What affects variation in the phonetics of NNN compounds?

Looking at the impact of mophological structure and more linguistic factors

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Project: EMB – Morphological Embedding and Phonetic Reduction
Associated project to the DFG Research Unit FOR2373

What affects durational variation?

speechrate

higher speechrate leads to shorter duration

number of phonological segments

more phonological segments lead to longer durations

accentuation

accented units have longer durations

(Turk & Sawusch 1996, de Jong 2004, Kunter 2011)

lexical frequency

more frequent units have shorter durations

(Pluymaekers et al. 2005, Gahl 2008, Bell et al. 2009)

What affects durational variation?

prosodic boundary strength

boundaries at higher prosodic domains, i.e. intonation phrase (IP) or prosodic utterance (U), affect durations of units closest to the boundary

(Turk & Shattuck-Hufnagel 2000, Turk & Shattuck-Hufnagel 2007, Bergmann 2017)

morphological boundary strength

units at weaker boundaries are more prone to phonetic reduction than units at stronger boundaries

(Lehiste 1972, Sproat & Fujimura 1993, Kunter & Plag 2016)

→ Embedded Reduction Hypothesis

Embedded Reduction Hypothesis (ERH)

In a complex word [X Y] Z,

the inner boundary between X and Y is more prone to phonetic reduction

than the outer boundary between Y and Z.

Morphological structure of NNN

LEFT-BRANCHING

[health$_{N1}$ care$_{N2}$] law$_{N3}$

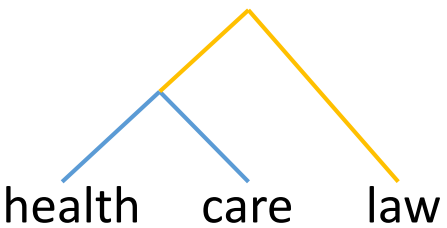
RIGHT-BRANCHING

corner$_{N1}$ [drug$_{N2}$ store$_{N3}$]

Morphological structure of NNN

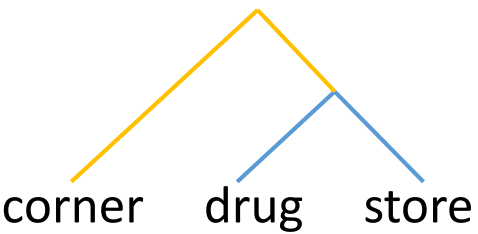
LEFT-BRANCHING

[health$_{N1}$ care$_{N2}$] law$_{N3}$



RIGHT-BRANCHING

corner$_{N1}$ [drug$_{N2}$ store$_{N3}$]



Morphological structure of NNN

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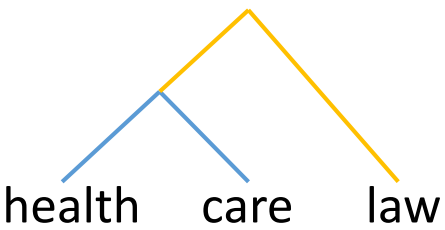
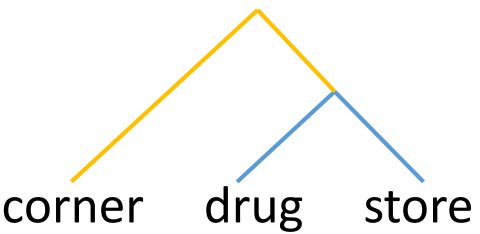


embedded constituents

free constituent

RIGHT-BRANCHING

corner$_{N1}$ [drug$_{N2}$ store$_{N3}$]



free constituent

embedded constituents

Predictions for NNN constituent durations

speechrate

higher speechrate leads to shorter constituent durations

number of phonological segments

more phonological segments lead to longer constituent durations

accentuation

accented constituents have longer durations

lexical frequency

more frequent constituents and pairs of constituents have shorter durations

Predictions for NNN constituent durations

prosodic boundary strength

pWord

left-branching: $(((\text{health})_{\omega}\ (\text{care})_{\omega})_{\omega}\ (\text{law})_{\omega})_{\omega}$

right-branching: $((\text{corner})_{\omega}\ ((\text{drug})_{\omega}\ (\text{store})_{\omega})_{\omega})_{\omega}$

→ pWord reflects internal structure, but does not affect constituent durations

Intonational Phrase, Prosodic Utterance

word-final lengthening, phrase-final lengthening

→ N3 constituents have lengthened durations

Predictions for NNN constituent durations

prosodic boundary strength

following pauses indicate strong prosodic boundaries

	PAUSE?	LENGTHENING?
NP-MEDIAL	no	no
NP-MEDIAL	yes	yes
PHRASE-FINAL	yes	yes

Predictions for NNN constituent durations

morphological boundary strength

→ ERH tested by Kunter & Plag (2016) for NNN compounds

ERH:

In a complex word [health care] law,

the inner boundary between health and care is more prone to phonetic reduction

than the outer boundary between care and law.

Predictions for NNN constituent durations

morphological boundary strength

→ ERH tested by Kunter & Plag (2016) for NNN compounds

ERH:

In a complex word corner [drug store],

the inner boundary between drug and store is more prone to phonetic reduction

than the outer boundary between corner and drug.

Predictions for NNN constituent durations

morphological boundary strength

LEFT-BRANCHING	RIGHT-BRANCHING
[health$_{N1}$ care$_{N2}$] law$_{N3}$	corner$_{N1}$ [drug$_{N2}$ store$_{N3}$]

The embedded constituents are relatively short.

