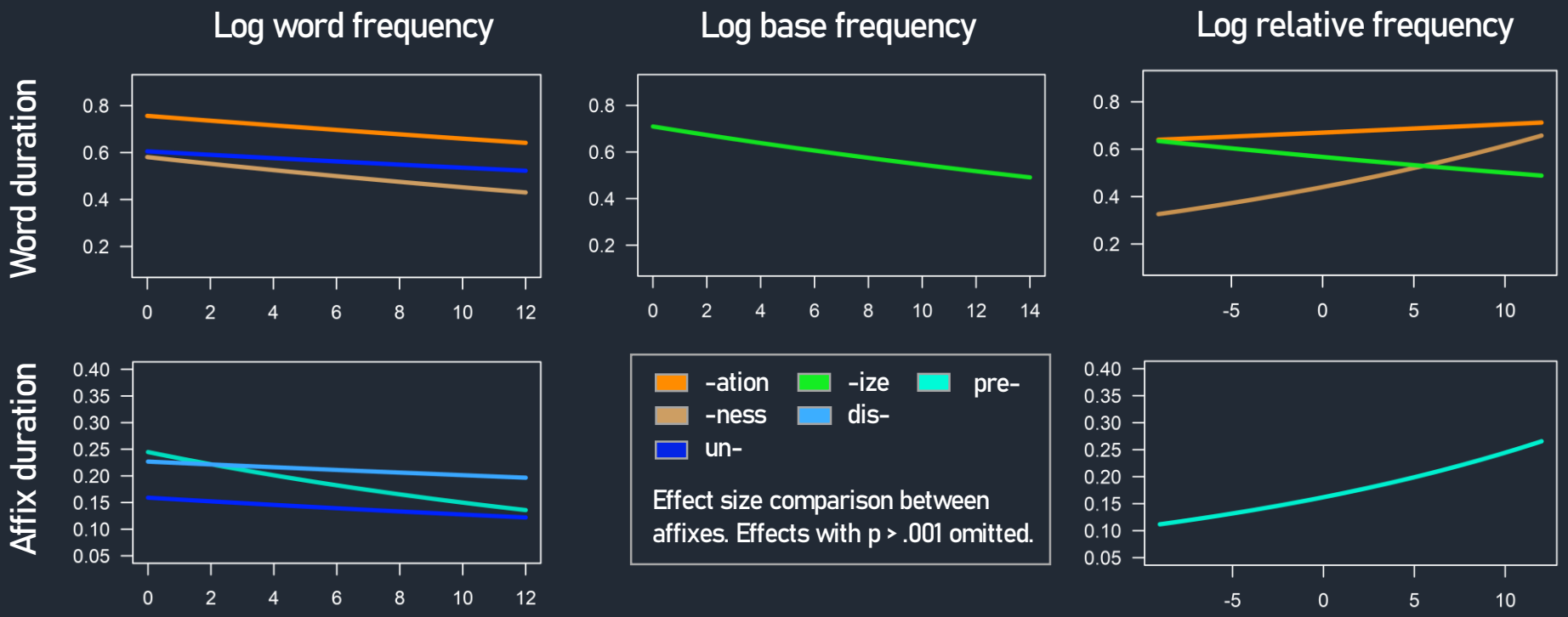


Affix duration



-ation
-ness
un-
-ize
dis-
pre-

Effect size comparison between affixes. Effects with p > .001 omitted.


