Interfaces of Phonetics, May 18–19, 2021

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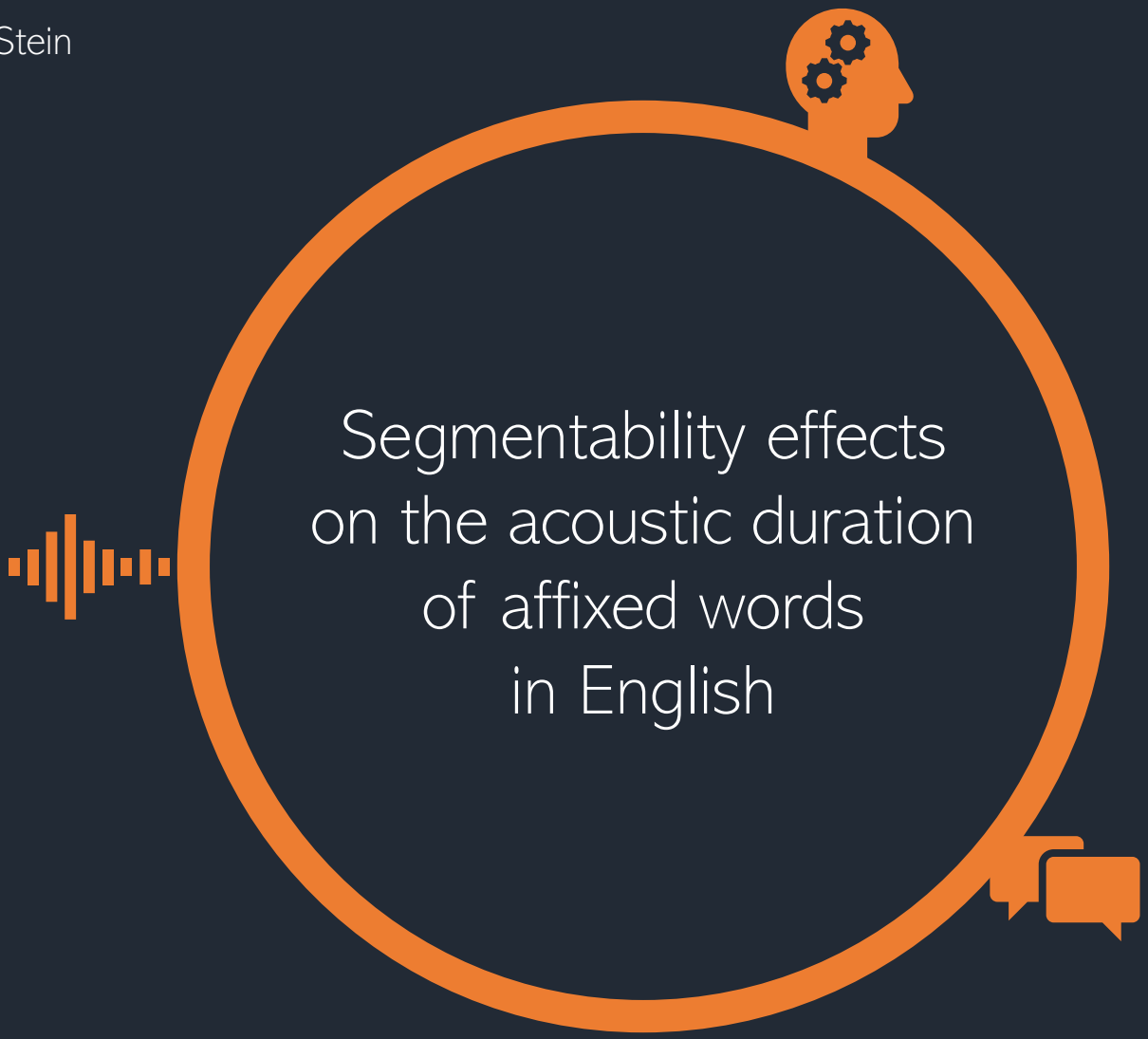
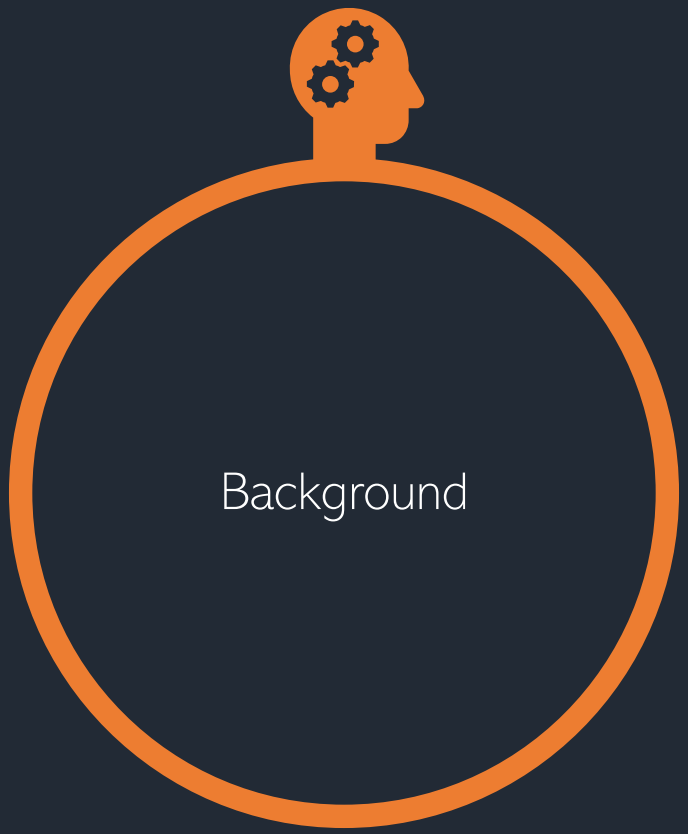
DFG Deutsche Forschungsgemeinschaft
FOR2373



Segmentability effects on the acoustic duration of affixed words in English


Background

Morphological segmentability

Morphological segmentability

the degree to which speakers can decompose a complex word into its constituents

Hay 2001, 2003, 2007

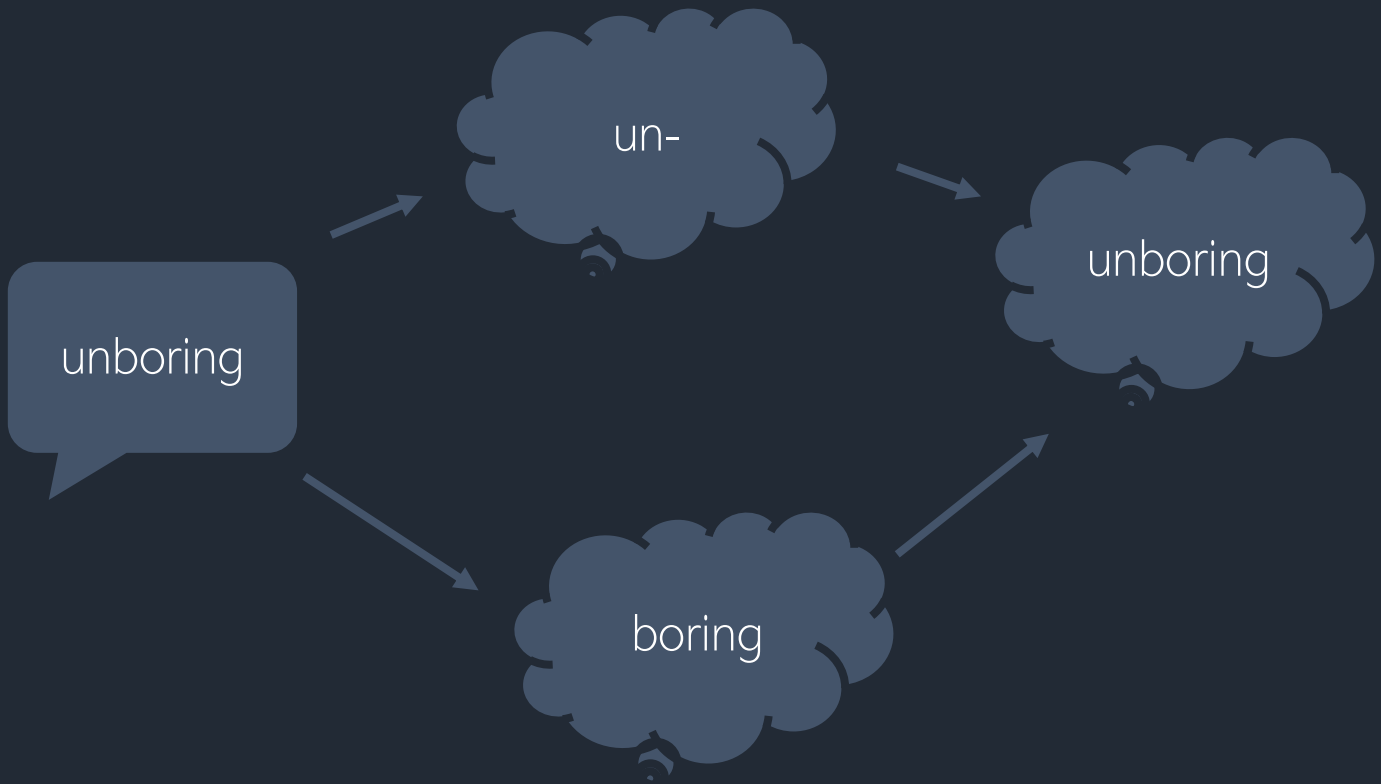
Morphological segmentability

the degree to which speakers can decompose a complex word into its constituents, operationalized as:

$$relative\ frequency = \frac{base\ frequency}{word\ frequency}$$

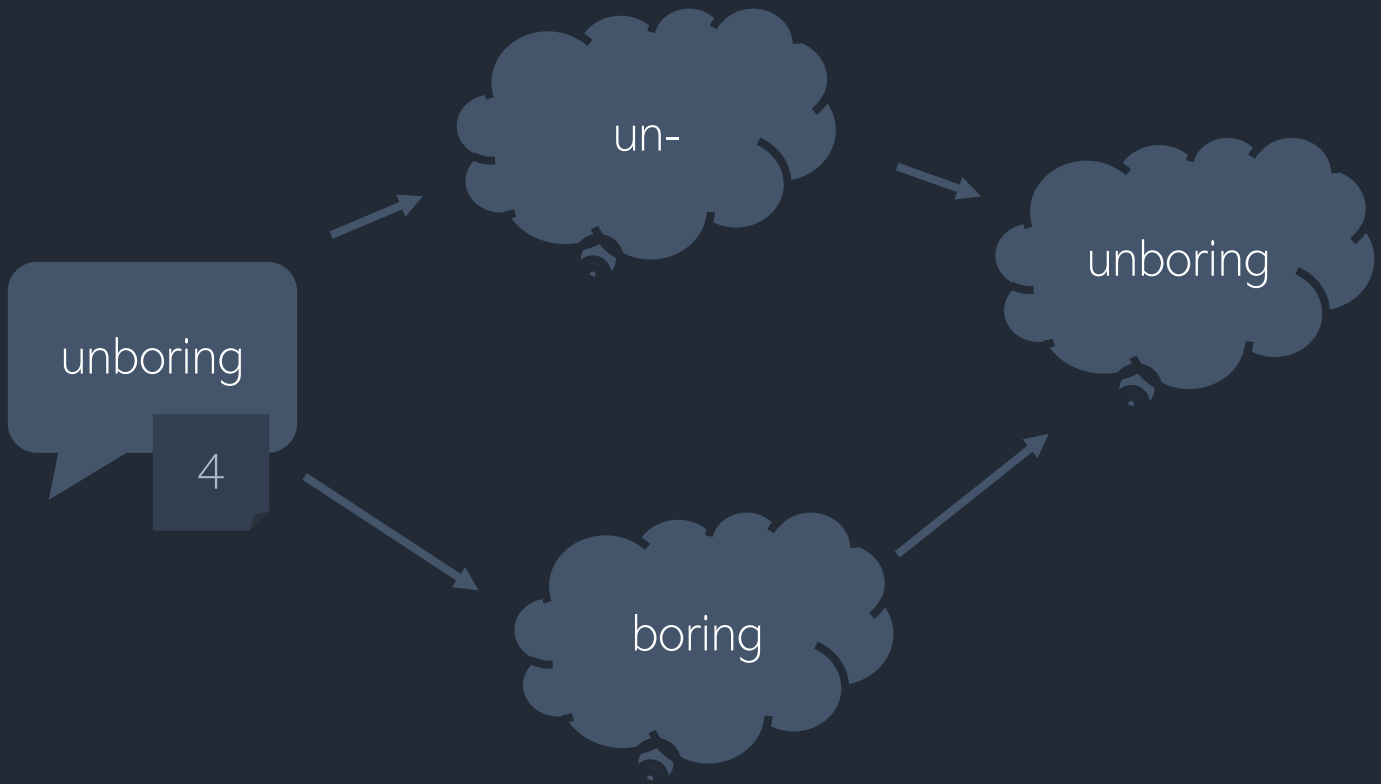
Hay 2001, 2003, 2007

Morphological segmentability



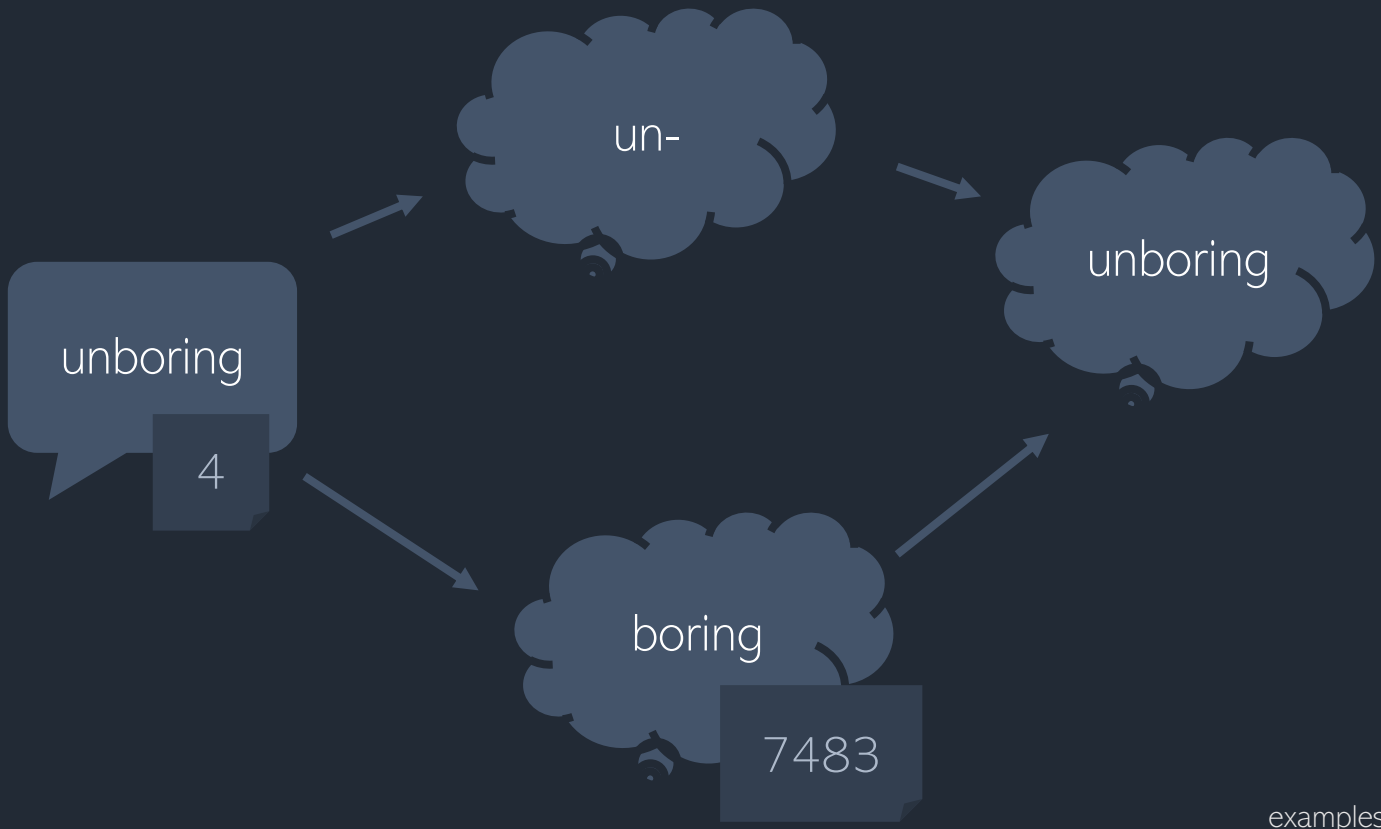
examples partly from Hay 2007
figure adapted from Hay 2001: 1045

Morphological segmentability



examples partly from Hay 2007
figure adapted from Hay 2001: 1045
frequencies taken from COCA, Davies 2008