The free constituent is relatively long.

This effect is independent of branching direction.

This project

Kunter & Plag (2016):

effect of branching direction and bigram frequency on constituent duration cannot be disentangled

EMB investigates factors which affect phonetic variation in NNN compounds

This project

experimental data:

factors of interest tested, controlled influential factors, unnatural speech

corpus data:

natural speech, uncontrolled factors

This project

experimental data:

factors of interest tested, controlled influential factors, unnatural speech

→ experiment I, NNN durations, /t,d/ deletion at internal boundaries

corpus data:

natural speech, uncontrolled factors

→ corpus study I, NNN durations

Experiment I

Data

[SHIFT MANAGERS] office

factory [SHIFT MANAGERS]

[factory SHIFT] MANAGERS

SHIFT [MANAGERS office]

reading task:

„The managers of the shift have their own office.

The shift managers office is usually not entered by the employees.”

Data

25 word pairs in 4 conditions = 100 compounds per speaker

41 speakers of North American English

3819 NNN compounds

(excluded items: misreadings, pauses, sound quality…)

Data collection made possible by the Phonetics Lab of the University of Alberta, Edmonton. Thanks to Ben Tucker for this.

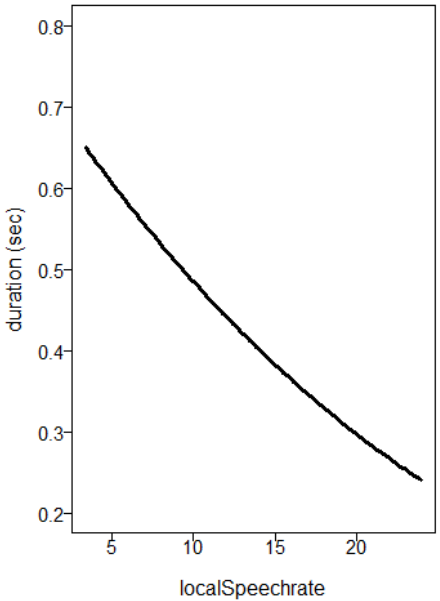
Model

statistical analysis: lmer modelling

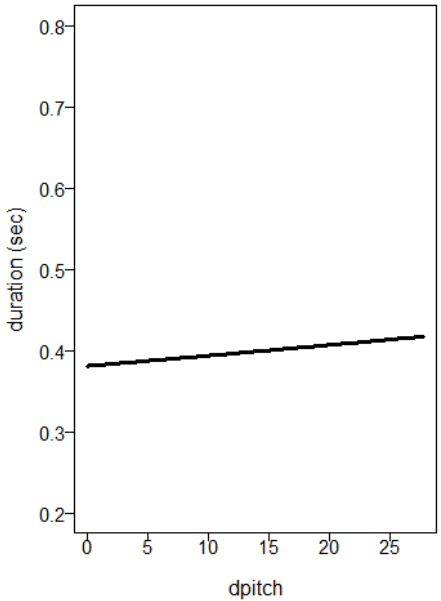
dependent variable:	constituent duration
central interactions:	constituent number * branching
predictors:	frequencies of each constituent bigram frequencies N1N2, N2N3 pitch range no. of phonological segments local speechrate
random effect:	speaker, constituent