Log word frequency
Log base frequency
Log relative frequency
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Affix duration
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un-
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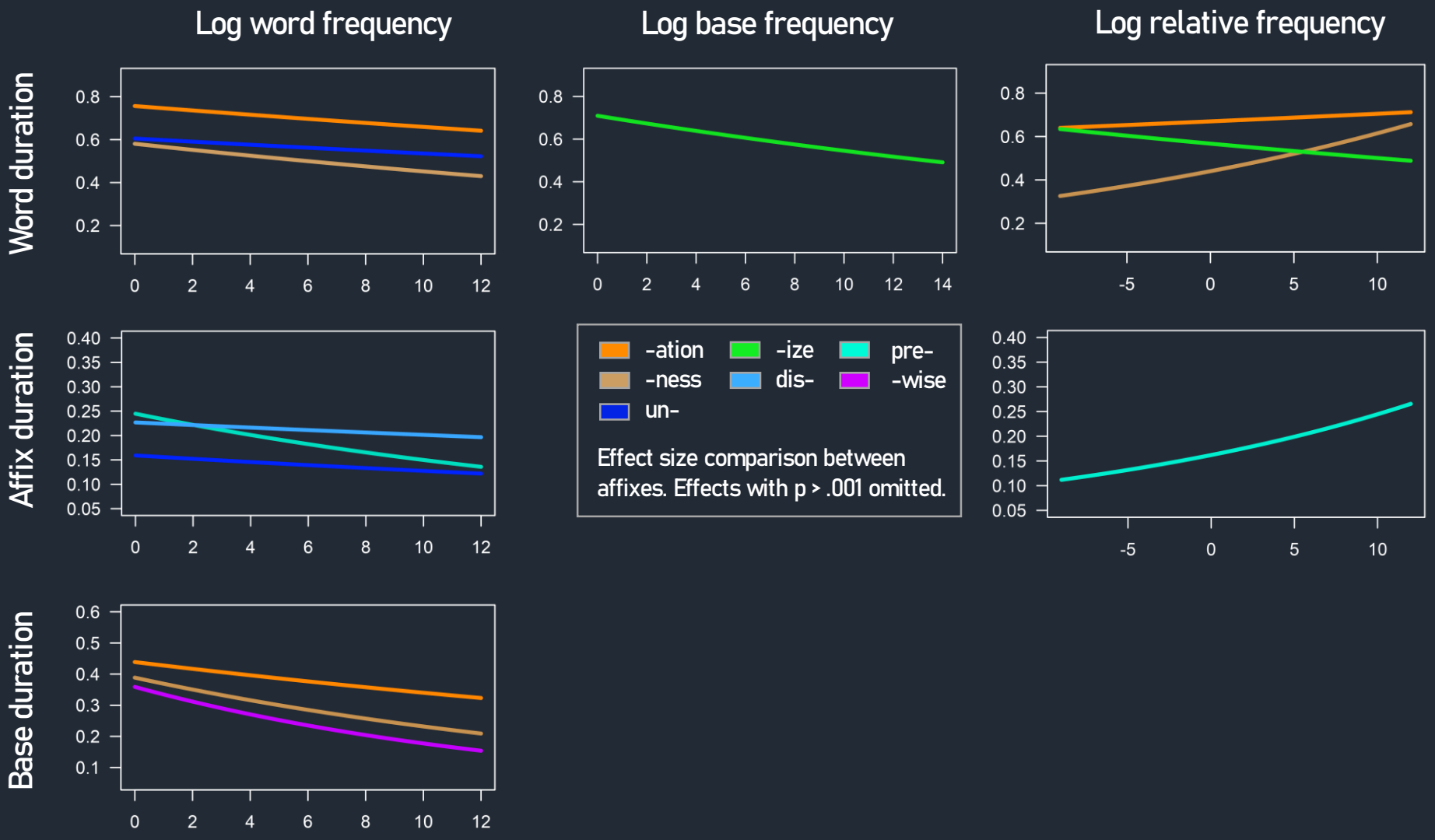
Log word frequency