Morphological segmentability



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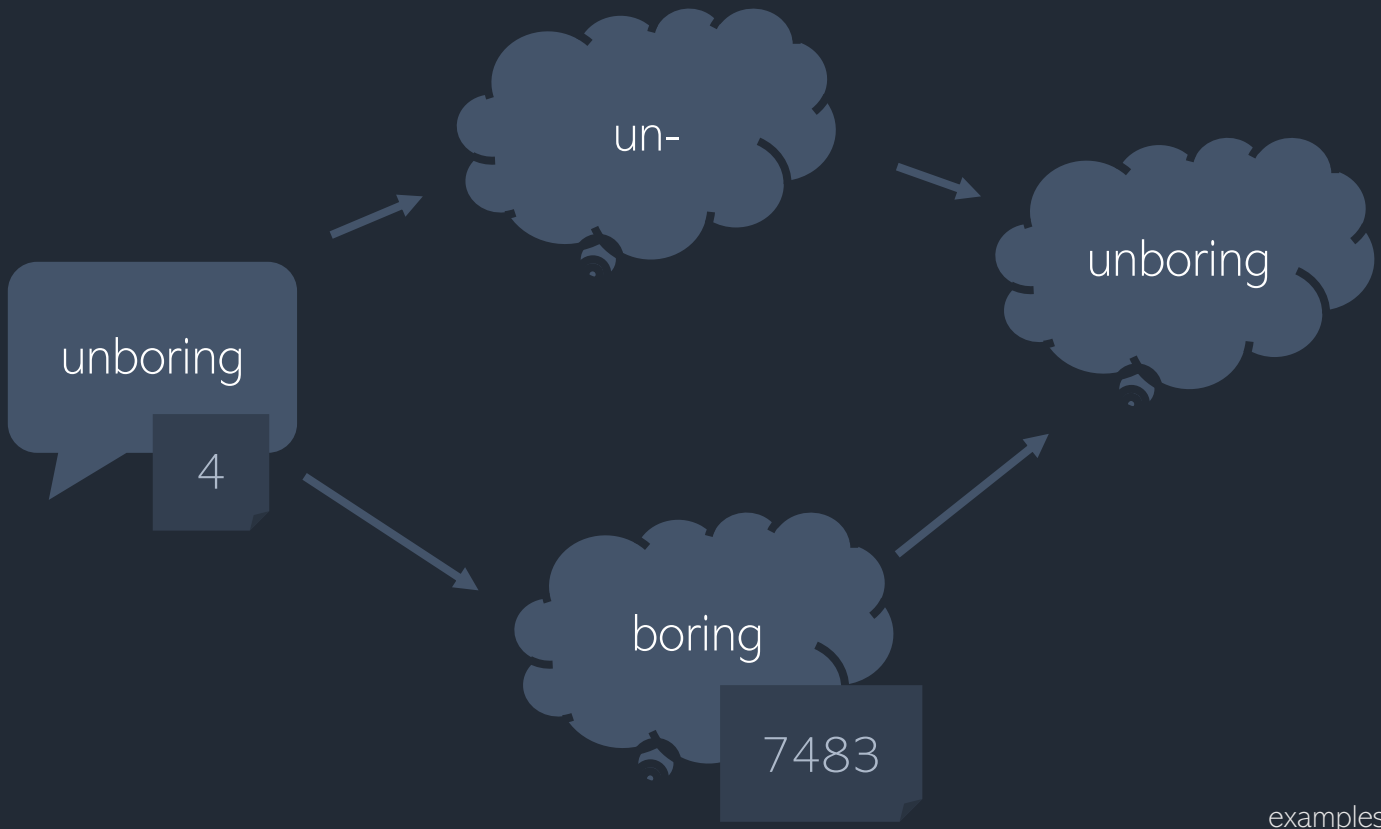
Morphological segmentability
high



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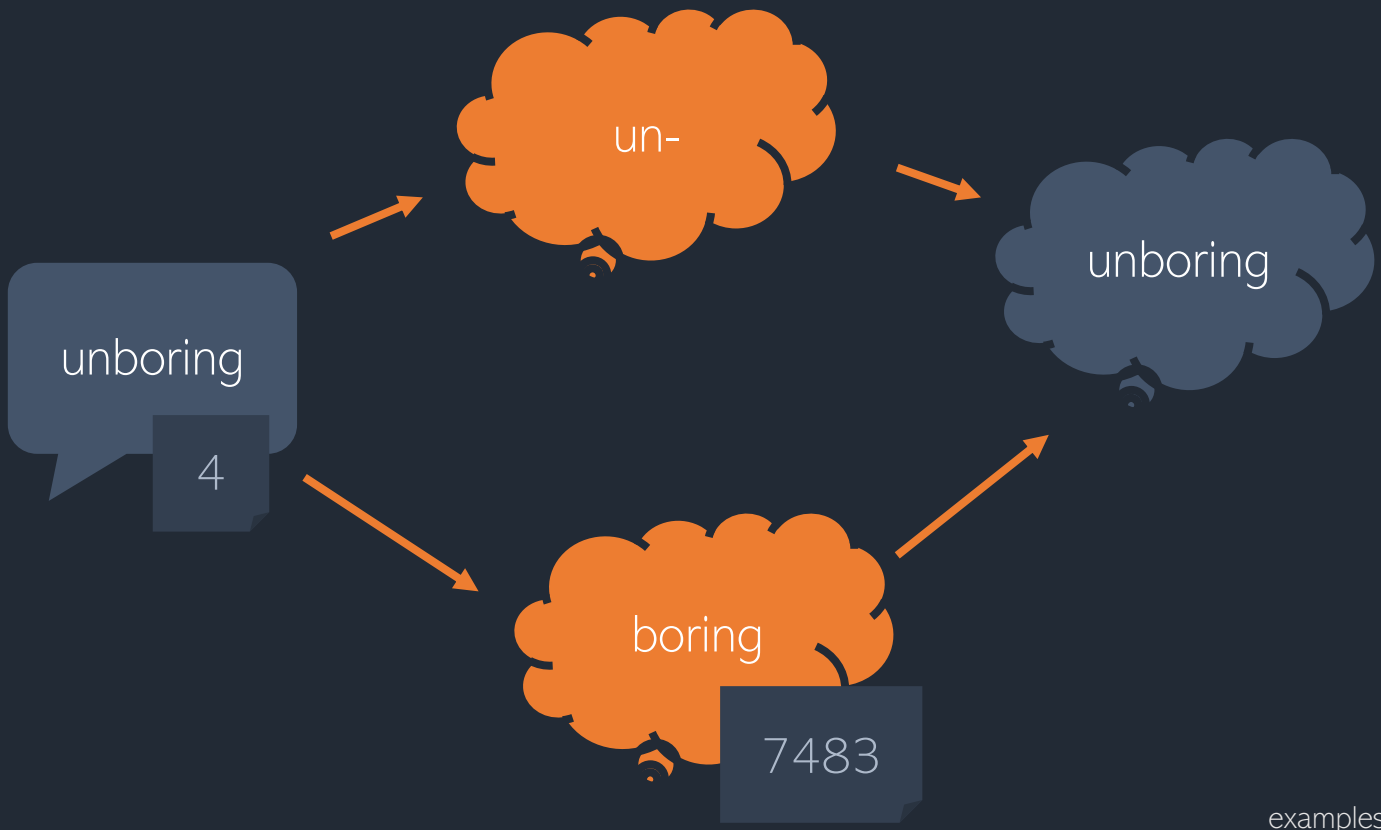

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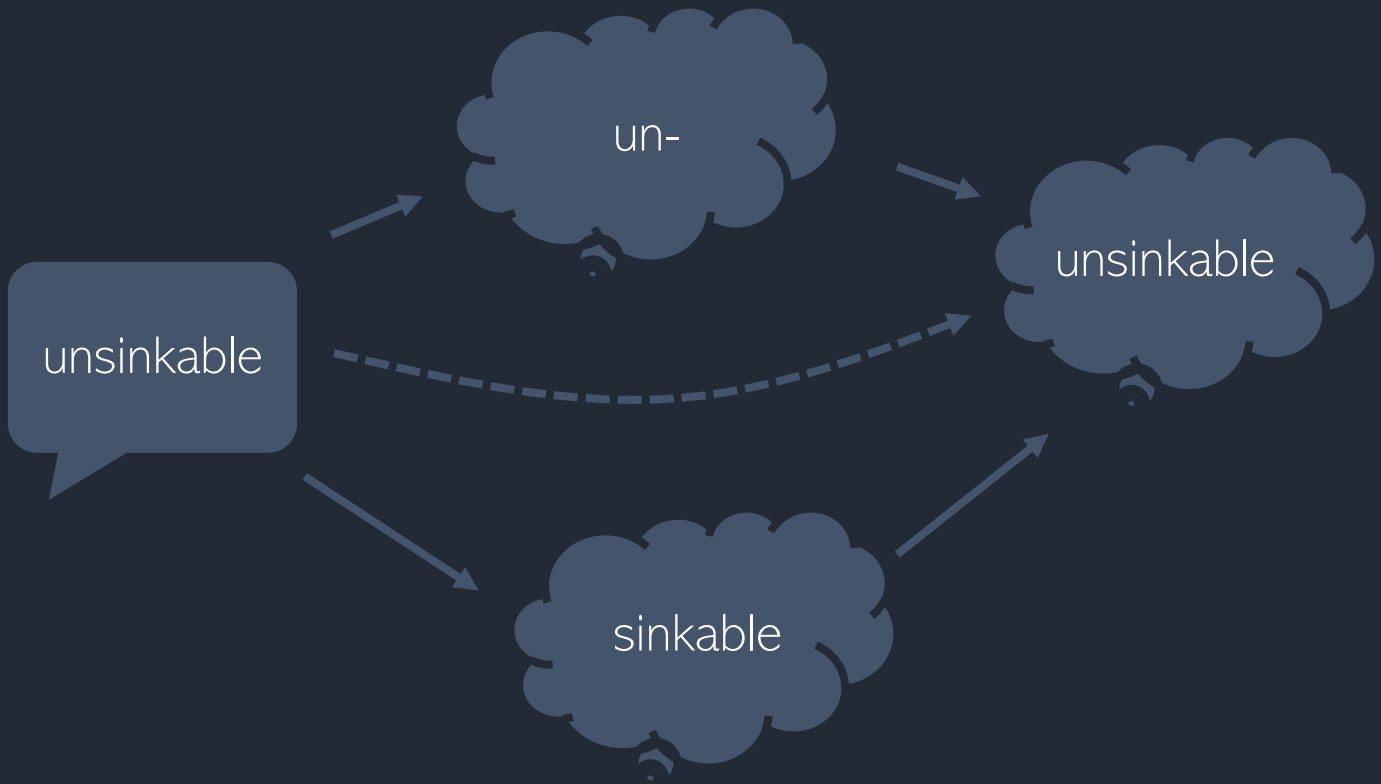
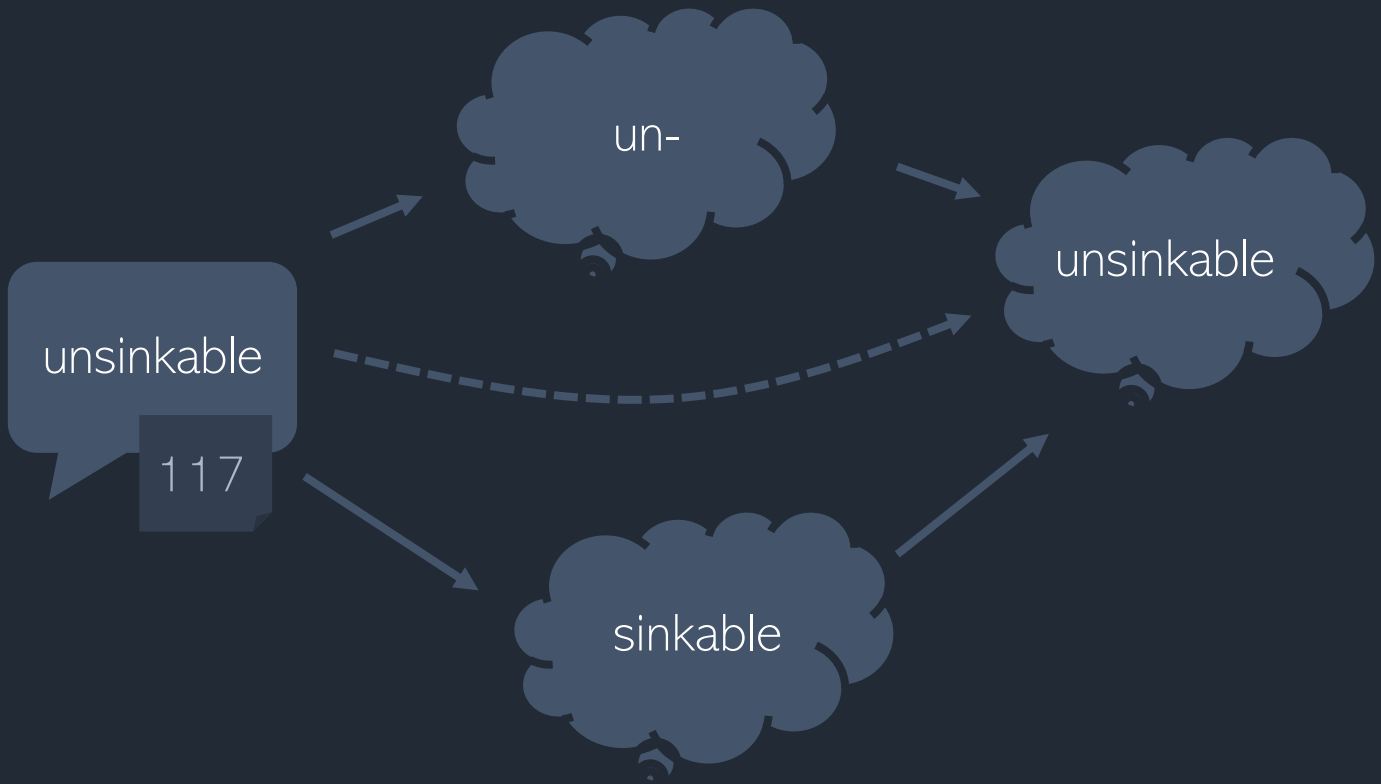


figure adapted from Hay 2001: 1045

Morphological segmentability



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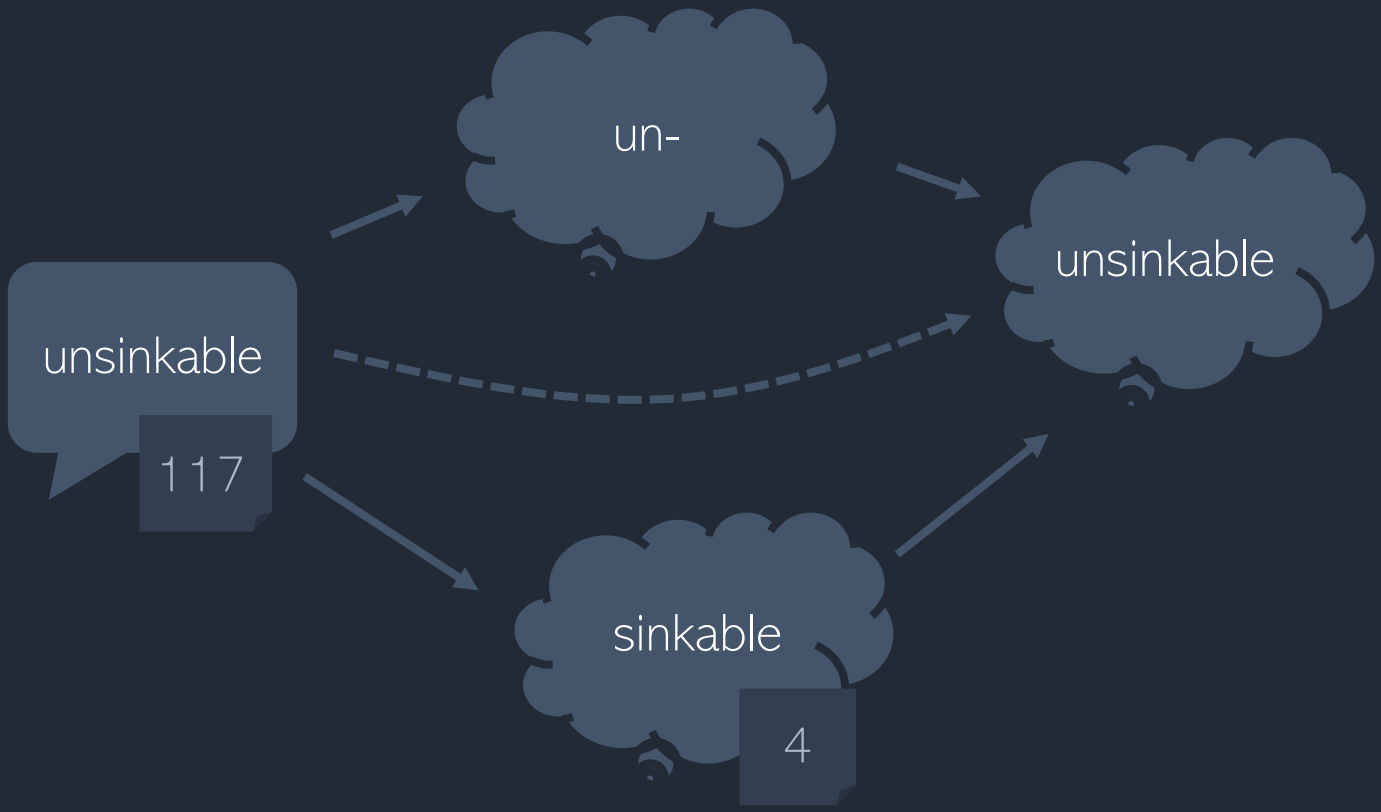

