HOW COULD THE GERMANIC WEAK INFLECTION OVERTHROW A REGULAR AND MORE FREQUENT COMPETITOR? A COMPUTER SIMULATION OF LANGUAGE USAGE

Dirk Pijpops[1], Katrien Beuls[2] & Freek Van de Velde[1]

[1]QLVL, University of Leuven
[2]AI-Lab, Vrije Universiteit Brussel

Strong inflection

- Vowel: *drive* ~ *drove*
  kijk ~ *keek*
- Indo-European aspect
- On the decline

Weak inflection

- Dental suffix: *kick* ~ *kick-ed*
  praat ~ *praat-te*
- Germanic innovation
- On the rise

RESEARCH QUESTION

How could the weak inflection have grown to overthrow the strong inflection?

RESEARCH QUESTION

How could the weak inflection have grown to overthrow the strong inflection, given that

i. The weak inflection had to start from a position vastly inferior in both type and token frequency

(↔ Hare and Elman 1995; Yang 2002)

ii. The strong inflection was still clearly regular?

(↔ Colaiori et al. 2015; Pijpops and Beuls 2015)

PROPOSALS

1. General applicability of the dental suffix

2. Restrictions on the strong system

3. Desintegration of the strong system

(Ball 1968: 164; Bailey 1997: 17)

PROPOSALS

1. **General applicability of the dental suffix**
2. Restrictions on the strong system
3. Desintegration of the strong system

(Ball 1968: 164; Bailey 1997: 17)

PROPOSALS

1. **General applicability of the dental suffix**

2. Restrictions on the strong system

3. Desintegration of the strong system

   ⇨ Desintegration of the strong system may be result, rather than cause

WHY AN AGENT-BASED MODEL (AND NOT ONE OF ITERATED LEARNING?)

- General applicability is usage property
- Usage-based view on language change (Croft 2000, Bybee 2010)
- Language as a Complex Adaptive System (Gilbert 2008, Beckner et al. 2008)

- Models of iterated learning focus on the acquisition of the Germanic past tense, as a case study of language acquisition in general:

Rumelhart and McClelland (1986), Pinker and Prince (1988), Macwhinney and Leinbach (1991), Plunkett and Marchman (1991, 1993), Ling and Marinov (1993), Hare & Elman (1995), Marcus et al. (1995), Plunkett and Juola (1999), Taatgen and Anderson (2002), Yang (2002), van Noord (2015)

What do we put in?

- Single, generally applicable weak suffix vs. multiple strong classes
- Weak suffix starts inferior in type and token frequency to any individual ablaut class
- Verbs show a realistic (Zipfian) frequency distribution
- Agents are gradually replaced

What do we NOT put in?

- Any restrictions on the strong system: each verb can be conjugated strongly
- Any irregular verbs, or ways to become irregular
- Any other possible advantage to the weak inflection
  - ↳ Agents will never forget strong verb forms (↔ Taatgen and Anderson 2002: 124)
  - ↳ No advantage of linear segmentability: Hearers recognize equally easy

    sing-ed 'sing + PAST'

    s-ou-ng 'sing + PAST'
  - ↳ No social structure or social preference

⇨ Explicitly unrealistic

Keep It Simple Stupid

(Landsbergen 2009: 18-19)

- Only finite past tenses
- No influence of phonetic resemblance

Evaluation criteria

1. Rise of the Weak Inflection (Carroll et al. 2012; Cuskley et al. 2014)
2. Gradual Rise (Cuskley et al. 2014)
3. Conserving Effect (Bybee 2006: 715; Lieberman et al. 2007)
4. Class Resilience (Mailhammer 2007; Carroll et al. 2012: 163-164)

⇨ Emergence should not be dependent on specific parameter settings

⇨ Define AND delimit

IMPLEMENTATIONAL LEVEL

Strong vowel alternations: extracted from Corpus of Spoken Dutch

I	ij → ee	krijg → kreeg
II-a	ie → oo	vlieg → vloog
II-b	ui → oo	kruip → kroop
III-a	i → o	vind → vond
III-b	e → o	trek → trok
III-c	e → ie	sterf → stierf
IV/V-a	ee → a	geef → gaf
V-b	i → a	zit → zat
VI	aa → oe	draag → droeg
VII-a	aa → ie	laat → liet
VII-b	a → i	hang → hing

Verbs: extracted from Corpus of Spoken Dutch

(all can be conjugated strongly, no irregulars, realistic frequency distribution)