Log base frequency
Log relative frequency
Word duration
Affix duration
Base duration
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dis-
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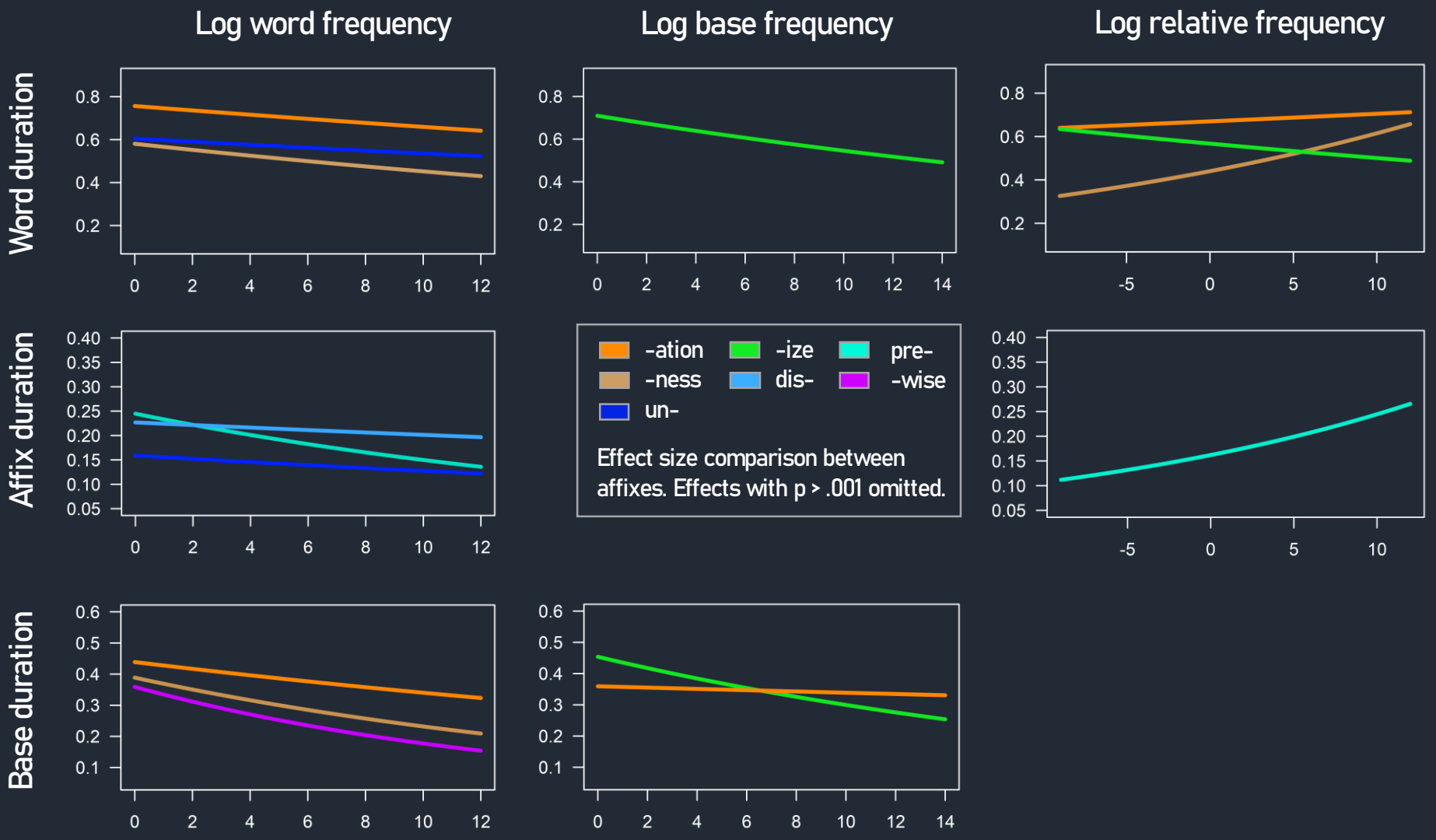
Effect size comparison between affixes. Effects with p > .001 omitted.