figure adapted from Hay 2001: 1045
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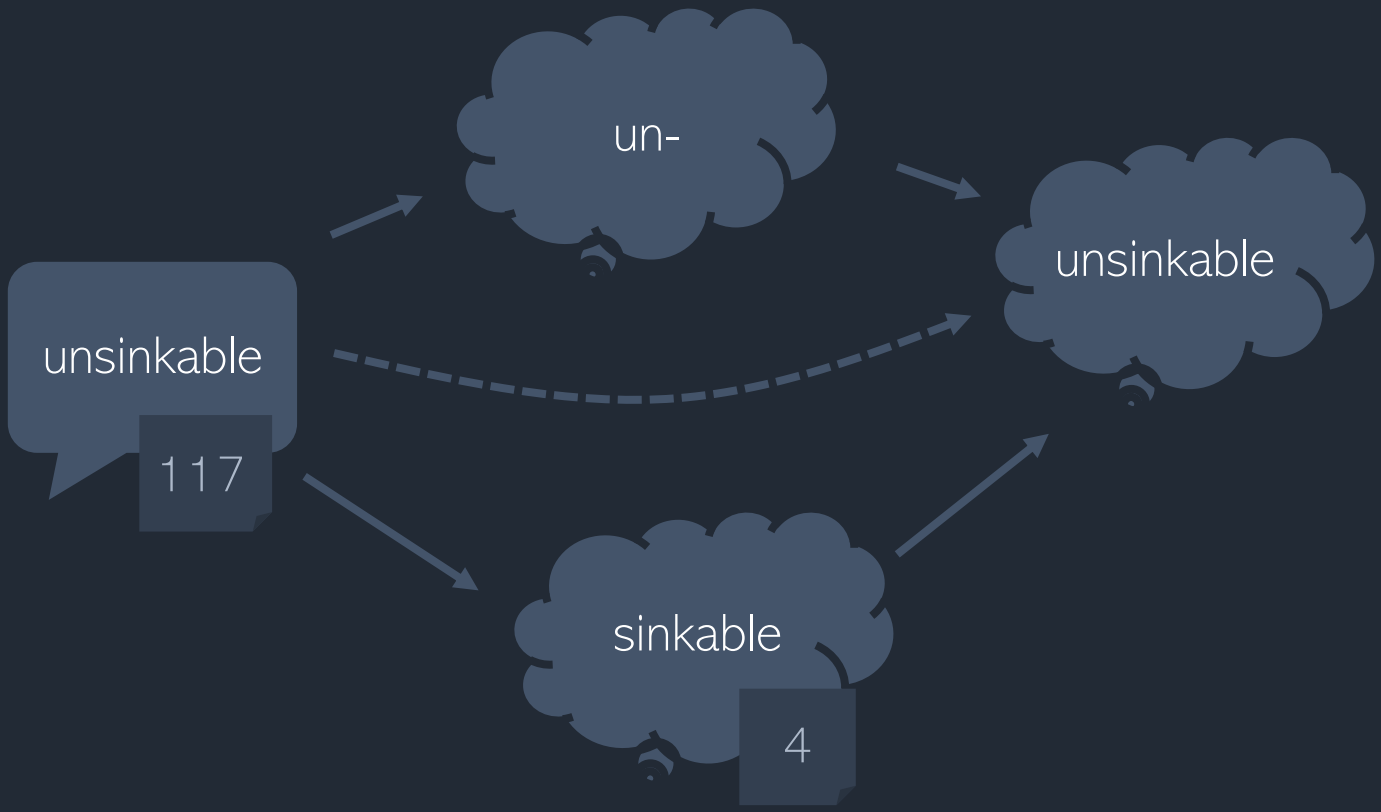
Morphological segmentability
low



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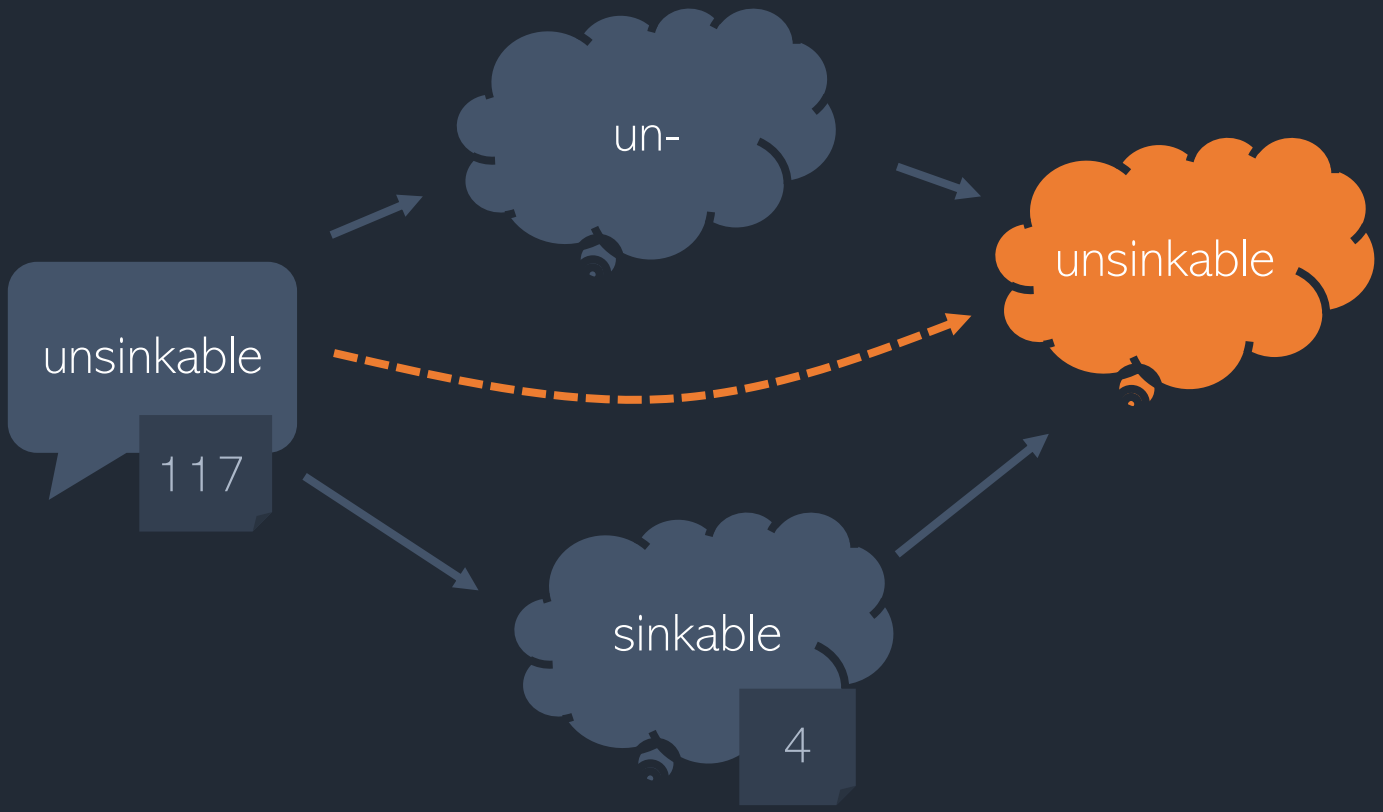

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The segmentability hypothesis

Hay 2001, 2003

The segmentability hypothesis

More segmentable words should be protected against reduction, i.e., longer in duration.

Hay 2001, 2003

Previous studies

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Higher relative frequency has been found to be associated with:

Previous studies

Higher relative frequency has been found to be associated with:

no change in duration

Pluymaekers et al. 2005b
Plag & Ben Hedia 2018
Ben Hedia & Plag 2017
Zimmerer et al. 2014
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longer durations

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longer durations

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Zuraw et al. 2020
Hay 2003
Hay 2007

shorter durations

Pluymaekers et al. 2005b
Schuppler et al. 2012

The suspect

Prosodic structure

Plag & Ben Hedia 2018

The suspect

Prosodic structure

Segmentability effects might be counteracted by a strong prosodic boundary:

Plag & Ben Hedia 2018

The suspect

Prosodic structure

Segmentability effects might be counteracted by a strong prosodic boundary:

- The weaker the prosodic boundary is, the less can higher relative frequency protect against reduction.

Plag & Ben Hedia 2018

The suspect

Prosodic structure

Segmentability effects might be counteracted by a strong prosodic boundary:

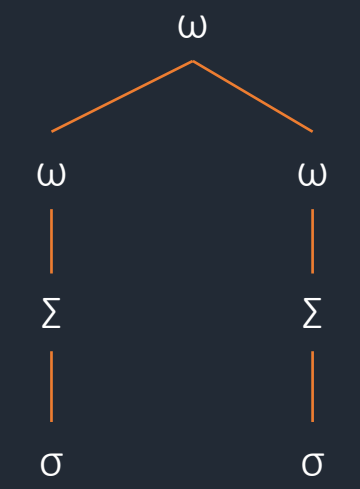
- The weaker the prosodic boundary is, the less can higher relative frequency protect against reduction.
- The stronger a prosodic boundary is, the more pre-boundary lengthening might cancel out reduction effects in barely segmentable words.

Plag & Ben Hedia 2018

Types of prosodic word integration

Raffelsiefen 1999

Types of prosodic word integration



PW

Raffelsiefen 1999

Types of prosodic word integration

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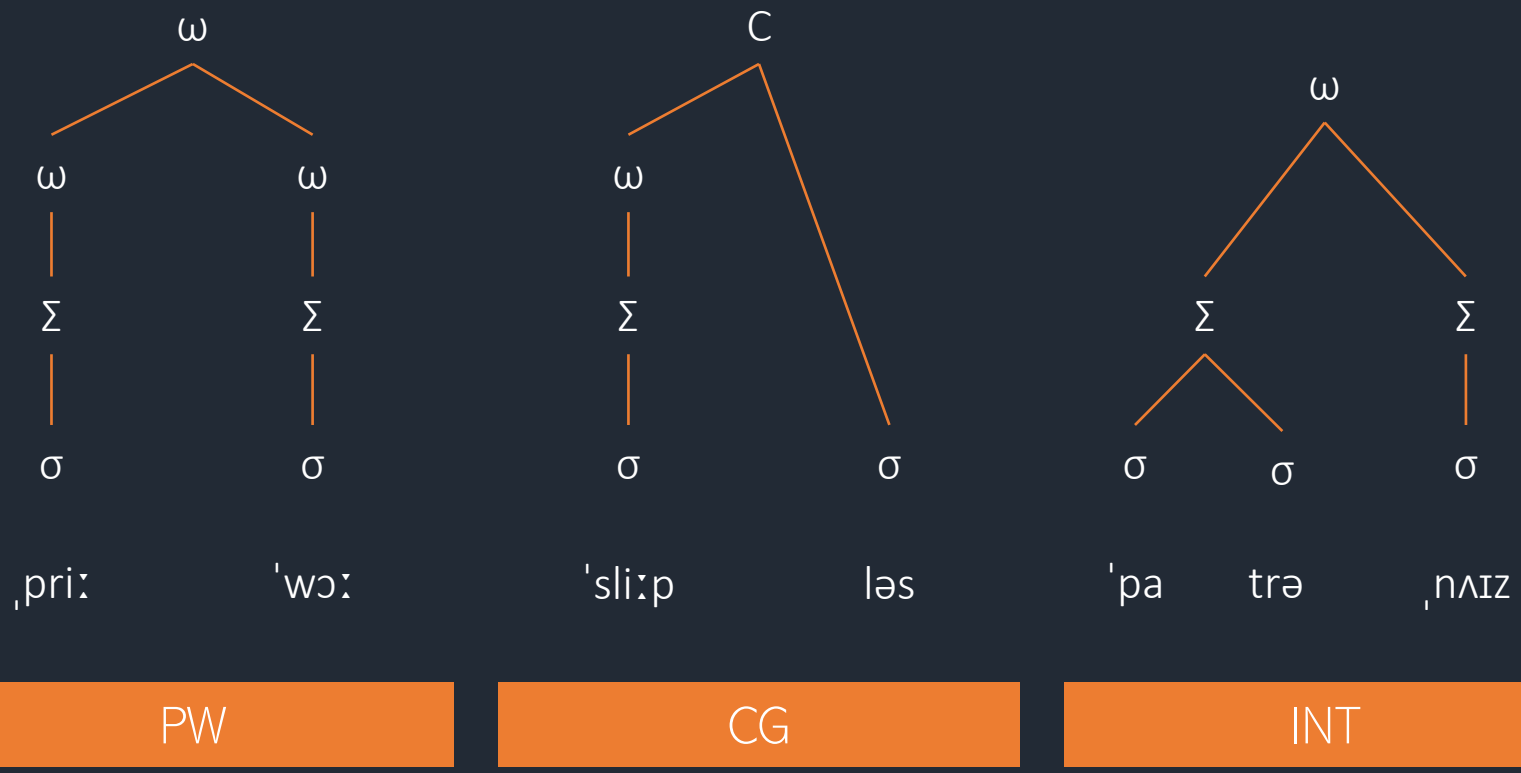
Types of prosodic word integration



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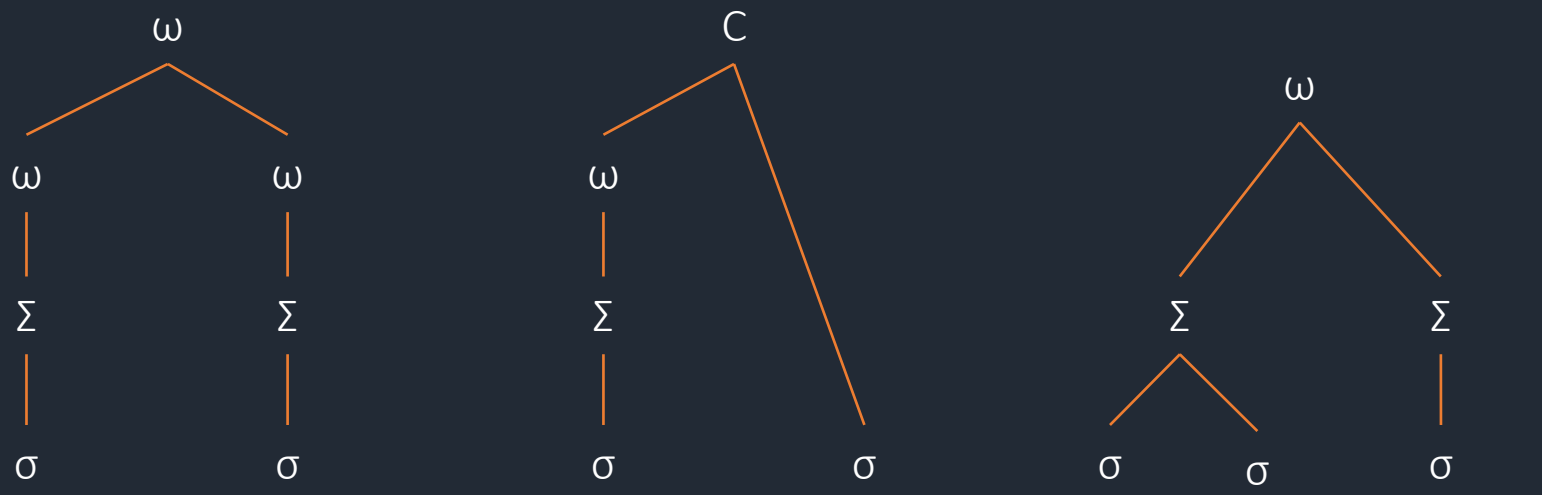