Results: main effects

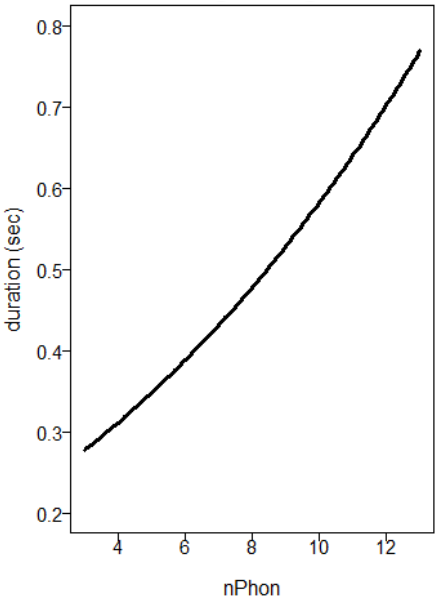
local speechrate



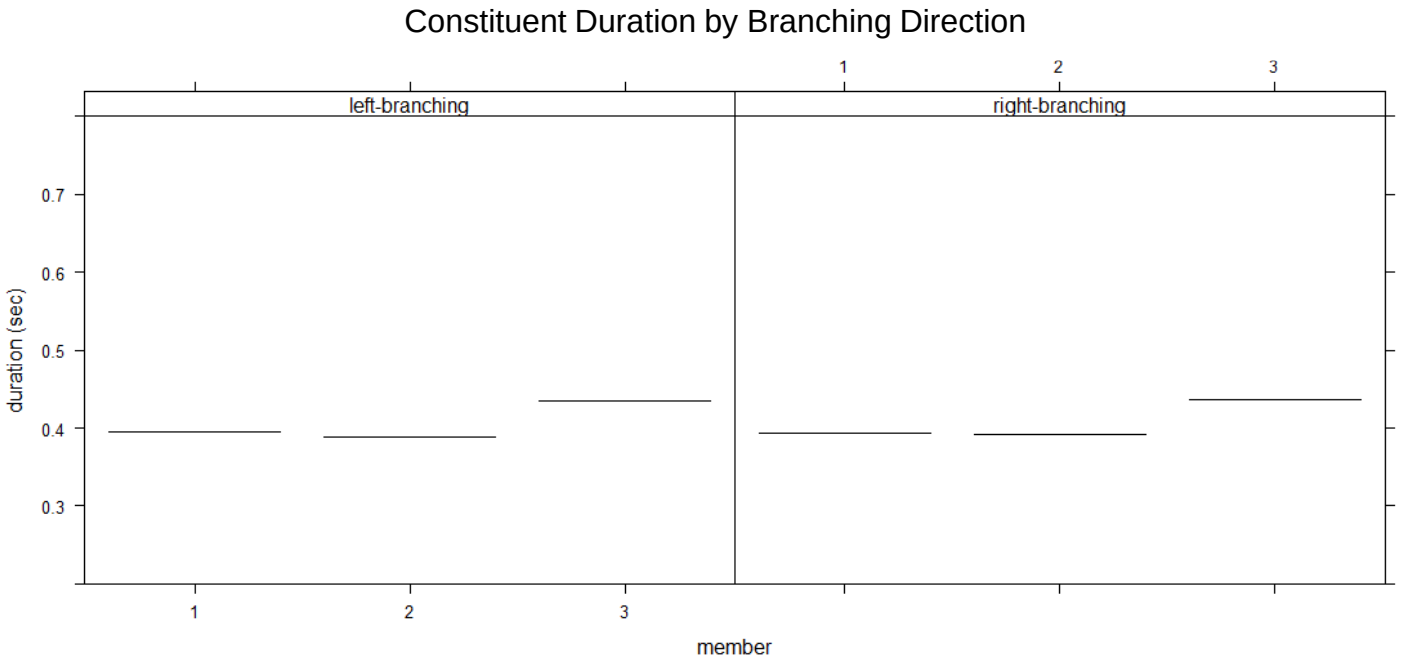
pitch range



number of phonological segments



Results: branching and constituent number



Conclusion

main effects: expected results

N3 is always longest

left-branching: N2 < N1 < N3

right-branching: N2 ~ N1 < N3

→ no effect of embeddedness

→ word-final N3 lengthening in both branching directions

→ERH not confirmed

Corpus study I

Data

[health$_{N1}$ care$_{N2}$] law$_{N3}$ corner$_{N1}$ [drug$_{N2}$ store$_{N3}$]

- data from BURSC (data set by Kösling & Plag 2009)
- 425 English triconstituent NNN compounds

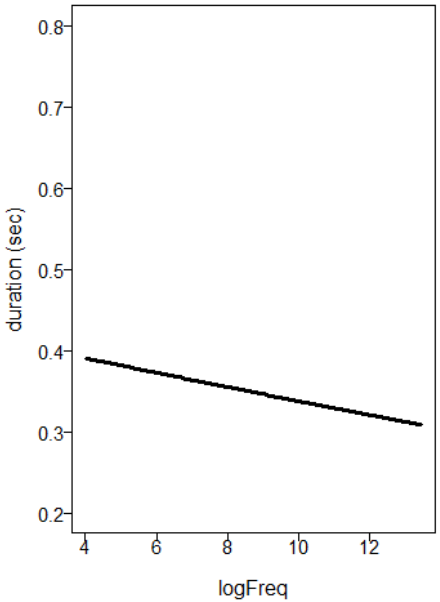
Model

statistical analysis: lmer modelling

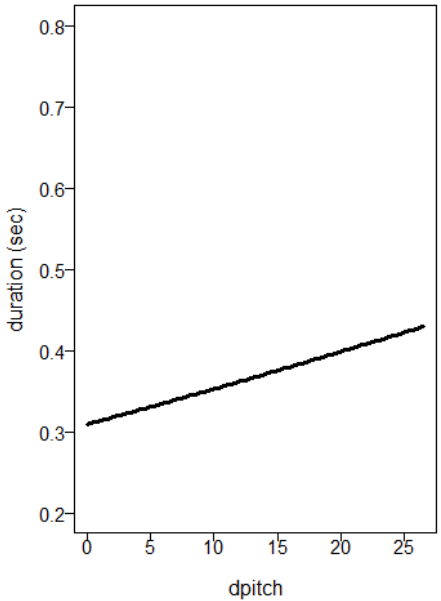
dependent variable:	constituent duration
central interactions:	constituent number * branching * N1N2 freq constituent number * branching * N2N3 freq constituent number * branching * boundary
predictors:	unigram frequencies of each constituent trigram frequency N1N2N3 pitch range no. of phonological segments
random effect:	speaker, constituent