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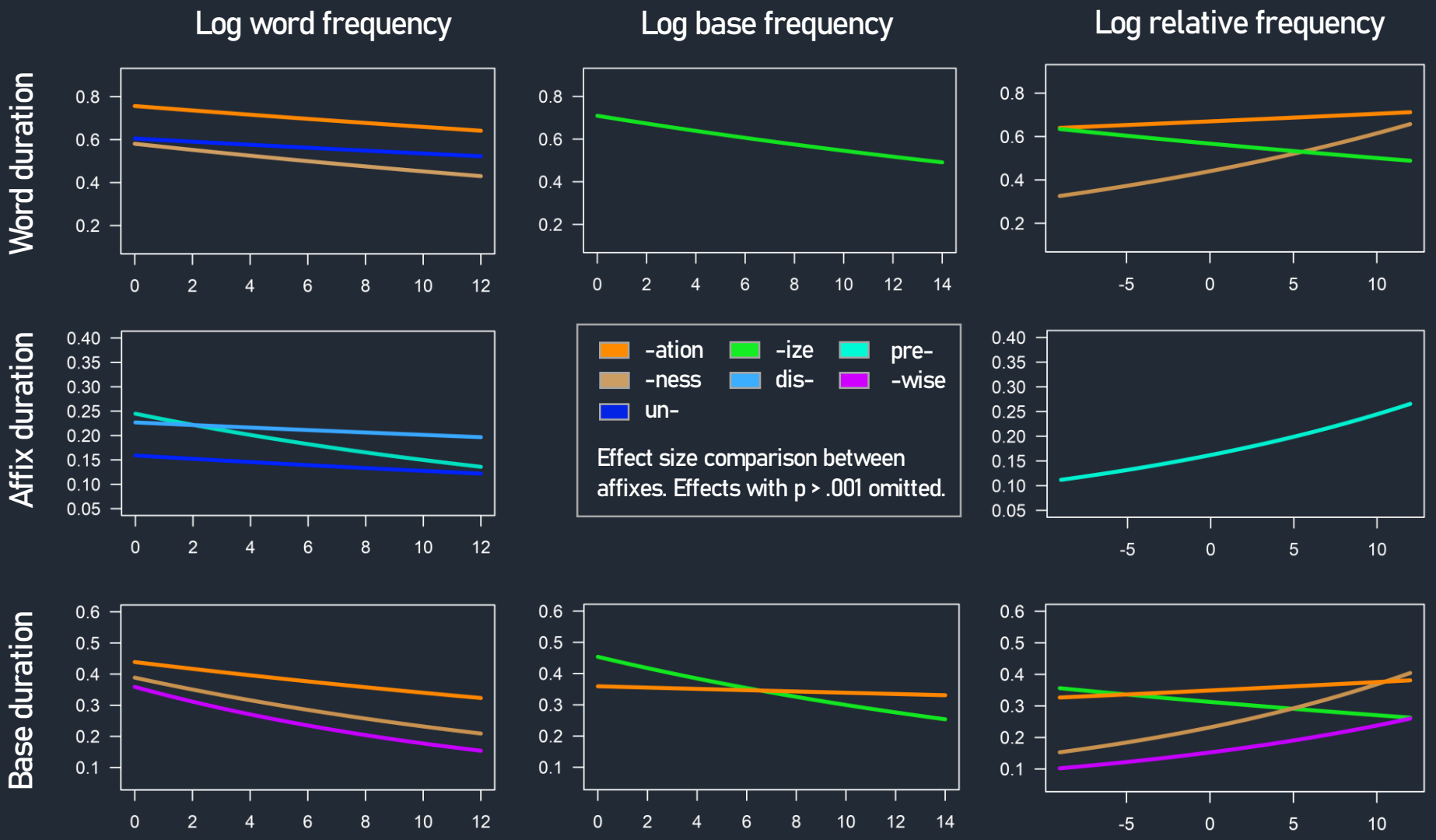
Log word frequency
Log base frequency
Log relative frequency
Word duration
Affix duration
Base duration
-ation
-ness
un-
-ize
dis-
pre-
-wise
Effect size comparison between affixes. Effects with p > .001 omitted.