Raffelsiefen 1999

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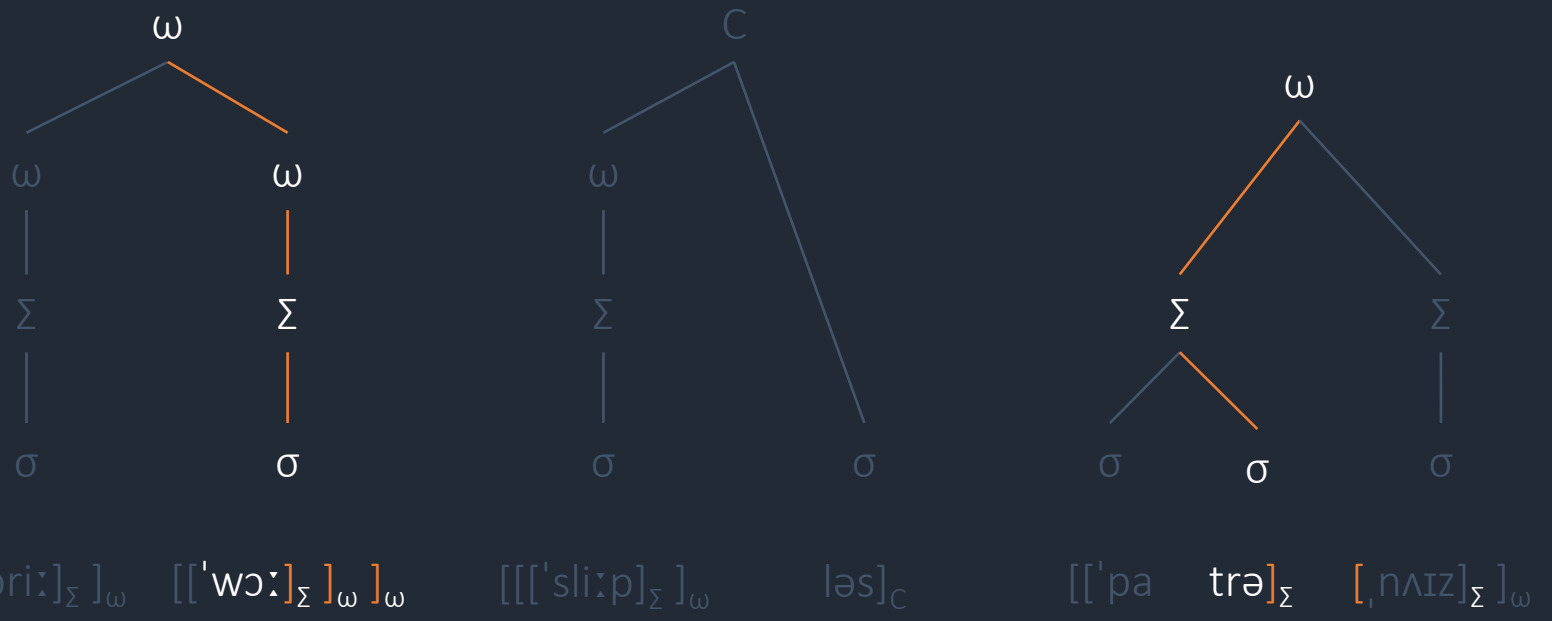
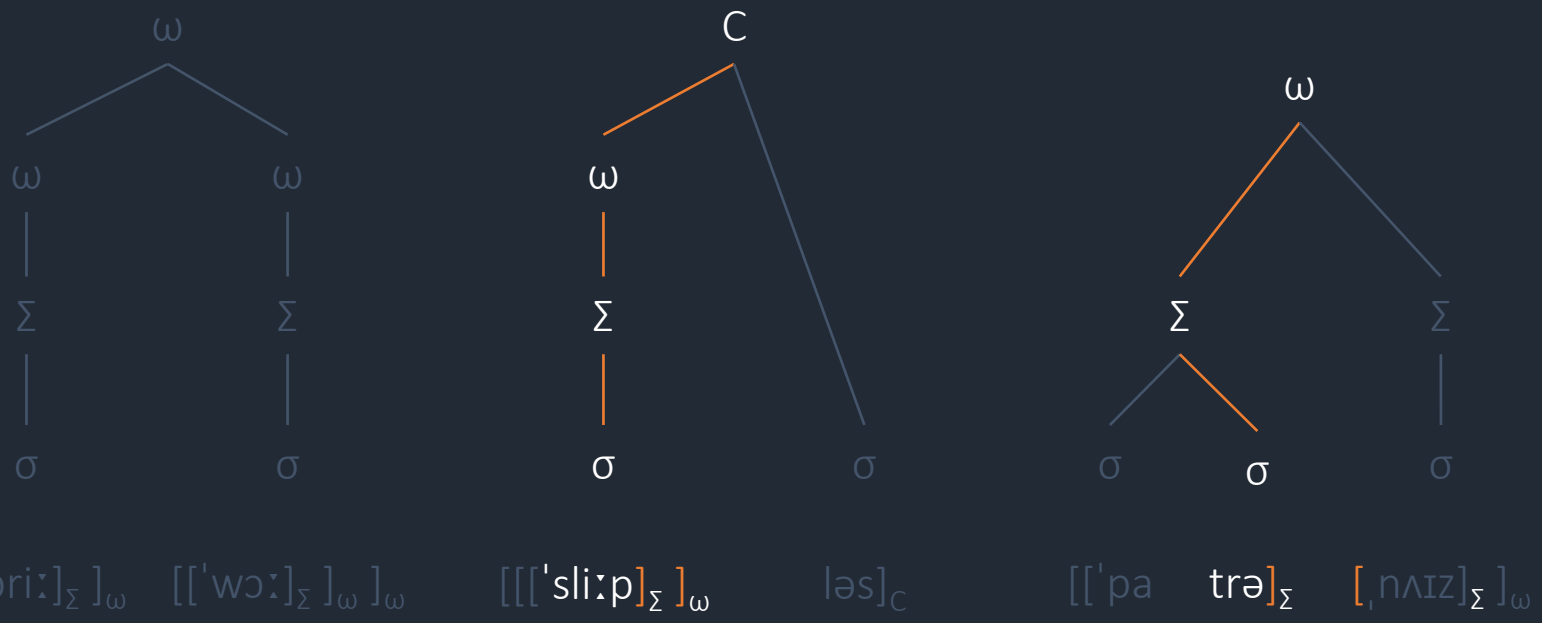


PW | CG | INT

Raffelsiefen 1999

Types of prosodic word integration



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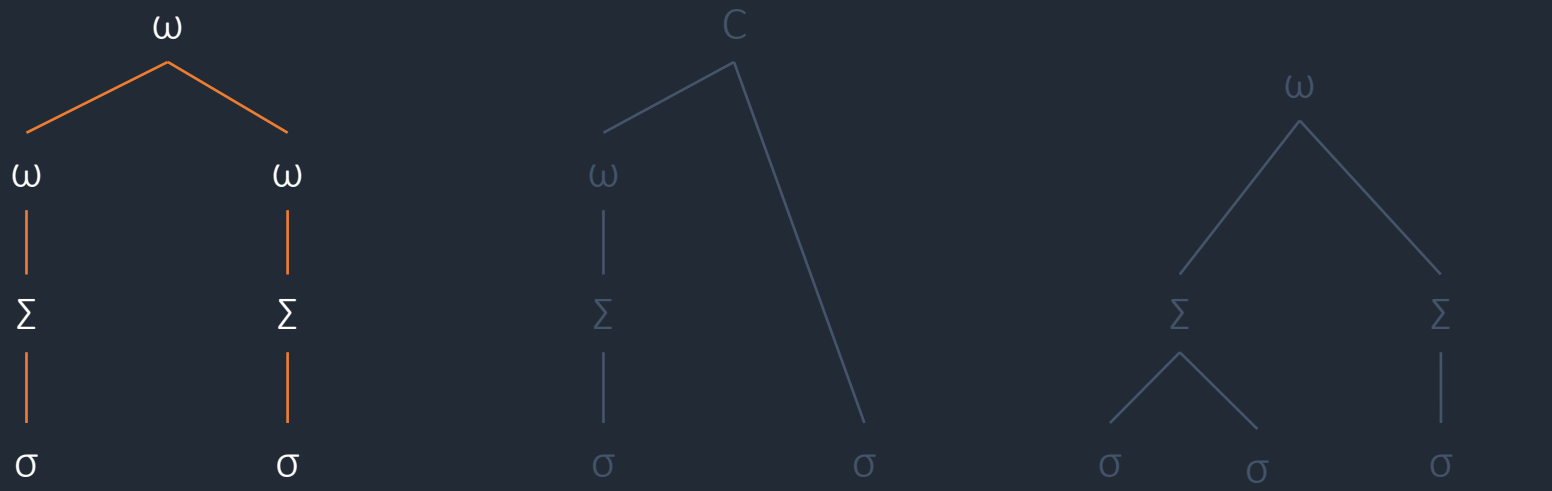

Raffelsiefen 1999

Expected prosodic lengthening hierarchies

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PW	INT	CG
base ‣ affix	affix ‣ base	affix ‣ base

X ‣ Y *X more lengthened than Y*

Expected prosodic lengthening hierarchies

PW	INT	CG	bases	affixes
base ‣ affix	affix ‣ base	affix ‣ base	PW ‣ CG ‣ INT	CG ‣ INT ‣ PW

X ‣ Y *X more lengthened than Y*

Summary of expectations

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H_1 Higher relative frequency should protect against reduction, i.e., be associated with longer durations.

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H_2 More prosodic integration should prevent relative frequency from protecting against reduction.

Summary of expectations

H_1 Higher relative frequency should protect against reduction, i.e., be associated with longer durations.

H_2 More prosodic integration should prevent relative frequency from protecting against reduction.

H_3 Pre-boundary lengthening should follow the expected prosodic lengthening hierarchies.


Methods

Data

	PW		CG		INT	
	tokens	types	tokens	types	tokens	types
Audio BNC	*dis-, in-, pre-, un-*		*-ness, -less*		*-ation, -ize*	
	1602	170	529	55	4168	220
QuakeBox	*dis-, un-, re-*		*-ness, -ment*		*-ation, -able, -ity*	
	684	69	441	37	1145	76
ONZE	*dis-, un-, re-*		*-ness, -ment*		*-ation, -able, -ity*	
	810	84	745	48	1556	125

Coleman et al. 2012, Walsh et al. 2013, Gordon et al. 2007

Data

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	810	84	745	48	1556	125

Modeling

mixed-effects regression with random intercepts for word type

Coleman et al. 2012, Walsh et al. 2013, Gordon et al. 2007

Model structure

duration difference ~ (1 | Word) +
relative frequency · type of morpheme +
relative frequency · prosodic category +
prosodic category · type of morpheme +
speech rate +
number of syllables +
bigram frequency +
mean biphone probability +
corpus

Model structure

duration difference ~ (1 | Word) + relative frequency · type of morpheme +
relative frequency · prosodic category +
prosodic category · type of morpheme +
speech rate +
number of syllables +
bigram frequency +
mean biphone probability +
corpus

duration difference
residuals of a linear model observed duration ~ baseline duration

Model structure

duration difference ~ (1 | Word) +
relative frequency · type of morpheme +
relative frequency · prosodic category +
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duration difference ~ (1 | Word) + relative frequency · type of morpheme +
relative frequency · prosodic category +
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corpus

$$relative\ frequency = \frac{base\ frequency}{word\ frequency}$$

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duration difference ~ (1 | Word) + relative frequency · type of morpheme +
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bigram frequency +
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corpus

type of morpheme
affix or base

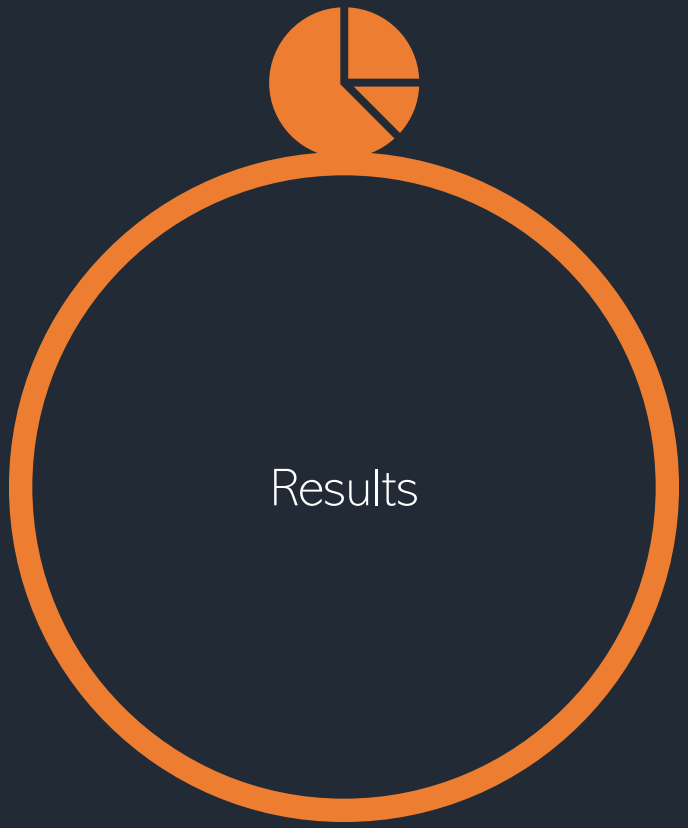
Model structure

duration difference ~ (1 | Word) + relative frequency · type of morpheme +
relative frequency · prosodic category +
prosodic category · type of morpheme +
speech rate +
number of syllables +
bigram frequency +
mean biphone probability +
corpus

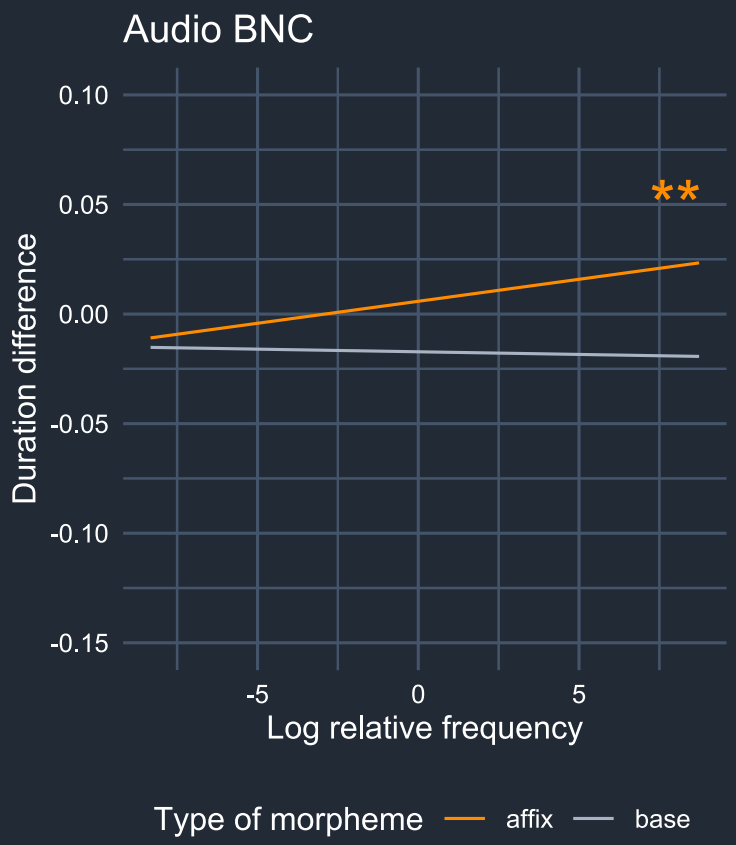
prosodic category
PW, CG, INT

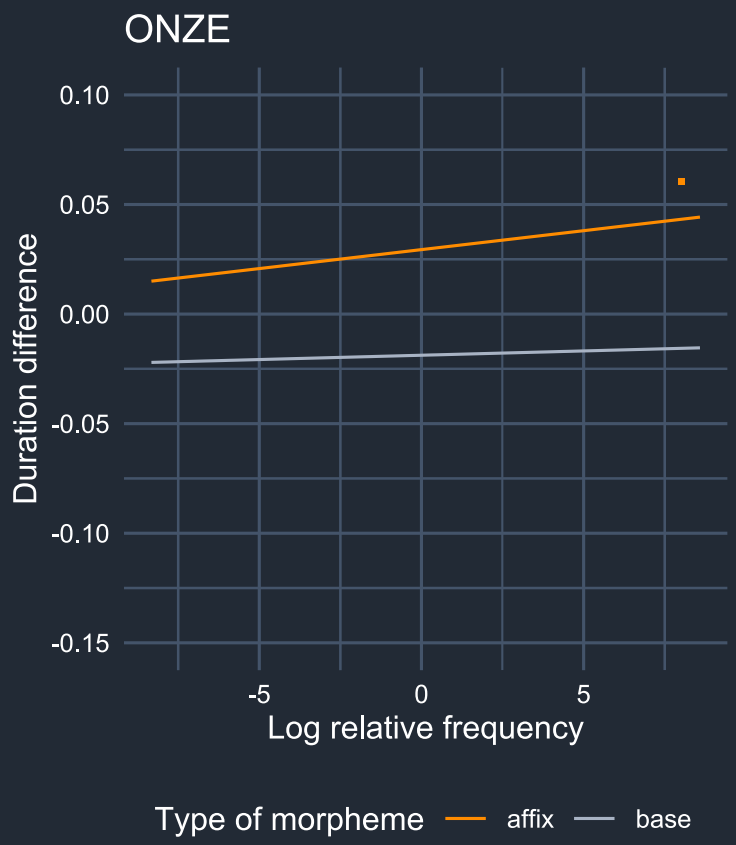
Model structure

duration difference ~ (1 | Word) +
relative frequency · type of morpheme +
relative frequency · prosodic category +
prosodic category · type of morpheme +
speech rate +
number of syllables +
bigram frequency +
mean biphone probability +
corpus


Results

Relative frequency · Type of morpheme





Relative frequency · Prosodic category

In general, prosodic word structure is not a gatekeeper for relative frequency effects.