Results: main effects

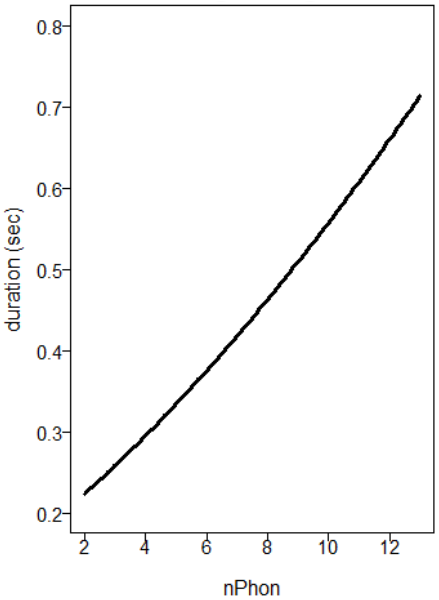
constituent frequency



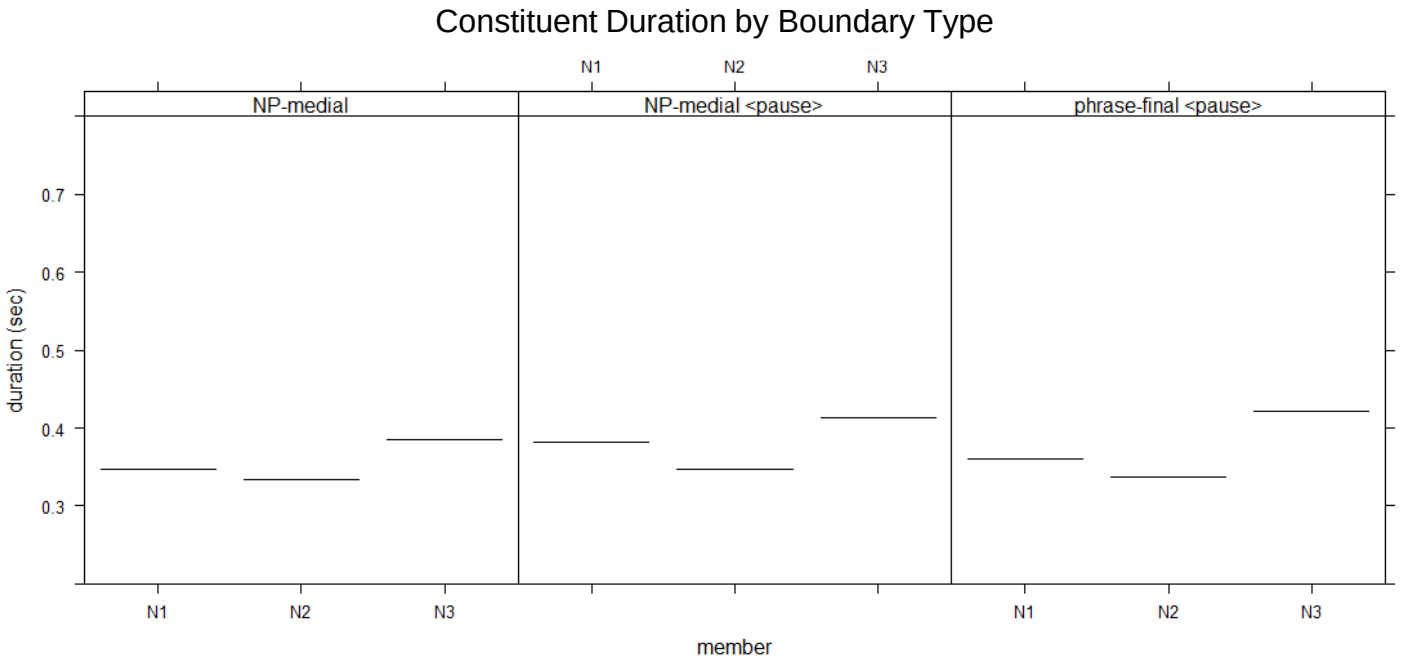
pitch range



number of phonological segments

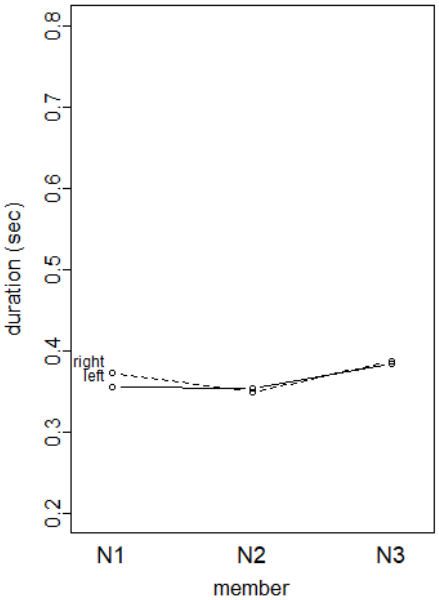


Results: following pause

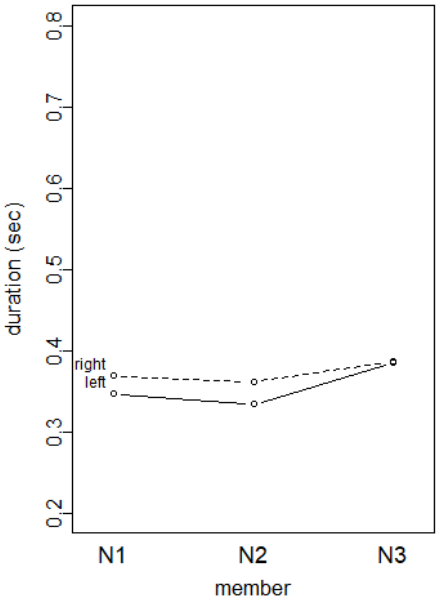


Results:
constituent number * branching * N1N2 frequencies

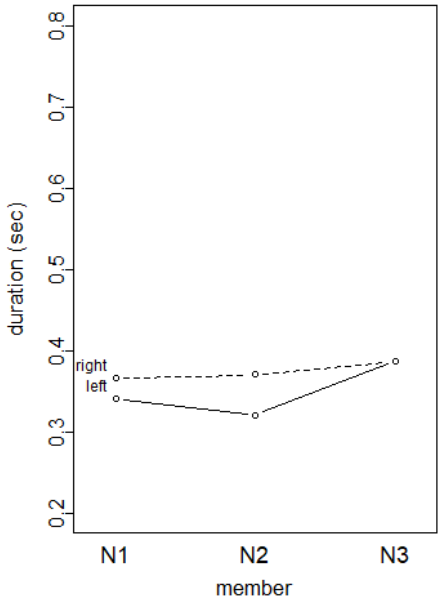
low N1N2 frequency



medial N1N2 frequency



high N1N2 frequency



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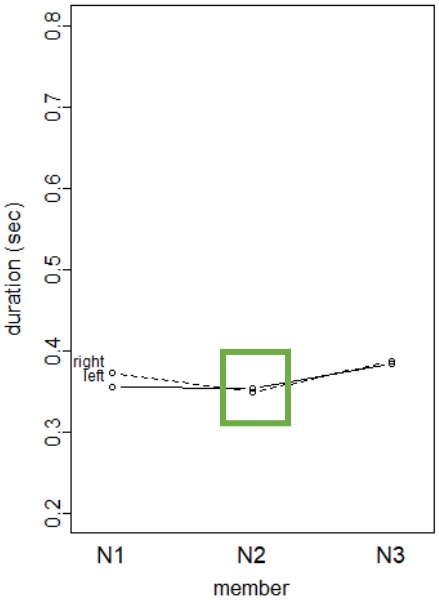
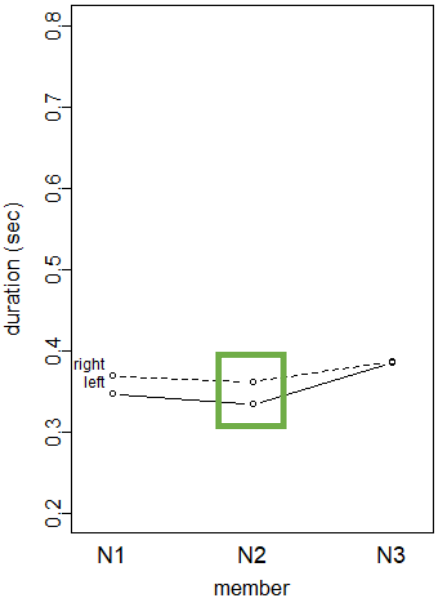
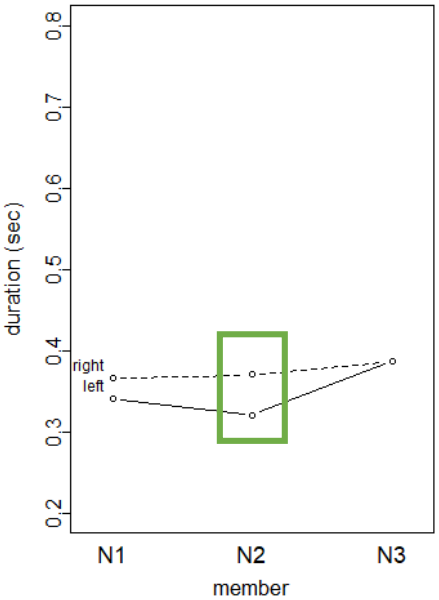