Informativity

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
affix	-less			pre-			-wise		
word frequency									
base frequency									
relative frequency									
affix	dis-			un-			in-		
word frequency									
base frequency									
relative frequency									

p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ...

- the type of affix? ✗
- the affix length? ✗
- the segmentation? ✗
- prosodic structure? ✗
- affix informativity?

Informativity

Measured in two ways:

Informativity

Measured in two ways:

Semantic information load score

Informativity

Measured in two ways:

Semantic information load score

5-point Likert scales coded for:

- clearness of semantic meaning
- type of base: free vs. bound root
- semantic transparency
- productivity

Informativity

Measured in two ways:

Semantic information load score

5-point Likert scales coded for:

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- productivity

Affix-specific semantic segmentability hierarchy

Informativity

Measured in two ways:

Semantic information load score

5-point Likert scales coded for:

- clearness of semantic meaning
- type of base: free vs. bound root
- semantic transparency
- productivity

Affix-specific semantic segmentability hierarchy

H: The higher the semantic information load, the longer the duration.

Informativity

Measured in two ways:

Semantic information load score

Conditional affix probability C_{aff}

5-point Likert scales coded for:

- clearness of semantic meaning
- type of base: free vs. bound root
- semantic transparency
- productivity

Affix-specific semantic segmentability hierarchy

H: The higher the semantic information load, the longer the duration.

Informativity

Measured in two ways:

Semantic information load score

5-point Likert scales coded for:

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Affix-specific semantic segmentability hierarchy

H: The higher the semantic information load, the longer the duration.

Conditional affix probability C_{aff}

Affix probability given preceding word:

SUFFIX EXAMPLE		PREFIX EXAMPLE		
A	B	A	B	C
random	*ize*	*her*	*pre-*	*...*

Informativity

Measured in two ways:

Semantic information load score

5-point Likert scales coded for:

- clearness of semantic meaning
- type of base: free vs. bound root
- semantic transparency
- productivity

Affix-specific semantic segmentability hierarchy

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Informativity: Semantic information load score

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
relative frequency									
affix	-less			pre-			-wise		
word frequency									
base frequency									
relative frequency									
affix	dis-			un-			in-		
word frequency									
base frequency									
relative frequency									