Prosodic category · Type of morpheme

	PW	INT	CG	bases	affixes
EXP	base ‣ affix	affix ‣ base	affix ‣ base	PW ‣ CG ‣ INT	CG ‣ INT ‣ PW

X ‣ *Y* *X more lengthened than Y*
X = *Y* *no difference*

Prosodic category · Type of morpheme

	PW	INT	CG	bases	affixes
EXP	base ▸ affix	affix ▸ base	affix ▸ base	PW ▸ CG ▸ INT	CG ▸ INT ▸ PW
BNC	base ▸ affix	affix ▸ base	base ▸ affix	PW ▸ CG ▸ INT	INT ▸ PW = CG

X ▸ Y *X more lengthened than Y*
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Prosodic category · Type of morpheme

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EXP	base ‣ affix	affix ‣ base	affix ‣ base	PW ‣ CG ‣ INT	CG ‣ INT ‣ PW
BNC	base ‣ affix	affix ‣ base	base ‣ affix	PW ‣ CG ‣ INT	INT ‣ PW = CG
QKE	base ‣ affix	affix ‣ base	base ‣ affix	PW ‣ CG = INT	INT ‣ PW = CG

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Prosodic category · Type of morpheme

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BNC	base ‣ affix	affix ‣ base	base ‣ affix	PW ‣ CG ‣ INT	INT ‣ PW = CG
QKE	base ‣ affix	affix ‣ base	base ‣ affix	PW ‣ CG = INT	INT ‣ PW = CG
ONZ	base ‣ affix	affix ‣ base	base ‣ affix	PW ‣ CG = INT	INT ‣ PW ‣ CG

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Prosodic category · Type of morpheme

	PW	INT	CG	bases	affixes
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BNC	base ‣ affix ✓	affix ‣ base ✓	base ‣ affix ✗	PW ‣ CG ✓ ‣ INT ✓	INT ‣ PW = CG ✗
QKE	base ‣ affix ✓	affix ‣ base ✓	base ‣ affix ✗	PW ‣ CG ✓ = INT ?	INT ‣ PW ✓ = CG ✗
ONZ	base ‣ affix ✓	affix ‣ base ✓	base ‣ affix ✗	PW ‣ CG ✓ = INT ?	INT ‣ PW ✓ ‣ CG ✗

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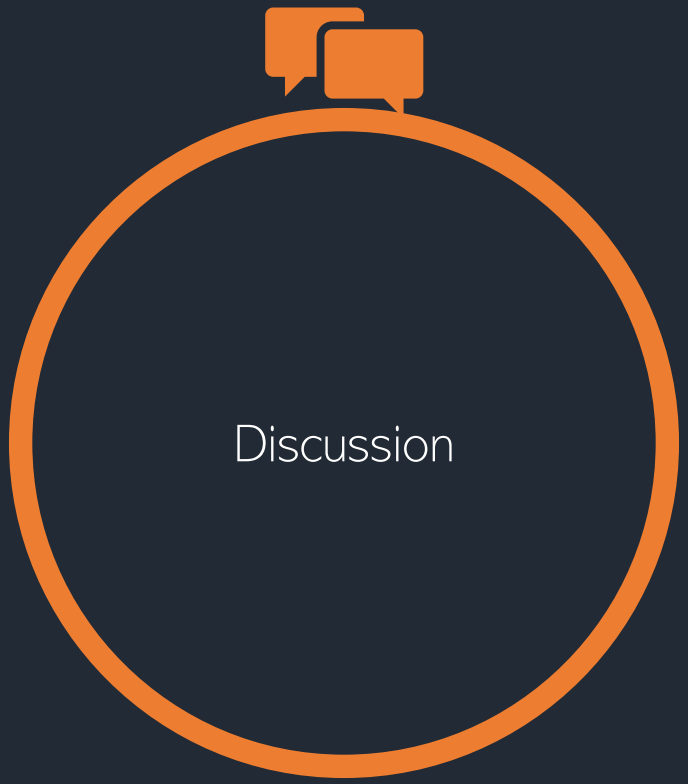
Prosodic category · Type of morpheme

In general, prosodic boundaries fail to account consistently for durational differences.


Discussion

H_1 partial support

Higher relative frequency can be associated with lengthening, but often isn't.

Hay 2003, Pluymaekers et al. 2005b, Hay 2007, Schuppler et al. 2012, Zimmerer et al. 2014, Ben Hedia & Plag 2017, Plag & Ben Hedia 2018, Zuraw et al. 2020, Bowden et al. 2010

H_1 partial support

Higher relative frequency can be associated with lengthening, but often isn't.

- If we take the effect seriously, it implies that morphological information is sometimes still reflected at the subphonemic level.

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- However, our study "replicates" the mixture of effects and null effects.

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- Additional analyses suggest that positive relative frequency effects on duration only emerge in the presence of word frequency effects.

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- However, our study "replicates" the mixture of effects and null effects.
- Additional analyses suggest that positive relative frequency effects on duration only emerge in the presence of word frequency effects.
- We might need to consider discarding relative frequency as a predictor of morpho-phonetic variation.

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H_2 rejected

The degree of prosodic word integration does not influence whether higher relative frequency can protect against reduction.

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H_2 rejected

The degree of prosodic word integration does not influence whether higher relative frequency can protect against reduction.

- This is indirectly consistent with previous studies, which have found effects of relative frequency on duration for both non-integrating affixes and integrating affixes.

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- This is indirectly consistent with previous studies, which have found effects of relative frequency on duration for both non-integrating affixes and integrating affixes.
- Previous studies also show that neither an integrating nor a non-integrating affix guarantees a relative frequency effect.

Hay 2003, Pluymaekers et al. 2005b, Hay 2007, Schuppler et al. 2012, Zimmerer et al. 2014, Ben Hedia & Plag 2017, Plag & Ben Hedia 2018, Zuraw et al. 2020

H_3 partial support

The prosodic structure of complex words cannot consistently explain durational variation.

Sproat & Fujimura 1993, Auer 2002, Sugahara & Turk 2009, Bergmann 2018, also see Klatt 1975, Vaissière 1983, Edwards & Beckman 1988, Beckman & Pierrehumbert 1986, Campbell 1990, Wightman et al. 1992

H_3 partial support

The prosodic structure of complex words cannot consistently explain durational variation.

- Some previous studies had suggested that prosodic structure can account for some durational variation.

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H_3 partial support

The prosodic structure of complex words cannot consistently explain durational variation.

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- However, there are important differences between these studies and ours (domains, conditions, methodologies, level of prosodic boundaries).

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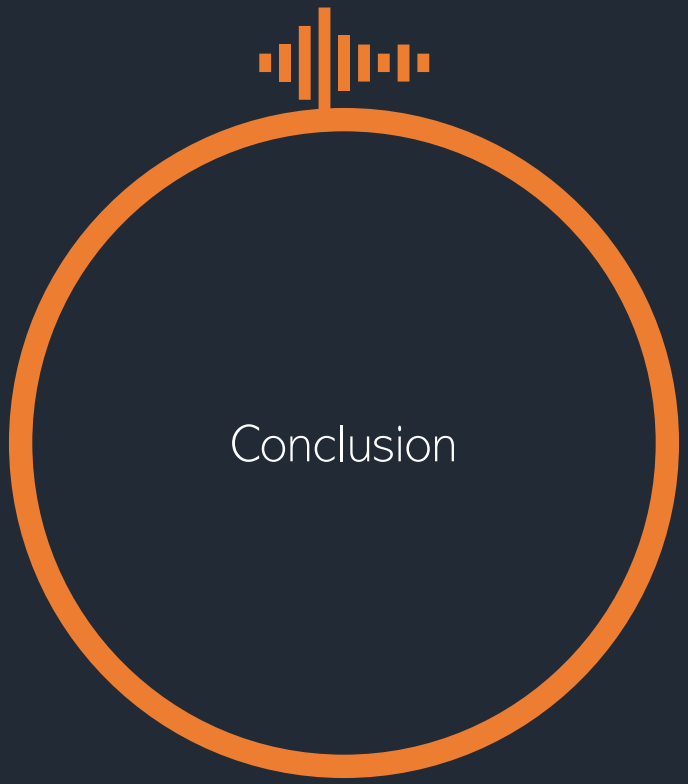
- Some previous studies had suggested that prosodic structure can account for some durational variation.
- However, there are important differences between these studies and ours (domains, conditions, methodologies, level of prosodic boundaries).
- In phonological theory and in models of speech production, it is unclear how the supposed word-internal boundaries translate into articulatory gestures or acoustic properties.

Sproat & Fujimura 1993, Auer 2002, Sugahara & Turk 2009, Bergmann 2018, also see Klatt 1975, Vaissière 1983, Edwards & Beckman 1988, Beckman & Pierrehumbert 1986, Campbell 1990, Wightman et al. 1992



Conclusion

Takeaway

Relative frequency and prosodic word integration do not reliably predict duration, and prosodic word integration is not responsible for the emergence of relative frequency effects.

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What's next?

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What's next?

- We may need to explore other factors for the morphology-phonetics interaction and for processing in the mental lexicon.

Takeaway

Relative frequency and prosodic word integration do not reliably predict duration, and prosodic word integration is not responsible for the emergence of relative frequency effects.

What's next?

- We may need to explore other factors for the morphology-phonetics interaction and for processing in the mental lexicon.
- The morphology-phonology-phonetics interface might be better modeled by non-morphemic, word-based approaches, such as discrimination learning.

Stein & Plag (submitted)


Thank you!

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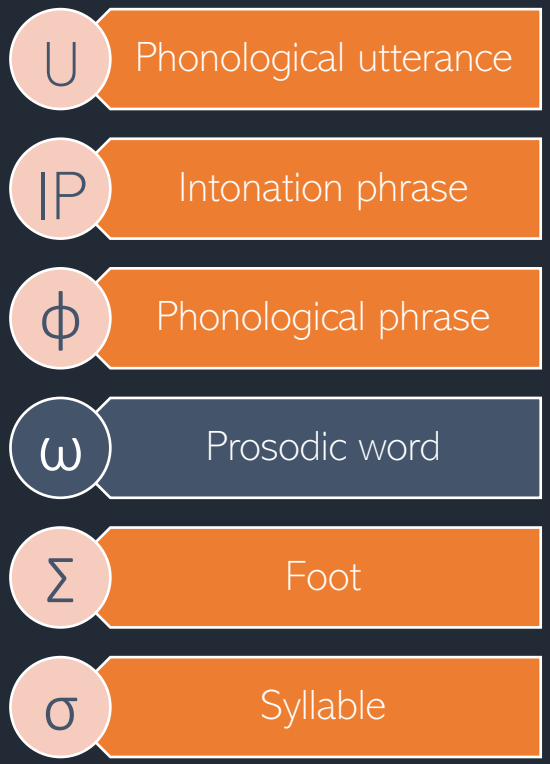
The prosodic hierarchy