- vinden 1518
- zitten 1157
- krijgen 359
- liggen 208
- …
- stinken 11
- dragen 11
- eten 10
- …
- bidden 1

World

Events	Chance of occurrence
vinden	34%
zitten	26%
…	…
stinken	0.2%
dragen	0.2%
…	…
bidden	0.02%

dragen →

Speaker

Lexicon		
vinden	vond	526
zitten	zat	201
…		
dragen	droeg	9
	draagde	1

‘droeg’ 90%
‘draagde’ 10%
→

World

Events	Chance of occurrence
vinden	34%
zitten	26%
…	…
stinken	0.2%
dragen	0.2%
…	…
bidden	0.02%

dragen →

Speaker

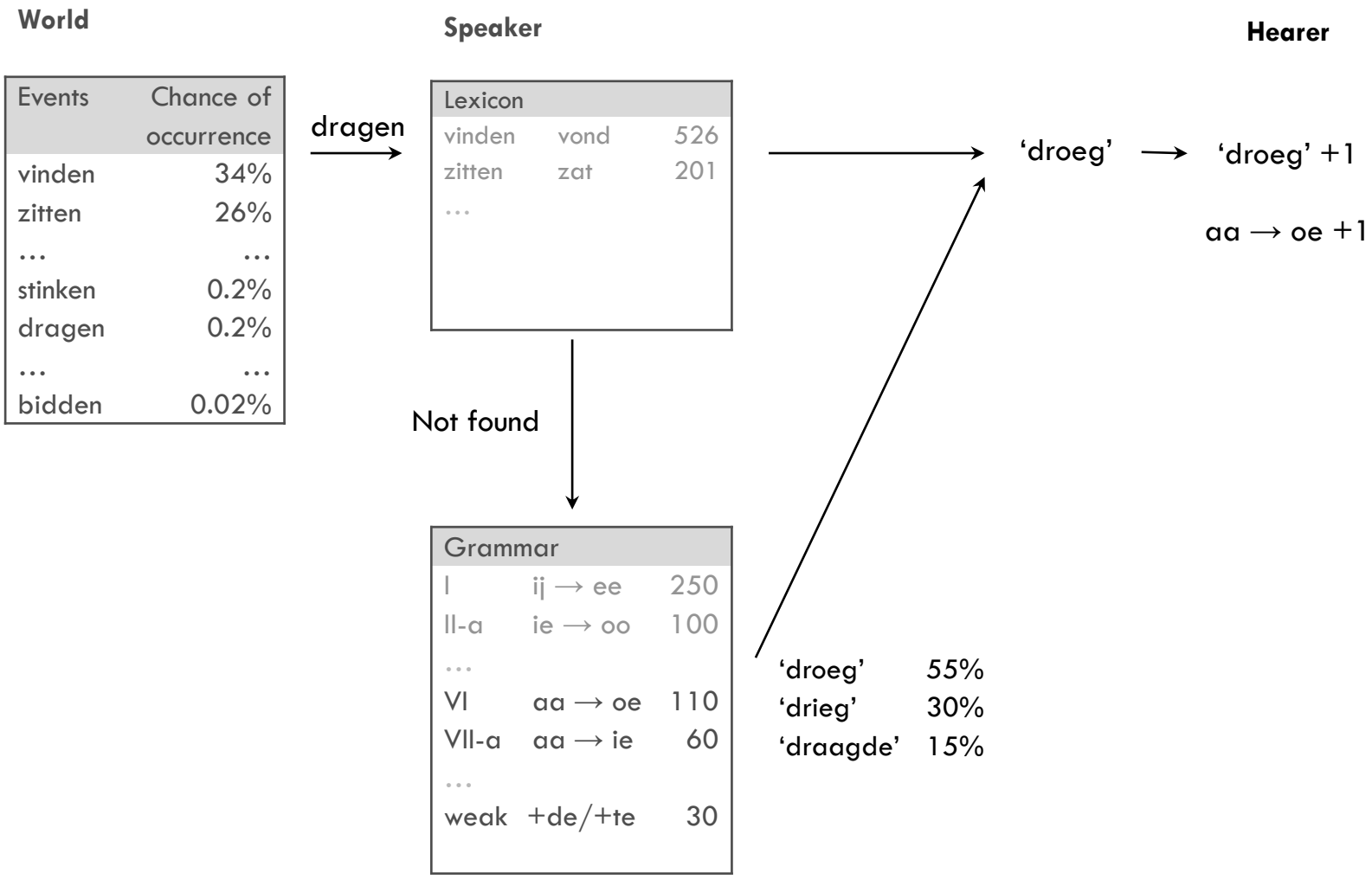
Lexicon		
vinden	vond	526
zitten	zat	201
…		
dragen	droeg	**9**
	draagde	**1**