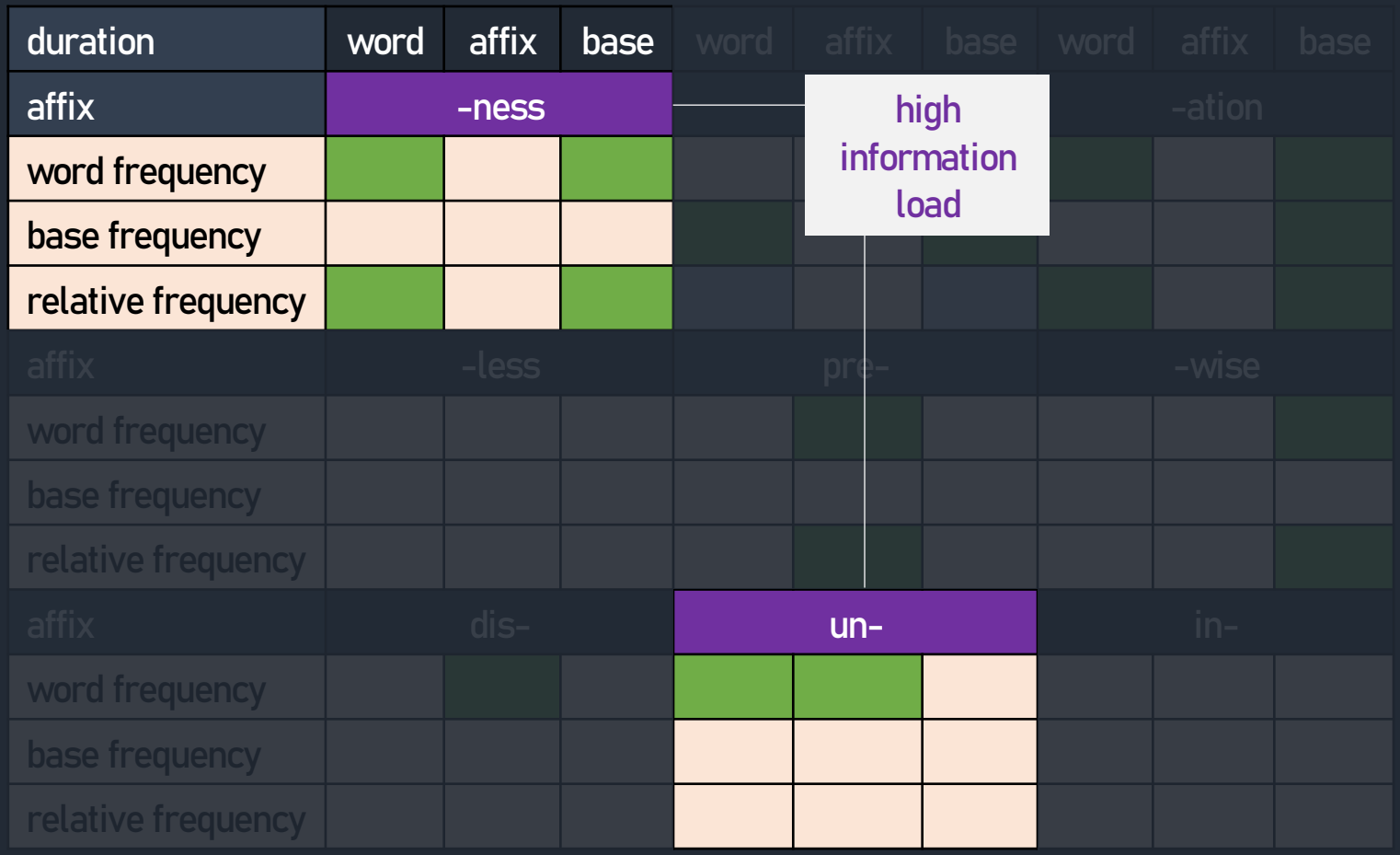
p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ...

- the type of affix? ✗
- the affix length? ✗
- the segmentation? ✗
- prosodic structure? ✗
- affix informativity?

Informativity: Semantic information load score



p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ...

the type of affix? ×

the affix length? ×

the segmentation? ×

prosodic structure? ×

affix informativity?

Informativity: Semantic information load score

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
word frequency									
base frequency									
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word frequency									
base frequency									
relative frequency									
affix	dis-			un-			in-		
word frequency									
base frequency									
relative frequency									

low information load

p < .001 expected direction

p < .001 unexpected direction

Are the differences related to ...