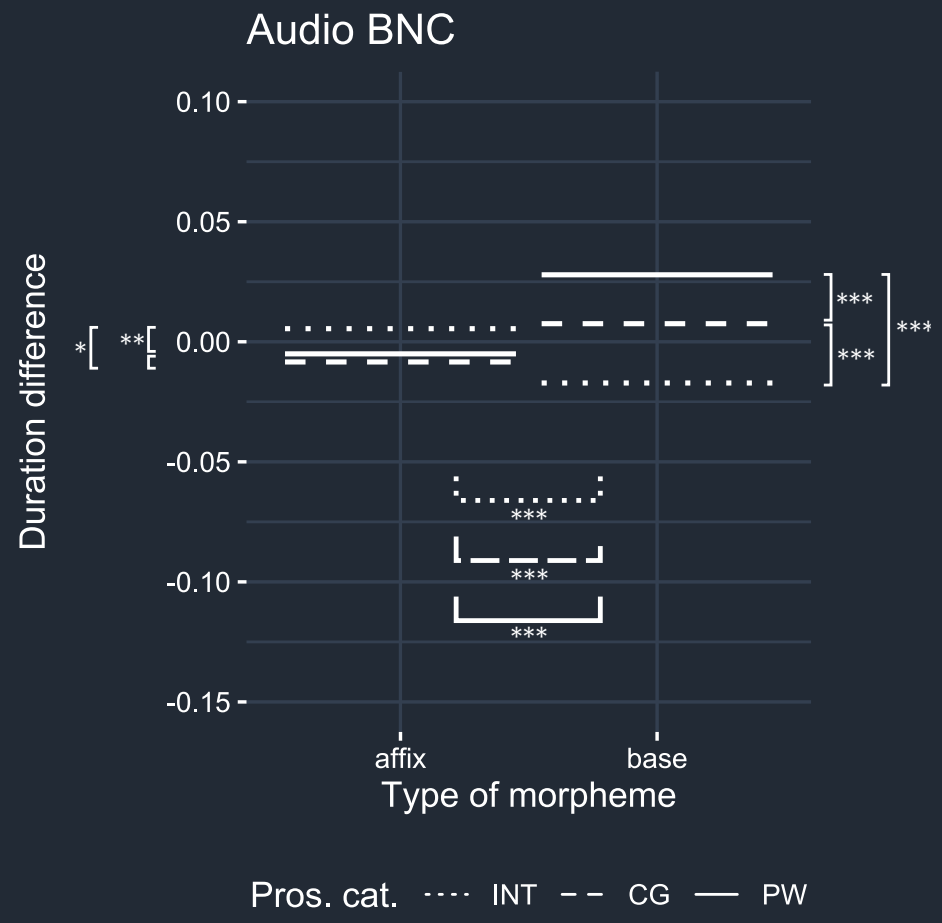
Some pword-diagnostics

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

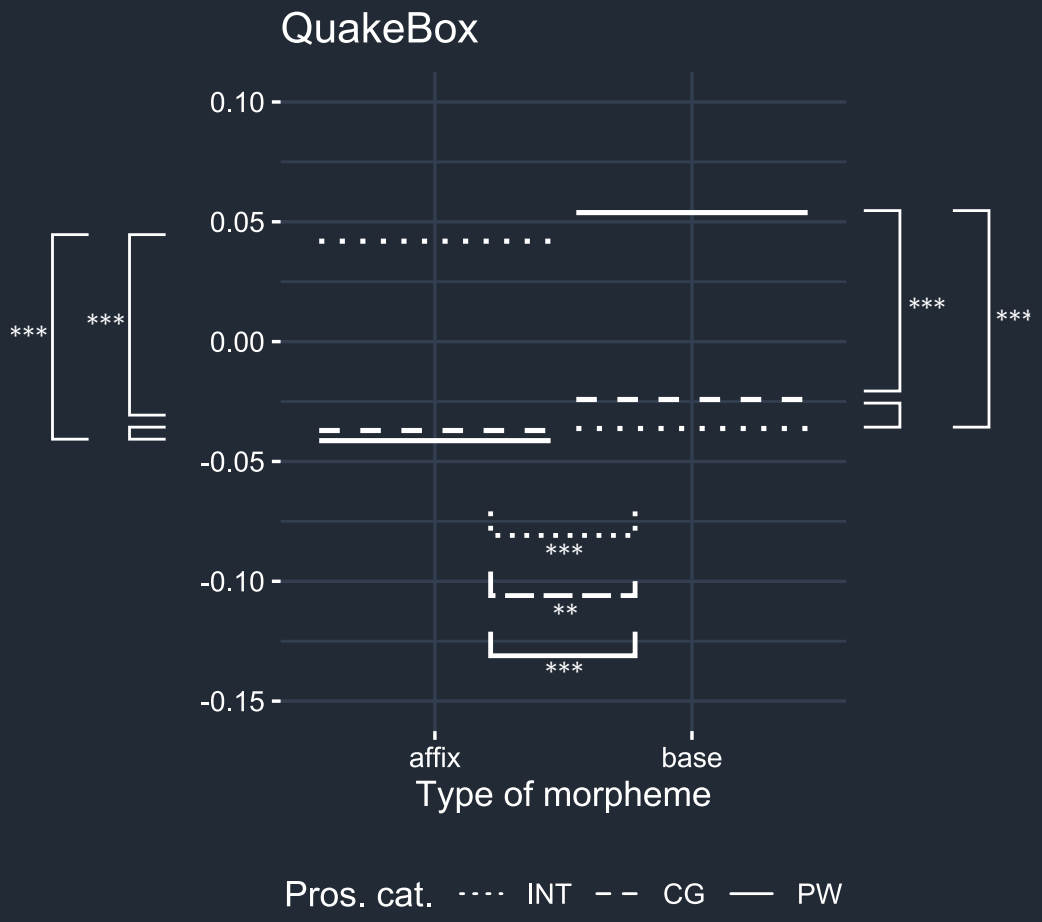
Morpho-prosodic alignment

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

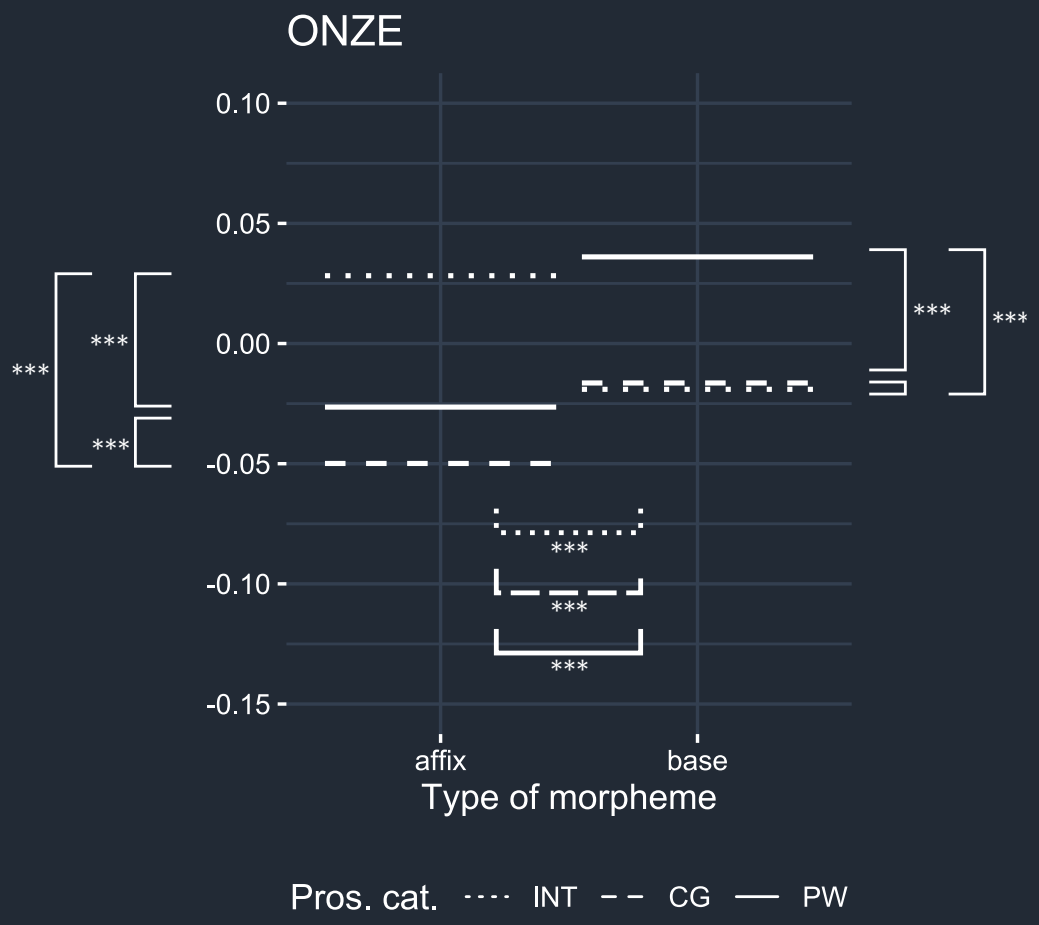
Prosodic category · Type of morpheme



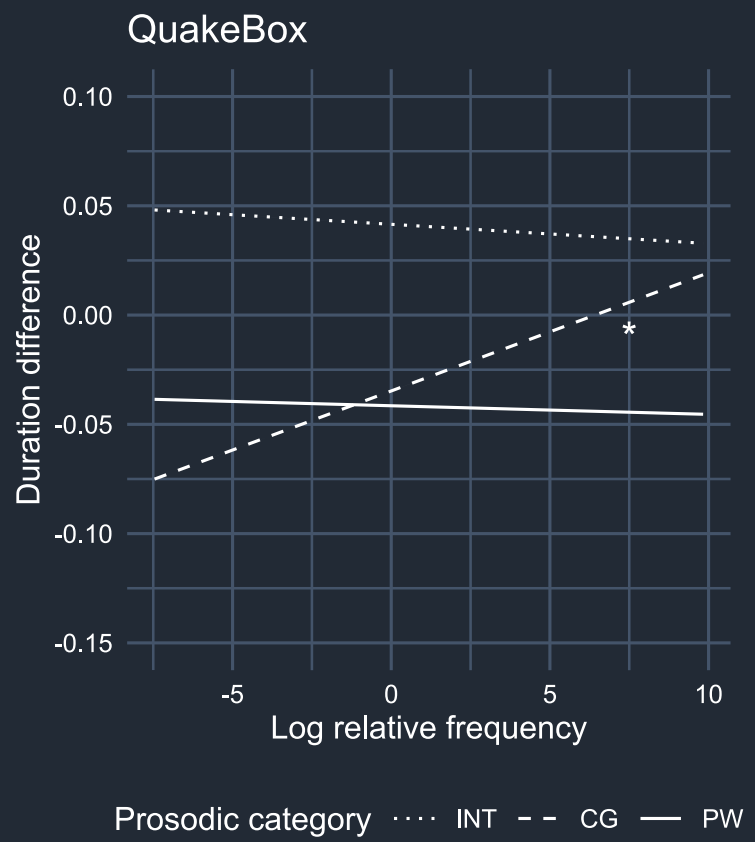
Prosodic category · Type of morpheme



Prosodic category · Type of morpheme



Relative frequency · Prosodic category



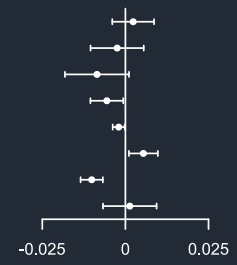
The model is not significantly better than the same model without this interaction.

Category-internal frequency models Audio BNC

word frequency

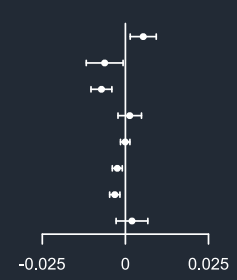
word duration

Affix	β	p
-ness	0.002	–
-less	-0.002	–
pre-	-0.009	–
-ize	-0.006	–
-ation	-0.002	*
dis-	0.005	*
un-	-0.01	***
in-	0.001	–



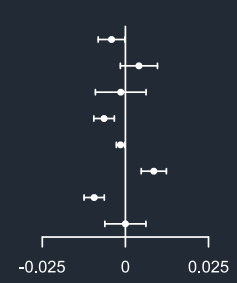
affix duration

Affix	β	p
-ness	0.005	**
-less	-0.006	–
pre-	-0.007	***
-ize	0.001	–
-ation	0	–
dis-	-0.002	**
un-	-0.003	***
in-	0.002	–



base duration

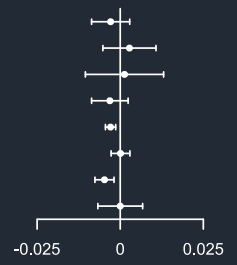
Affix	β	p
-ness	-0.004	–
-less	0.004	–
pre-	-0.001	–
-ize	-0.006	***
-ation	-0.001	*
dis-	0.009	***
un-	-0.009	***
in-	0	–



base frequency

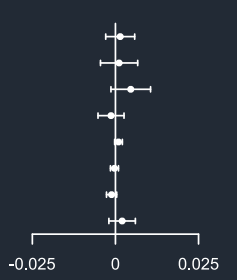
word duration

Affix	β	p
-ness	-0.003	–
-less	0.003	–
pre-	0.001	–
-ize	-0.003	–
-ation	-0.003	***
dis-	0	–
un-	-0.005	**
in-	0	–



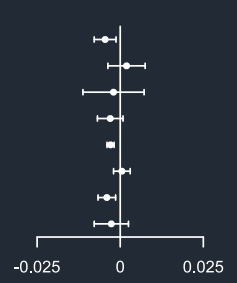
affix duration

Affix	β	p
-ness	0.001	–
-less	0.001	–
pre-	0.005	–
-ize	-0.001	–
-ation	0.001	–
dis-	0	–
un-	-0.001	–
in-	0.002	–



base duration

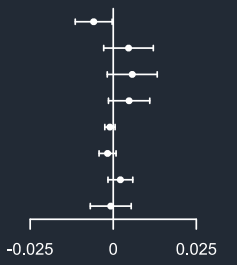
Affix	β	p
-ness	-0.005	**
-less	0.002	–
pre-	-0.002	–
-ize	-0.003	–
-ation	-0.003	***
dis-	0	–
un-	-0.004	**
in-	-0.003	–



relative frequency

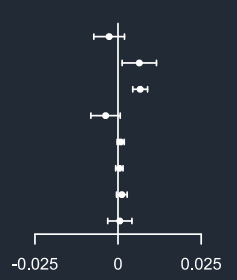
word duration

Affix	β	p
-ness	-0.006	*
-less	0.005	–
pre-	0.006	–
-ize	0.005	–
-ation	-0.001	–
dis-	-0.002	–
un-	0.002	–
in-	-0.001	–



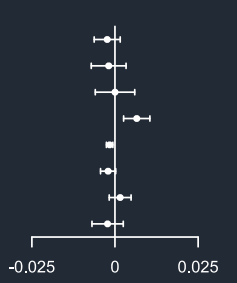
affix duration

Affix	β	p
-ness	-0.003	–
-less	0.006	–
pre-	0.007	***
-ize	-0.004	–
-ation	0.001	–
dis-	0	–
un-	0.001	–
in-	0.001	–



base duration

Affix	β	p
-ness	-0.002	–
-less	-0.002	–
pre-	0	–
-ize	0.007	**
-ation	-0.002	**
dis-	-0.002	–
un-	0.002	–
in-	-0.002	–

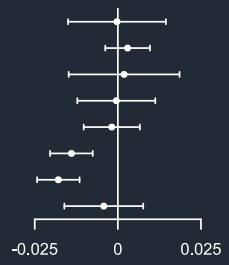


Category-internal frequency models QuakeBox

word frequency

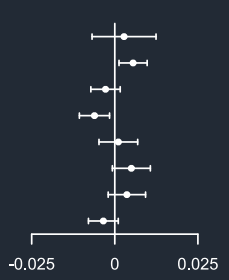
word duration

Affix	β	p
-ness	0	–
-ation	0.003	–
dis-	0.002	–
un-	0	–
-able	-0.002	–
-ity	-0.014	***
-ment	-0.018	***
re-	-0.004	–



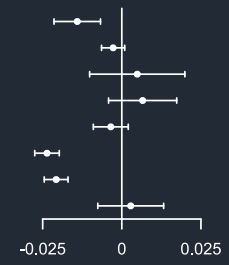
affix duration

Affix	β	p
-ness	0.003	–
-ation	0.006	*
dis-	-0.003	–
un-	-0.006	**
-able	0.001	–
-ity	0.005	–
-ment	0.004	–
re-	-0.003	–



base duration

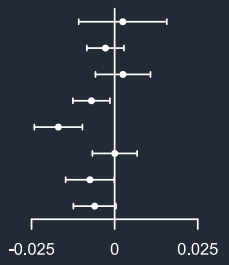
Affix	β	p
-ness	-0.014	***
-ation	-0.003	–
dis-	0.005	–
un-	0.007	–
-able	-0.003	–
-ity	-0.024	***
-ment	-0.021	***
re-	0.003	–



base frequency

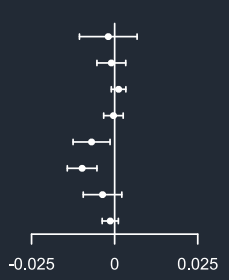
word duration

Affix	β	p
-ness	0.002	–
-ation	-0.003	–
dis-	0.003	–
un-	-0.007	*
-able	-0.017	***
-ity	0	–
-ment	-0.007	*
re-	-0.006	–



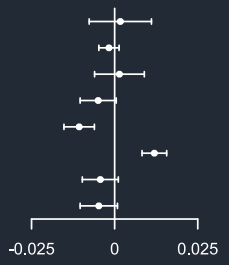
affix duration

Affix	β	p
-ness	-0.002	–
-ation	-0.001	–
dis-	0.001	–
un-	0	–
-able	-0.007	*
-ity	-0.01	***
-ment	-0.004	–
re-	-0.001	–



base duration

Affix	β	p
-ness	0.002	–
-ation	-0.002	–
dis-	0.001	–
un-	-0.005	–
-able	-0.011	***
-ity	0.012	***
-ment	-0.004	–
re-	-0.005	–



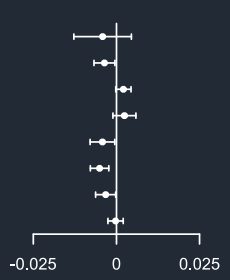
relative frequency

word duration

Affix	β	p
-ness	0.003	–
-ation	-0.003	–
dis-	0.002	–
un-	-0.011	**
-able	-0.007	–
-ity	0.008	***
-ment	0.007	**
re-	-0.004	–

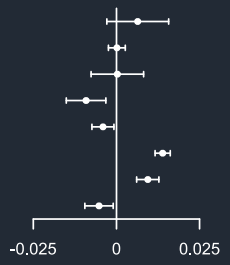
affix duration

Affix	β	p
-ness	-0.004	–
-ation	-0.004	*
dis-	0.002	–
un-	0.002	–
-able	-0.004	*
-ity	-0.005	***
-ment	-0.003	*
re-	0	–



base duration

Affix	β	p
-ness	0.006	–
-ation	0	–
dis-	0	–
un-	-0.009	**
-able	-0.004	*
-ity	0.014	***
-ment	0.009	***
re-	-0.005	*

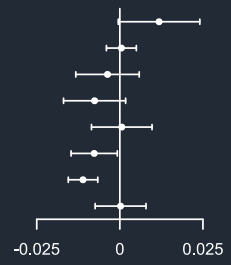


Category-internal frequency models ONZE

word frequency

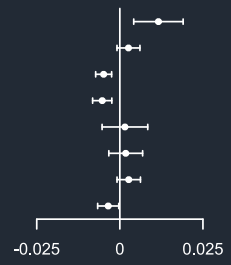
word duration

Affix	β	p
-ness	0.012	–
-ation	0	–
dis-	-0.004	–
un-	-0.008	–
-able	0.001	–
-ity	-0.008	–
-ment	-0.011	***
re-	0	–



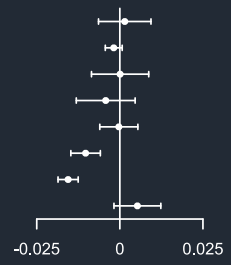
affix duration

Affix	β	p
-ness	0.012	**
-ation	0.003	–
dis-	-0.005	***
un-	-0.005	***
-able	0.002	–
-ity	0.002	–
-ment	0.003	–
re-	-0.003	–



base duration

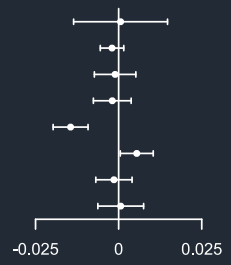
Affix	β	p
-ness	0.001	–
-ation	-0.002	–
dis-	0	–
un-	-0.004	–
-able	0	–
-ity	-0.01	***
-ment	-0.016	***
re-	0.005	–



base frequency

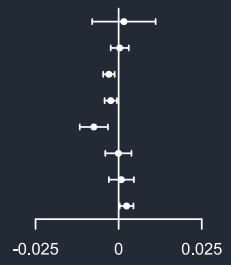
word duration

Affix	β	p
-ness	0.001	–
-ation	-0.002	–
dis-	-0.001	–
un-	-0.002	–
-able	-0.014	***
-ity	0.005	*
-ment	-0.001	–
re-	0.001	–



affix duration

Affix	β	p
-ness	0.002	–
-ation	0	–
dis-	-0.003	***
un-	-0.002	*
-able	-0.007	***
-ity	0	–
-ment	0.001	–
re-	0.002	*



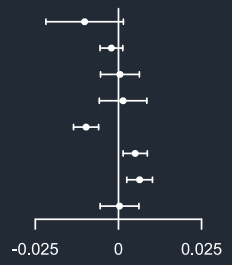
base duration

Affix	β	p
-ness	-0.003	–
-ation	-0.003	**
dis-	0.002	–
un-	-0.001	–
-able	-0.008	***
-ity	0.007	***
-ment	-0.001	–
re-	-0.001	–

relative frequency

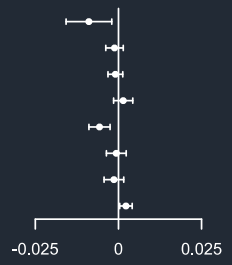
word duration

Affix	β	p
-ness	-0.01	–
-ation	-0.002	–
dis-	0	–
un-	0.001	–
-able	-0.01	***
-ity	0.005	**
-ment	0.006	**
re-	0	–