medial N1N2 frequency

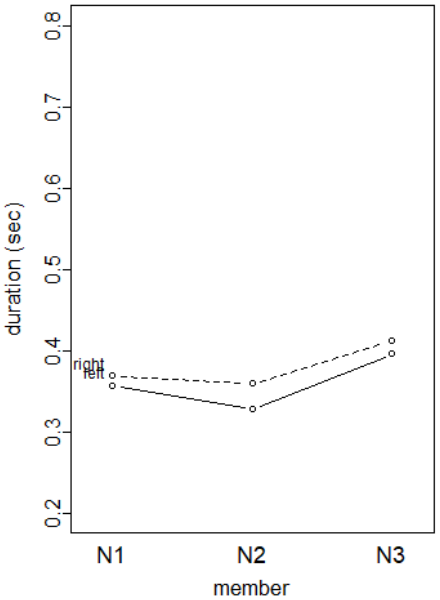


high N1N2 frequency

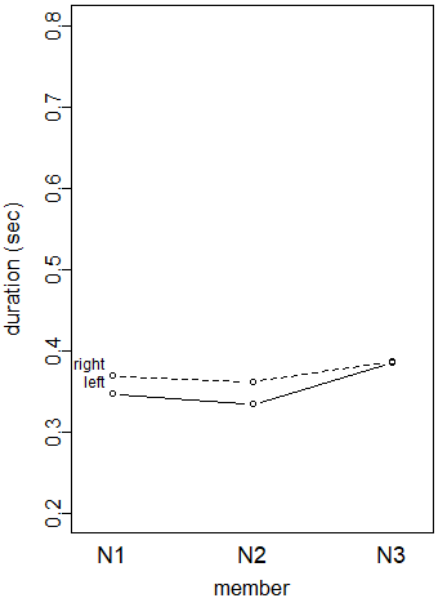


Results:
constituent number * branching * N2N3 frequencies

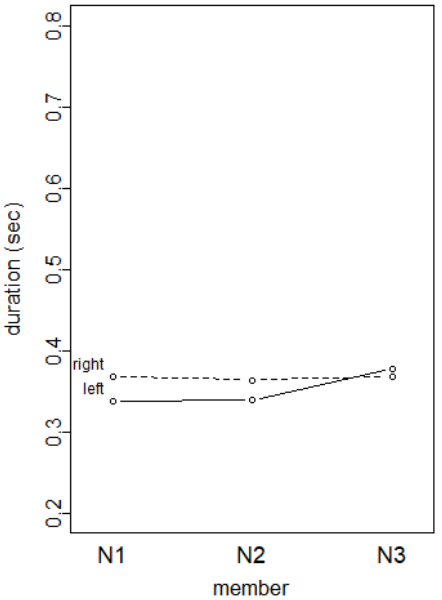
low N2N3 frequency



medial N2N3 frequency



high N2N3 frequency



Results:
constituent number * branching * N2N3 frequencies

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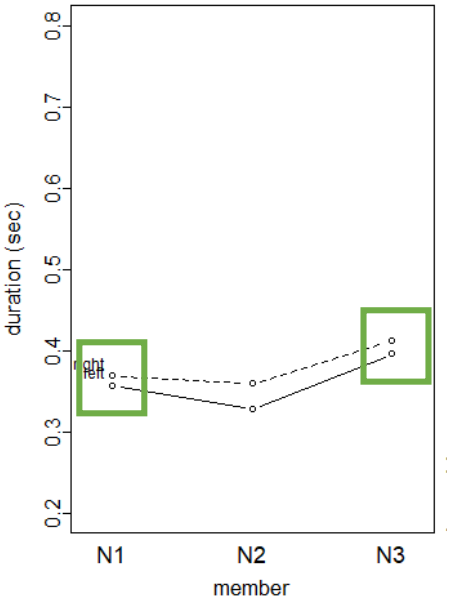
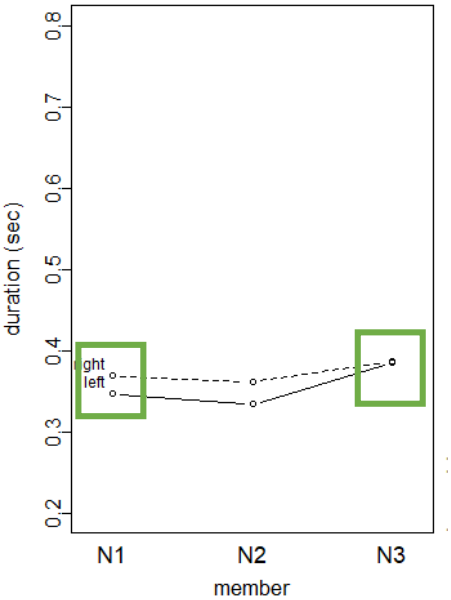
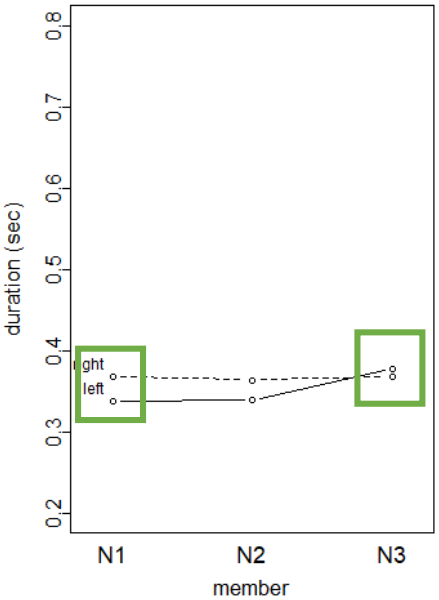


medial N2N3 frequency



high N2N3 frequency



Conclusion

main effects: expected results

Conclusion

prosodic boundaries affect N3 durations

→ N2 < N1 < N3

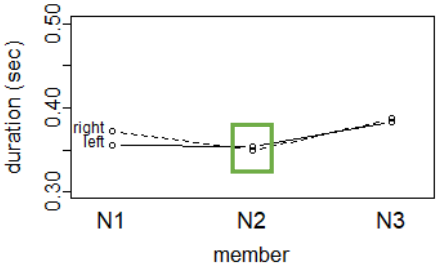
→ final lengthening takes place on N3, but not on N1 or N2

→ type of boundary does not make the difference,
the presence of a pause does

→ no difference between branching directions

Conclusion

low N1N2 frequency



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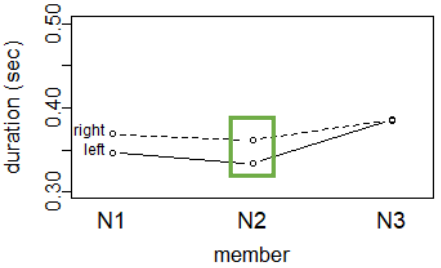

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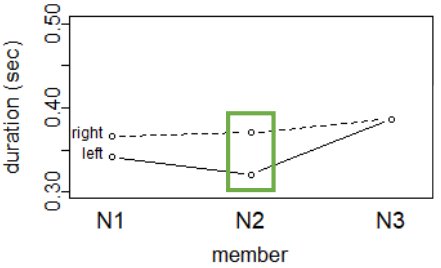


high N1N2 frequencies lead to shorter N2 in left-branching NNN
→ expected: lexical frequency

high N1N2 frequencies lead to longer N2 in right-branching NNN
→ disambiguation effect:

high N1N2 matches the embedded compound in left-branching NNN, long N2 in right-branching NNN emphasizes the right-branching internal structure