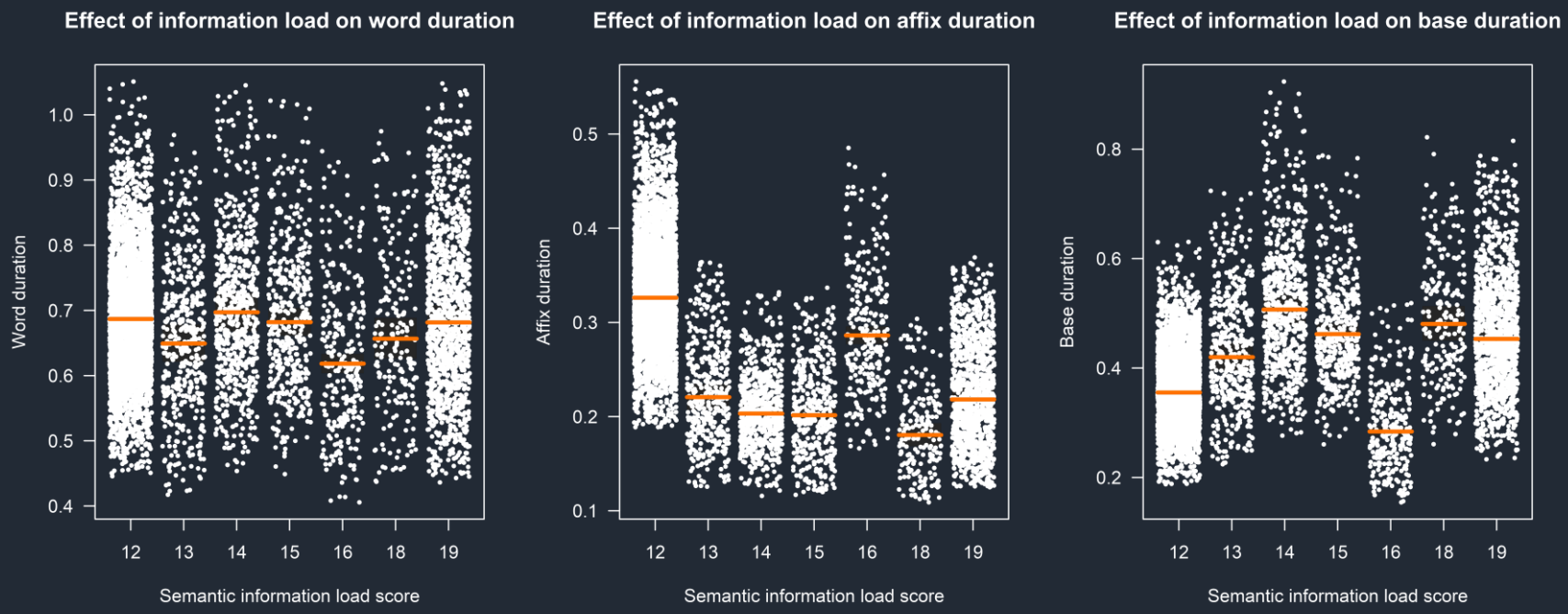
- the type of affix? ×
- the affix length? ×
- the segmentation? ×
- prosodic structure? ×
- affix informativity?

Informativity: Semantic information load score

Meta-model including all affixes

- Additional predictor: semantic information load score
- Additional covariate: number of timing slots
- N = 7441

- This does not support the predictions of semantic information load.



Informativity: Conditional affix probability

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base frequency									
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Are the differences related to ...

- the type of affix? ×
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- the segmentation? ×
- prosodic structure? ×
- affix informativity?

Informativity: Conditional affix probability

duration	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ation		
affix probability									

affix	-less			pre-			-wise		
affix probability									

affix	dis-			un-			in-		
affix probability									

p < .001 negative correlation

Are the differences related to ...

- the type of affix? ×
- the affix length? ×
- the segmentation? ×
- prosodic structure? ×
- affix informativity? ×

Results: Updated

In sum, we have a mixed picture.

- Some results are in line with Caselli et al. 2016:
  - All three frequency measures can independently predict duration.
  - This is evidence for both types of storage in the mental lexicon, as well as for segmentability effects.

- However, there are also null effects, which require explanation.
  - So far, we cannot attribute the differences to:
    - the domain of durational measurement (word, affix, base)
    - the type of affix (prefix, suffix)
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    - the prosodic category (pword, clitic group, integrating)
    - the informativity of the affix (information load, probability).