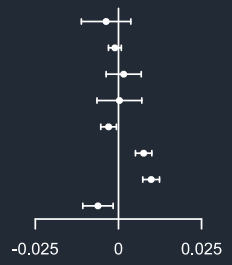
affix duration

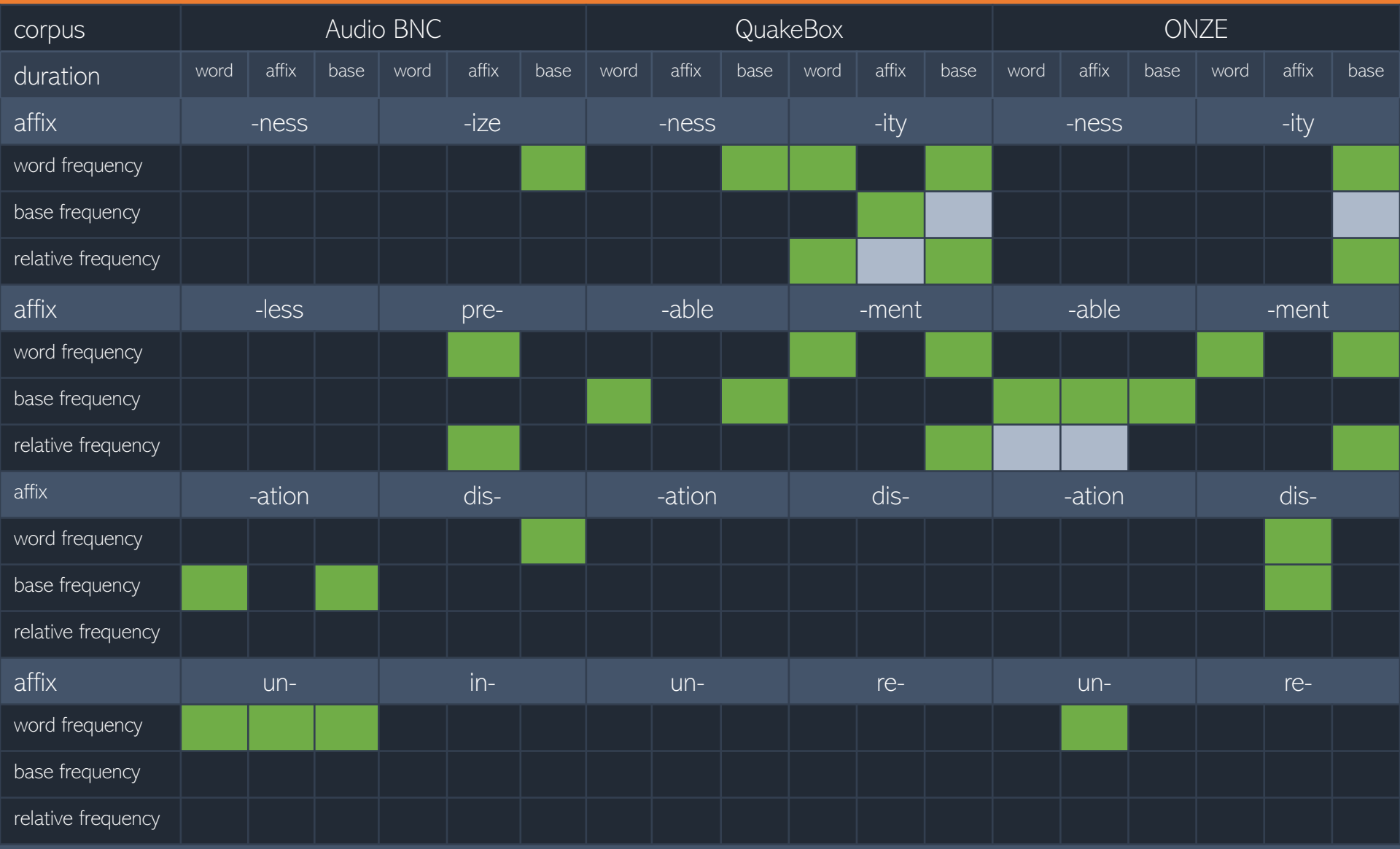
Affix	β	p
-ness	-0.009	*
-ation	-0.001	–
dis-	-0.001	–
un-	0.001	–
-able	-0.006	***
-ity	-0.001	–
-ment	-0.001	–
re-	0.002	*



base duration

Affix	β	p
-ness	-0.004	–
-ation	-0.001	–
dis-	0.002	–
un-	0	–
-able	-0.003	*
-ity	0.008	***
-ment	0.01	***
re-	-0.006	**




corpus
Audio BNC
QuakeBox
ONZE
duration
word affix base word affix base word affix base word affix base word affix base word affix base
affix
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word frequency
base frequency
relative frequency
affix
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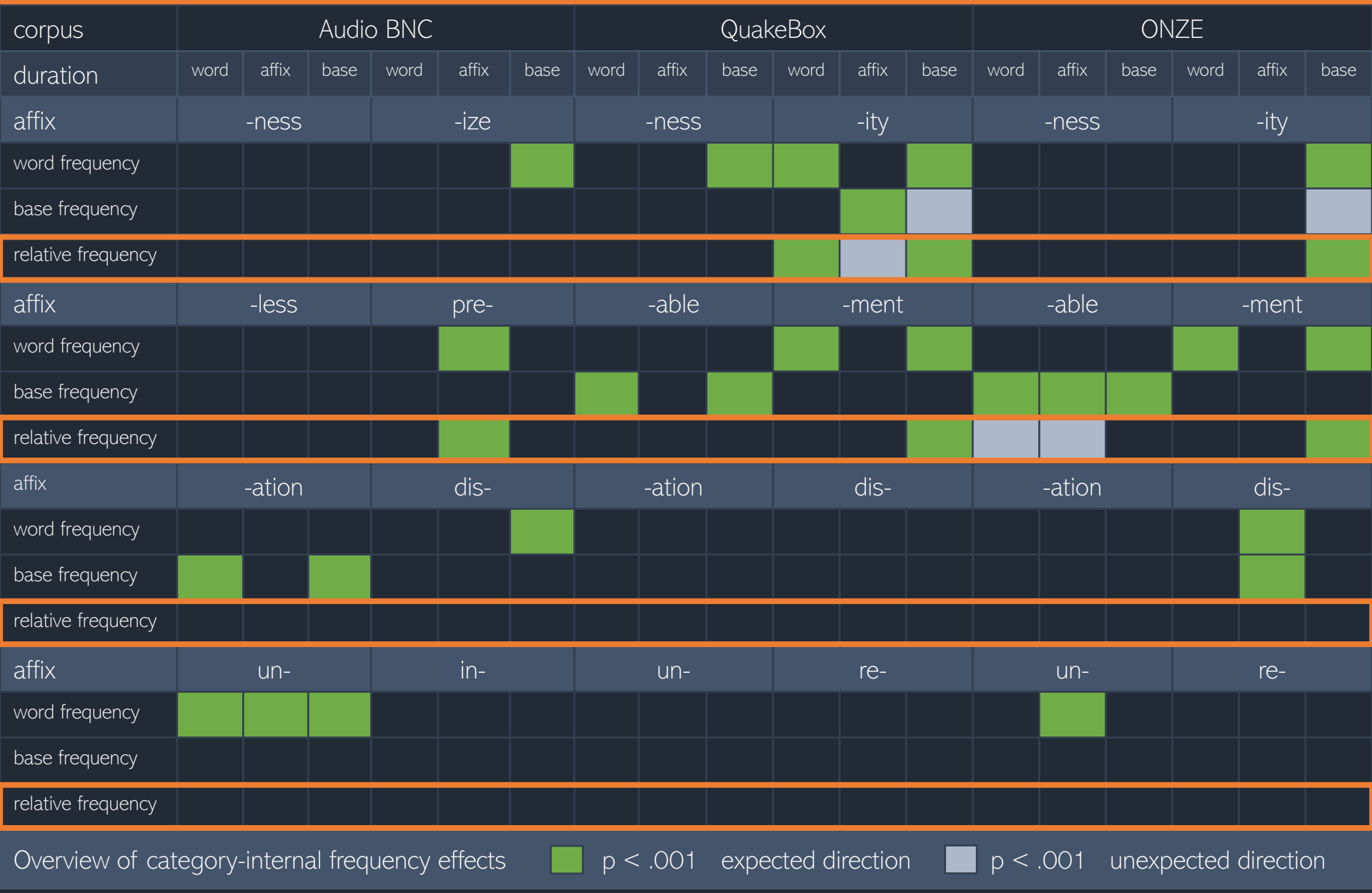
word frequency
base frequency
relative frequency
affix
-ation dis- -ation dis- -ation dis-
word frequency
base frequency
relative frequency
affix
un- in- un- re- un- re-
word frequency
base frequency
relative frequency
Overview of category-internal frequency effects
p < .001 expected direction
p < .001 unexpected direction


corpus
Audio BNC
QuakeBox
ONZE
duration
word affix base word affix base word affix base word affix base word affix base word affix base
affix
-ness -ize -ness -ity -ness -ity
word frequency
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-less pre- -able -ment -able -ment
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relative frequency
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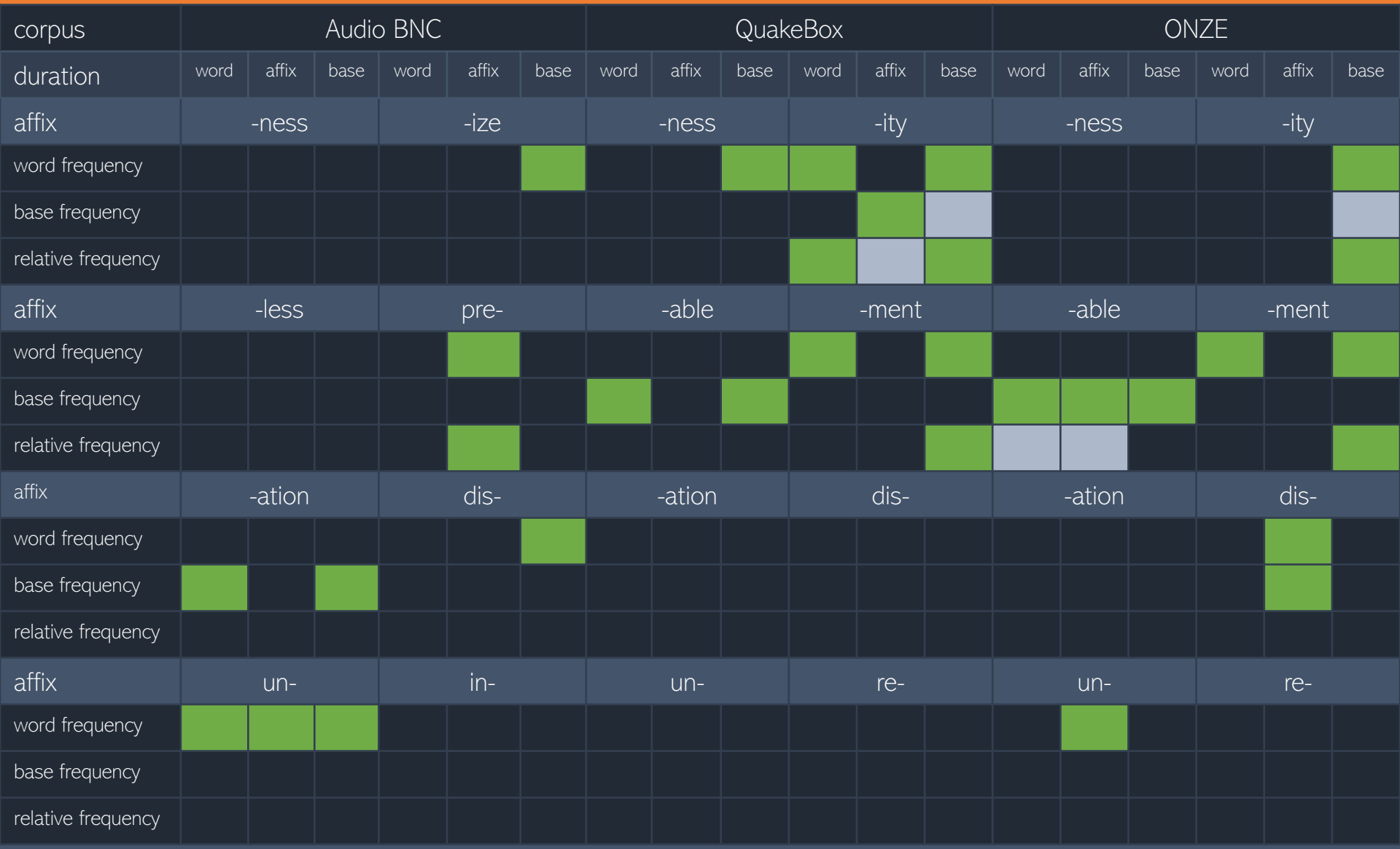
word frequency
base frequency
relative frequency
affix
un- in- un- re- un- re-
word frequency
base frequency
relative frequency
Overview of category-internal frequency effects
p < .001 expected direction
p < .001 unexpected direction


corpus
Audio BNC
QuakeBox
ONZE
duration
word affix base word affix base word affix base word affix base word affix base word affix base
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word frequency
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relative frequency
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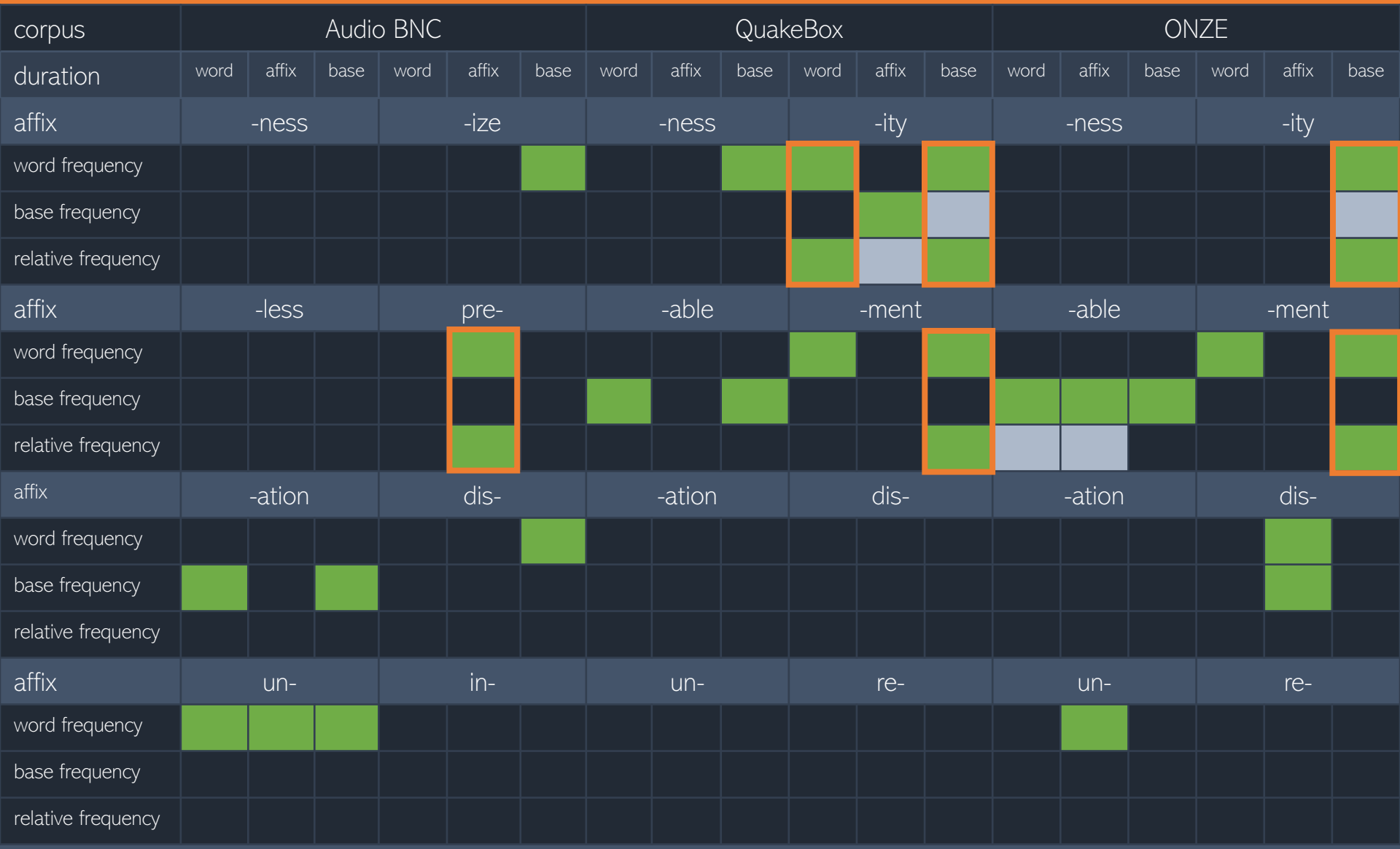
un- in- un- re- un- re-
word frequency
base frequency
relative frequency
Overview of category-internal frequency effects
p < .001 expected direction
p < .001 unexpected direction