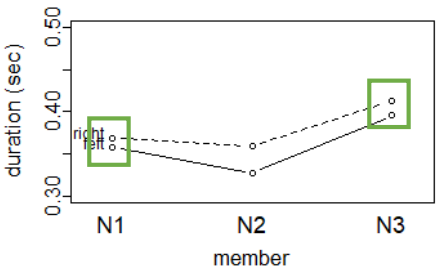
Conclusion

high N2N3 frequencies lead to shorter N3 in right-branching NNN
→ expected: lexical frequency

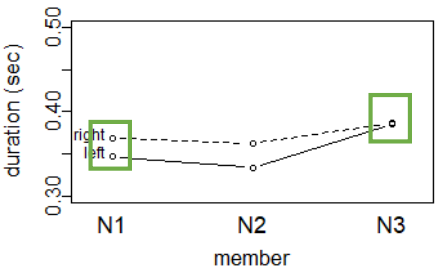
high N2N3 frequencies lead to shorter N1 in left-branching NNN
→ disambiguation effect:

high N2N3 matches the embedded compound in right-branching NNN, short N1 in left-branching NNN emphasizes the left-branching internal structure

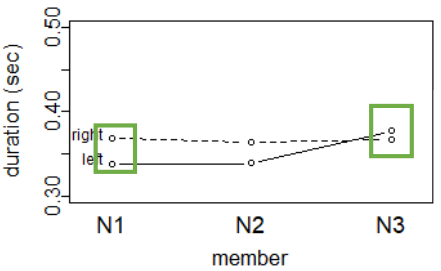
low N2N3 frequency



medial N2N3 frequency

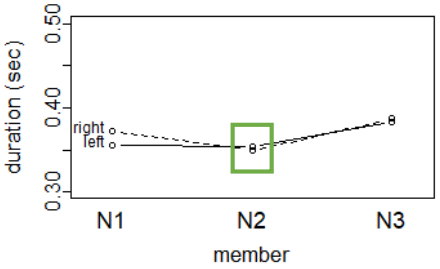


high N2N3 frequency

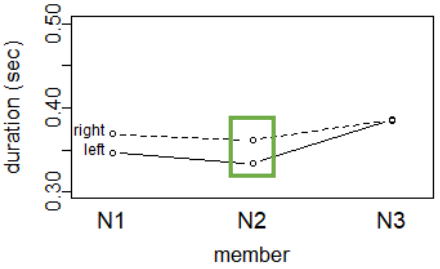


Conclusion

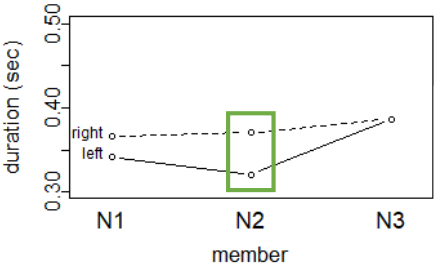
low N1N2 frequency



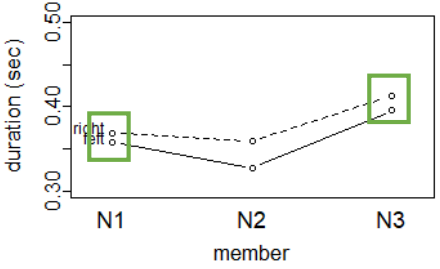
medial N1N2 frequency



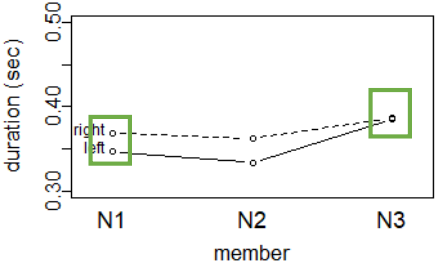
high N1N2 frequency



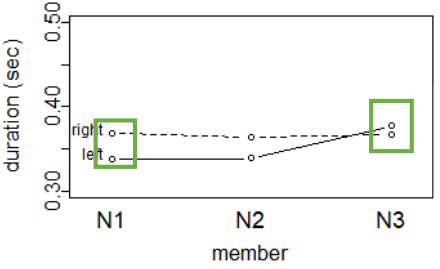
low N2N3 frequency



medial N2N3 frequency



high N2N3 frequency



Summary

	Experiment I		Corpus study I	
	LEFT-BRANCHING	RIGHT-BRANCHING	LEFT-BRANCHING	RIGHT-BRANCHING
Constituent Duration	N2 < N1 < N3	N2 ~ N1 < N3	N2 < N1 < N3	

Summary

	EXPERIMENT I		**CORPUS STUDY I**	
	LEFT-BRANCHING	RIGHT-BRANCHING	LEFT-BRANCHING	RIGHT-BRANCHING
CONSTITUENT DURATION	N2 < N1 < N3	N2 ~ N1 < N3	N2 < N1 < N3	
PROSODIC BOUNDARY	**constant NP-final position:** word-final N3 lengthening		**varied position:** word-final N3 lengthening < phrase-final N3 lengthening	

Summary

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PROSODIC BOUNDARY	**constant NP-final position:** word-final N3 lengthening		**varied position:** word-final N3 lengthening < phrase-final N3 lengthening	
BIGRAM FREQUENCIES	controlled bigram frequencies, no effect		effect of N1N2 on N2	effect of N2N3 on N3

Summary

	Experiment I		Corpus study I	
	LEFT-BRANCHING	RIGHT-BRANCHING	LEFT-BRANCHING	RIGHT-BRANCHING
Constituent Duration	N2 < N1 < N3	N2 ~ N1 < N3	N2 < N1 < N3	
Prosodic Boundary	**constant NP-final position:** word-final N3 lengthening		**varied position:** word-final N3 lengthening < phrase-final N3 lengthening	
Bigram Frequencies	controlled bigram frequencies, no effect		effect of N1N2 on N2	effect of N2N3 on N3
Disambiguation	---		effect of N2N3 on N1 (shortening)	effect of N1N2 on N2 (lengthening)

What‘s next?