Prosodic word diagnostics

Prosodic word diagnostics

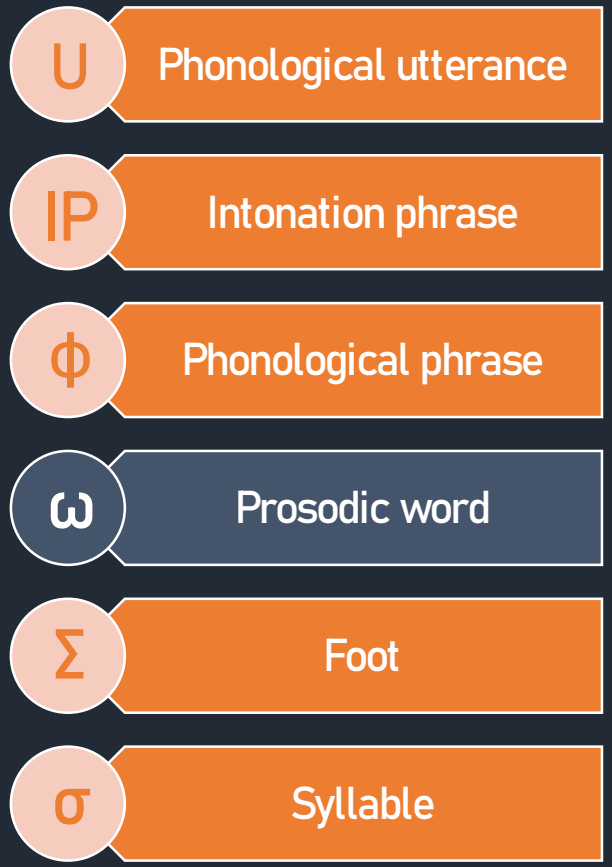
The prosodic hierarchy

- U — Phonological utterance
- IP — Intonation phrase
- ϕ — Phonological phrase
- ω — Prosodic word
- Σ — Foot
- σ — Syllable

Hildebrandt 2015, Raffelsiefen 1999, 2007

Prosodic word diagnostics

The prosodic hierarchy



Some pword-diagnostics

- onset or coda conditions, LOI-violations
- ambisyllabicity
- stress and relative prominence
- trisyllabic laxing, vowel reduction
- minimal word requirements
- compositionality, type of base

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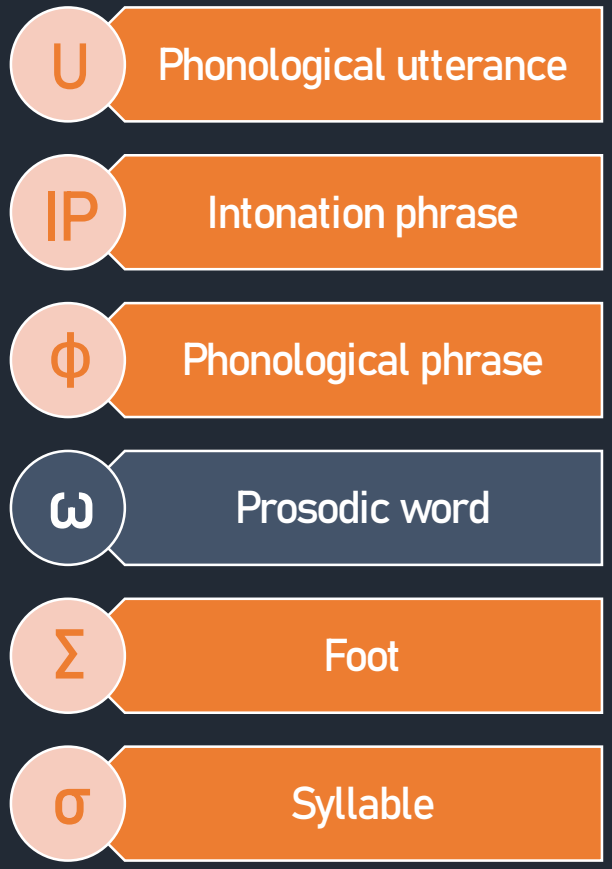

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Morpho-prosodic alignment

- A morpheme cannot include multiple pwords, but a pword can include multiple morphemes.

Hildebrandt 2015, Raffelsiefen 1999, 2007