corpus
Audio BNC
QuakeBox
ONZE
duration
word affix base word affix base word affix base word affix base word affix base word affix base
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word frequency
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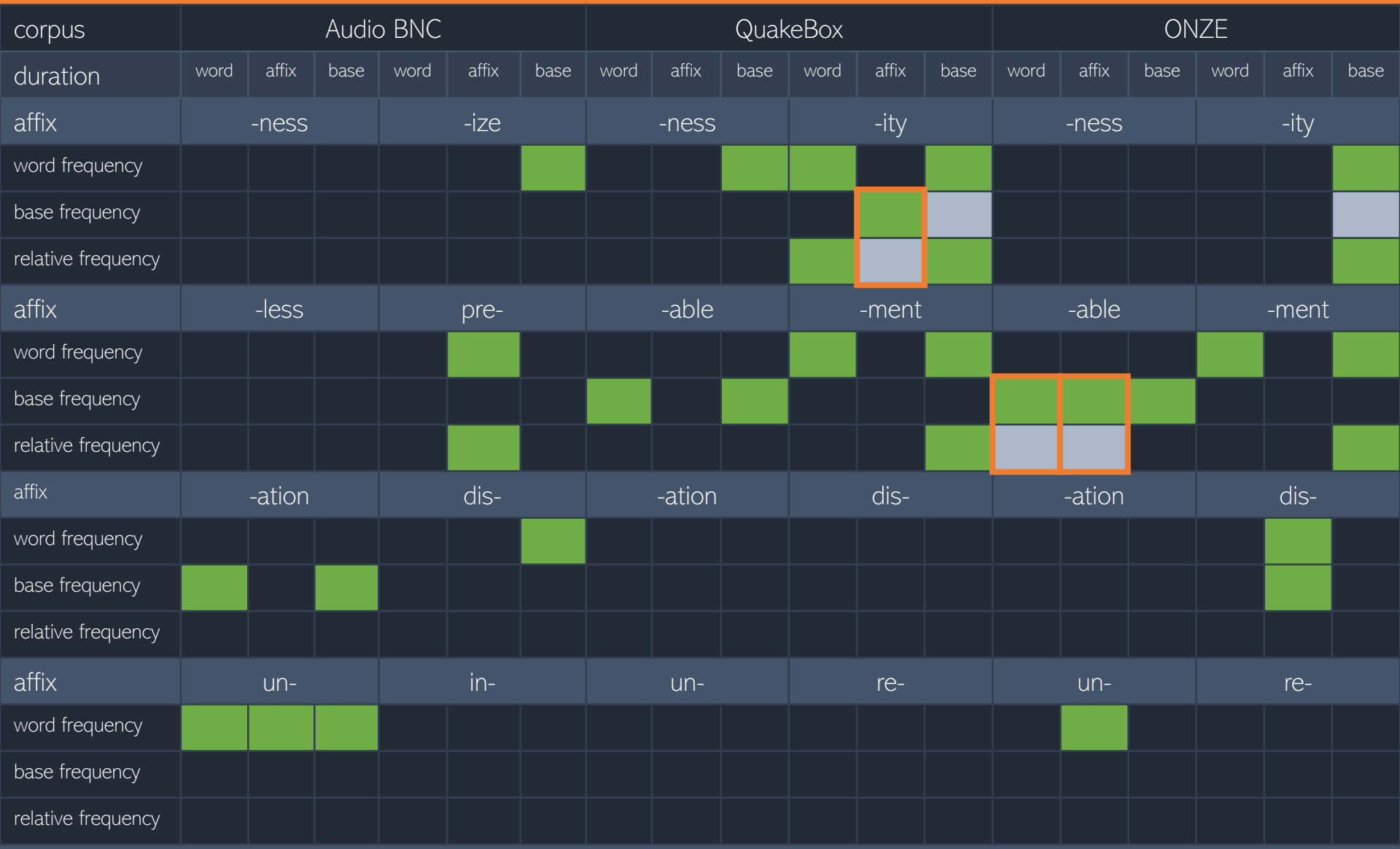
word frequency
base frequency
relative frequency
Overview of category-internal frequency effects
p < .001 expected direction
p < .001 unexpected direction


corpus
Audio BNC
QuakeBox
ONZE
duration
word
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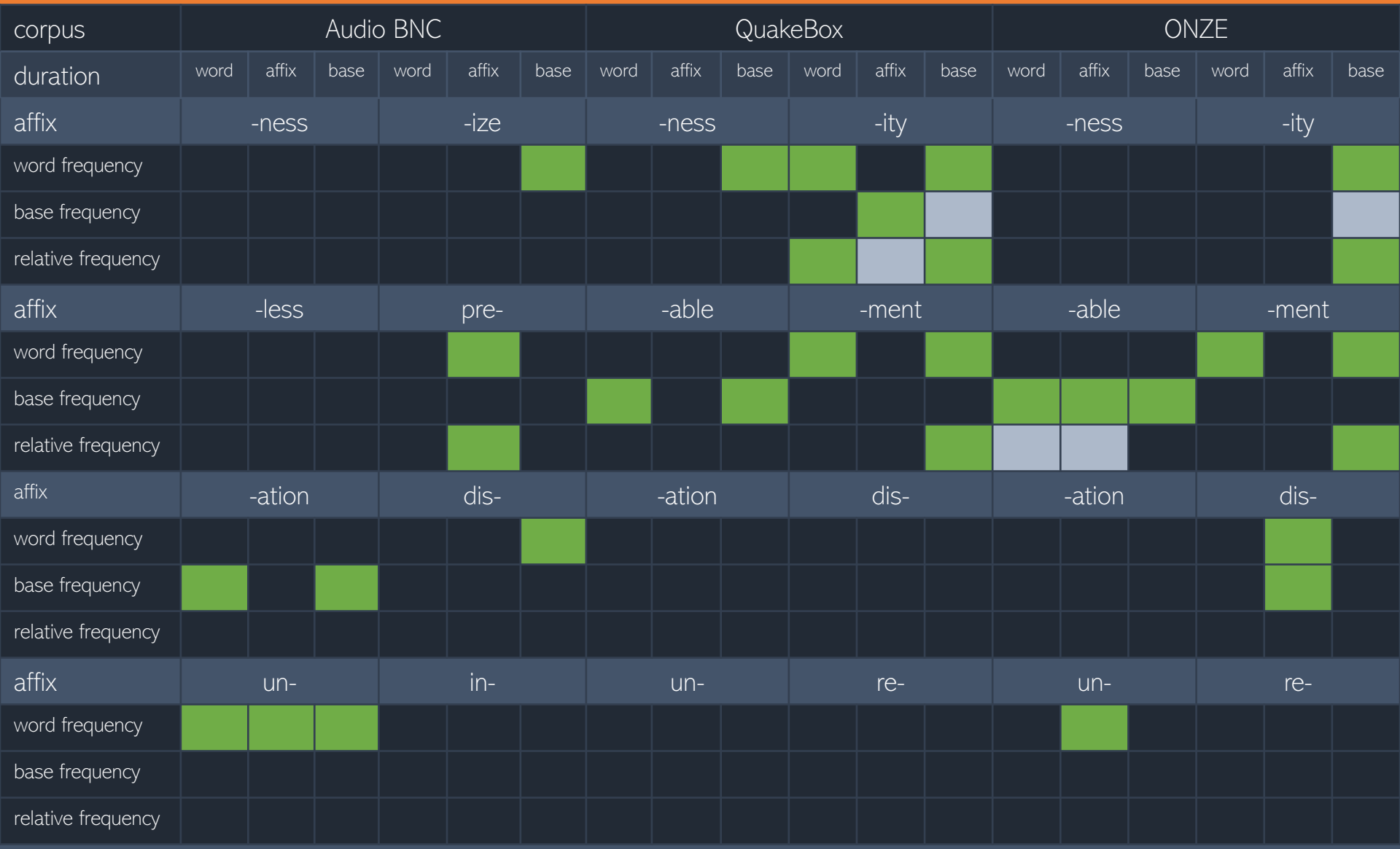
word frequency
base frequency
relative frequency
Overview of category-internal frequency effects
p < .001 expected direction
p < .001 unexpected direction


corpus
Audio BNC
QuakeBox
ONZE
duration
word affix base word affix base word affix base word affix base word affix base word affix base
affix
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word frequency
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word frequency
base frequency
relative frequency
affix
-ation dis- -ation dis- -ation dis-
word frequency
base frequency
relative frequency
affix
un- in- un- re- un- re-
word frequency
base frequency
relative frequency
Overview of category-internal frequency effects
p < .001 expected direction
p < .001 unexpected direction

Informativity

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.

Conditional affix probability C_{aff}

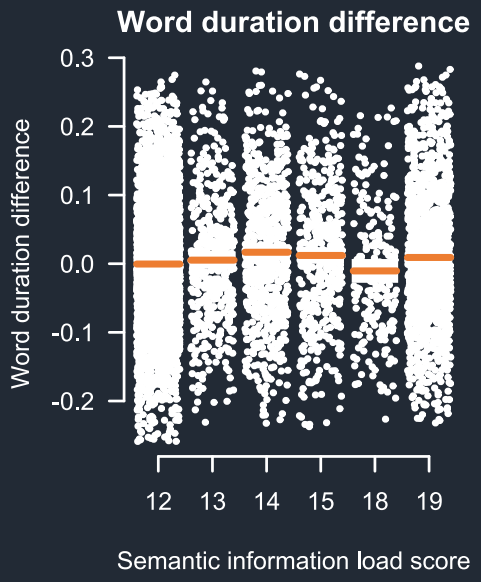
Affix probability given preceding word:

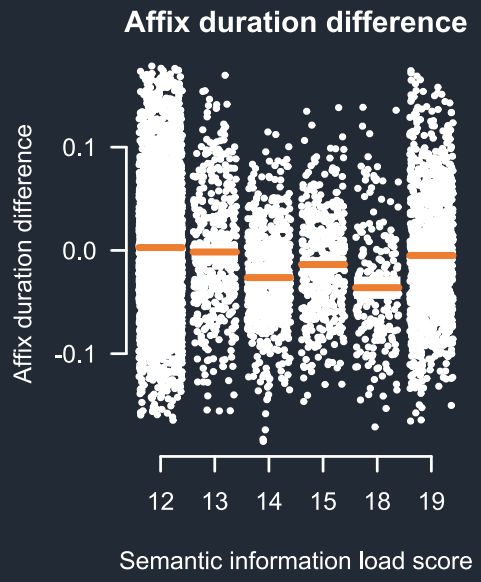
SUFFIX EXAMPLE		PREFIX EXAMPLE		
A	B	A	B	C
random	*ize*	*her*	*pre-*	…

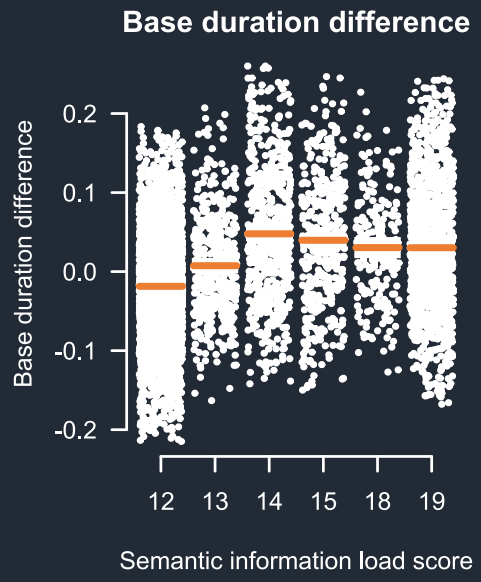
$$C_{aff} = \frac{Freq(AB)}{Freq(A)}$$

H: The higher the conditional affix probability, the shorter the duration.

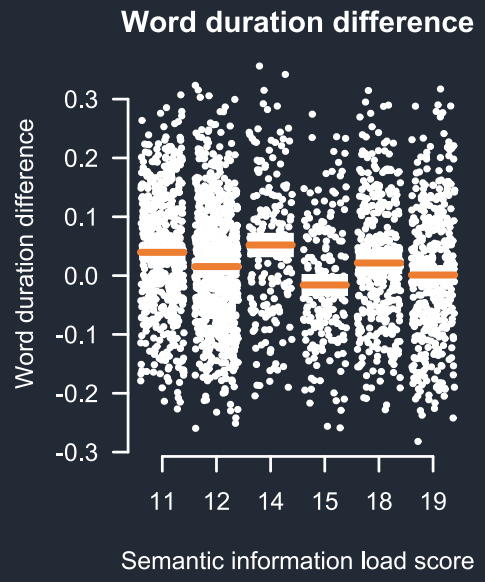
Semantic information load score

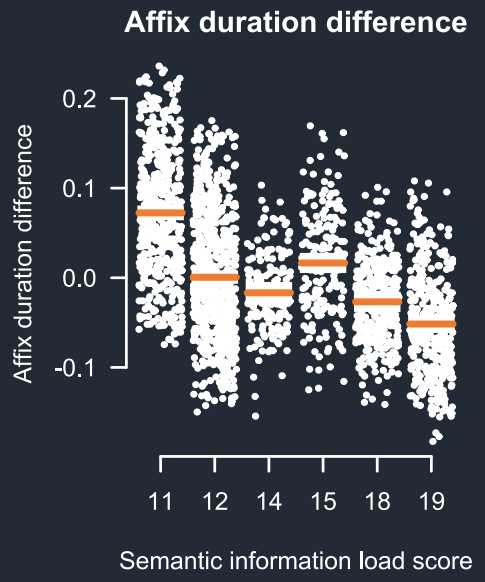


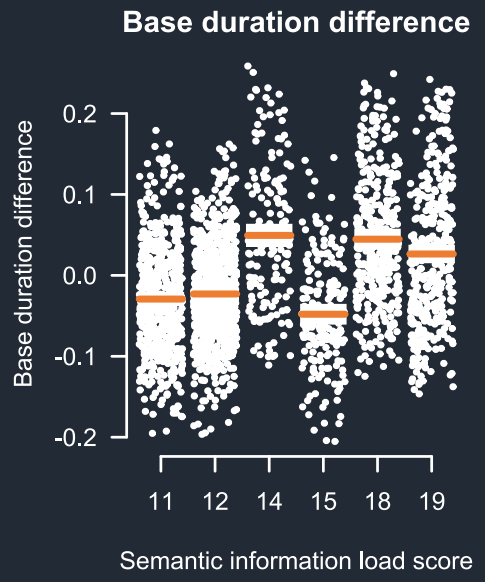




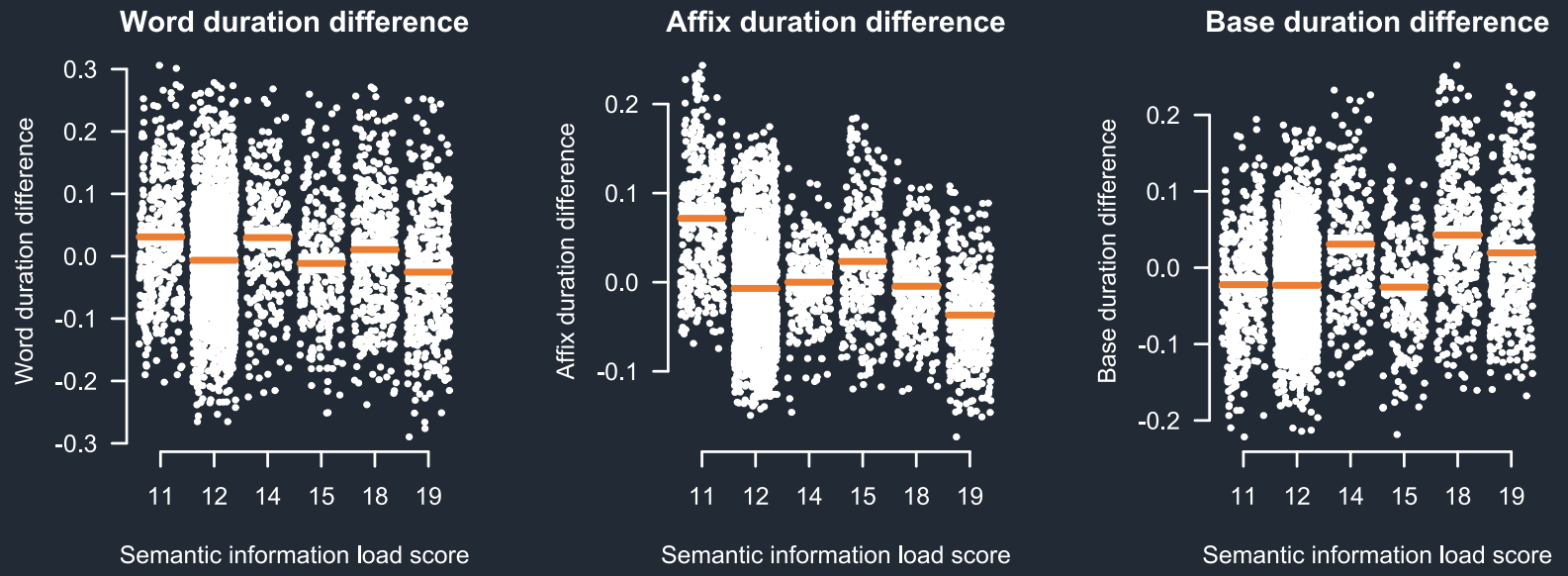
Semantic information load score







Semantic information load score



Conditional affix probability C_{aff}

corpus	Audio BNC						QuakeBox						ONZE					
duration	word	affix	base	word	affix	base	word	affix	base	word	affix	base	word	affix	base	word	affix	base
affix	-ness			-ize			-ness			-ity			-ness			-ity		
C_{aff}																		
affix	-less			pre-			-able			-ment			-able			-ment		
C_{aff}																		
affix	-ation			dis-			-ation			dis-			-ation			dis-		
C_{aff}																		
affix	un-			in-			un-			re-			un-			re-		
C_{aff}																		

$p < .001$ negative effect $p < .001$ positive effect