EMB

Experiment II

→ NNN with varied bigram frequencies,

NNN with varied position at different prosodic boundaries,

…

Corpus Study II

→ plosive deletion in NNN compounds

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Summary

	EXPERIMENT I		CORPUS STUDY I	
	LEFT-BRANCHING	RIGHT-BRANCHING	LEFT-BRANCHING	RIGHT-BRANCHING
CONSTITUENT DURATION	N2 < N1 < N3	N2 ~ N1 < N3	N2 < N1 < N3	
PROSODIC BOUNDARY	**constant NP-final position:** word-final N3 lengthening		**varied position:** word-final N3 lengthening < phrase-final N3 lengthening	
BIGRAM FREQUENCIES	controlled bigram frequencies, no effect		effect of N1N2 on N2	effect of N2N3 on N3
DISAMBIGUATION	---		effect of N2N3 on N1 (shortening)	effect of N1N2 on N2 (lengthening)

Experiment, ref: member = N3, branching = left

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	8.161e-01	8.138e-03	1.010e+02	100.277	<2e-16 ***
member1	-2.042e-02	1.117e-03	1.125e+04	-18.273	<2e-16 ***
member2	-2.414e-02	9.051e-04	1.137e+04	-26.672	<2e-16 ***
branchingright-branching	3.561e-04	7.771e-04	1.129e+04	0.458	0.647
localSpeechrate	-9.999e-03	1.420e-04	9.134e+03	-70.417	<2e-16 ***
nPhon	2.193e-02	1.110e-03	8.700e+01	19.755	<2e-16 ***
dpitch	6.762e-04	5.304e-05	1.134e+04	12.748	<2e-16 ***
member1:branchingright-branching	-1.204e-03	1.098e-03	1.129e+04	-1.096	0.273
member2:branchingright-branching	1.443e-03	1.098e-03	1.129e+04	1.313	0.189

(interaction significant with member=N1)

Corpus Study, ref: member = N3, branching = left, boundary = NP-medial

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	4.526e-01	1.991e-02	5.657e+02	22.729	< 2e-16 ***
logN1N2Freq	8.337e-04	1.169e-03	1.199e+03	0.713	0.475989
branchingright	2.636e-02	1.590e-02	1.192e+03	1.658	0.097529 .
memberN1	-1.390e-02	1.210e-02	1.245e+03	-1.149	0.250910
memberN2	-2.887e-02	1.223e-02	1.245e+03	-2.361	0.018365 *
logN2N3Freq	-3.076e-03	1.377e-03	1.229e+03	-2.233	0.025719 *
boundaryNP-medial <pause>	2.016e-02	1.078e-02	1.206e+03	1.870	0.061714 .
boundaryphrase-final <pause>	3.434e-02	5.800e-03	1.236e+03	5.921	4.13e-09 ***
logFreq	-7.931e-03	1.529e-03	6.099e+02	-5.188	2.89e-07 ***
nPhon	3.688e-02	1.039e-03	6.342e+02	35.495	< 2e-16 ***
dpitch	4.109e-03	4.818e-04	1.112e+03	8.529	< 2e-16 ***
logN1N2Freq:branchingright	-7.981e-04	2.585e-03	1.196e+03	-0.309	0.757595
logN1N2Freq:memberN1	-3.187e-03	1.745e-03	1.236e+03	-1.826	0.068065 .
logN1N2Freq:memberN2	-6.797e-03	1.765e-03	1.236e+03	-3.850	0.000124 ***
branchingright:memberN1	-2.829e-02	2.285e-02	1.147e+03	-1.238	0.215805
branchingright:memberN2	-4.405e-02	2.294e-02	1.224e+03	-1.920	0.055070 .
branchingright:logN2N3Freq	-4.780e-03	2.501e-03	1.219e+03	-1.911	0.056284 .
memberN1:logN2N3Freq	-3.312e-04	1.918e-03	1.198e+03	-0.173	0.862925
memberN2:logN2N3Freq	5.200e-03	1.916e-03	1.198e+03	2.714	0.006738 **
memberN1:boundaryNP-medial <pause>	-5.869e-03	1.500e-02	1.095e+03	-0.391	0.695624
memberN2:boundaryNP-medial <pause>	-1.286e-02	1.475e-02	1.079e+03	-0.872	0.383394
memberN1:boundaryphrase-final <pause>	-2.423e-02	8.006e-03	1.161e+03	-3.026	0.002532 **
memberN2:boundaryphrase-final <pause>	-2.796e-02	7.946e-03	1.182e+03	-3.518	0.000451 ***
logN1N2Freq:branchingright:memberN1	1.920e-03	3.747e-03	1.161e+03	0.512	0.608412
logN1N2Freq:branchingright:memberN2	1.103e-02	3.699e-03	1.180e+03	2.981	0.002929 **
branchingright:memberN1:logN2N3Freq	7.639e-03	3.450e-03	1.165e+03	2.214	0.027025 *
branchingright:memberN2:logN2N3Freq	3.325e-03	3.508e-03	1.199e+03	0.948	0.343435