‘droeg’ **90%**
‘draaagde’ **10%**
→

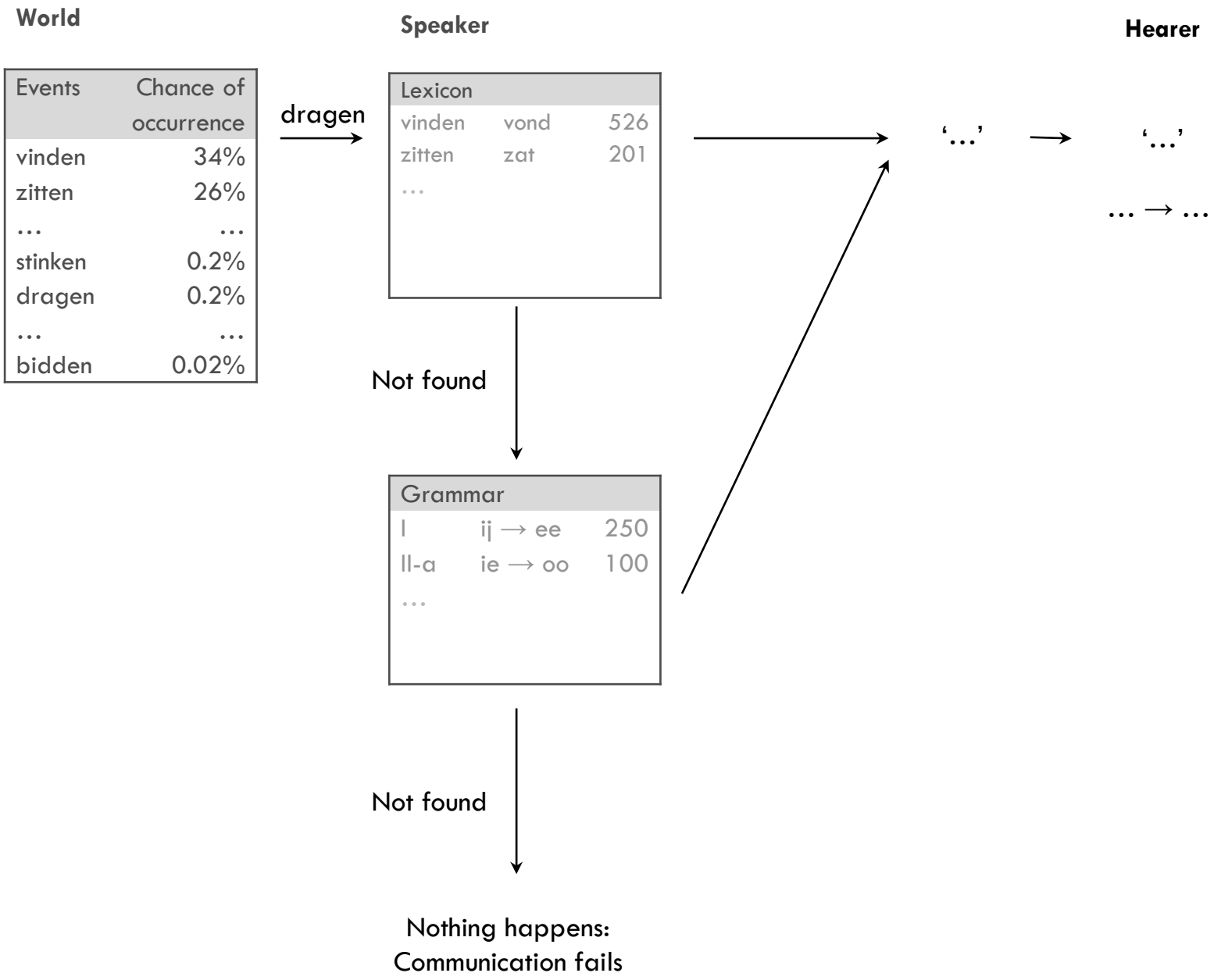
Hearer

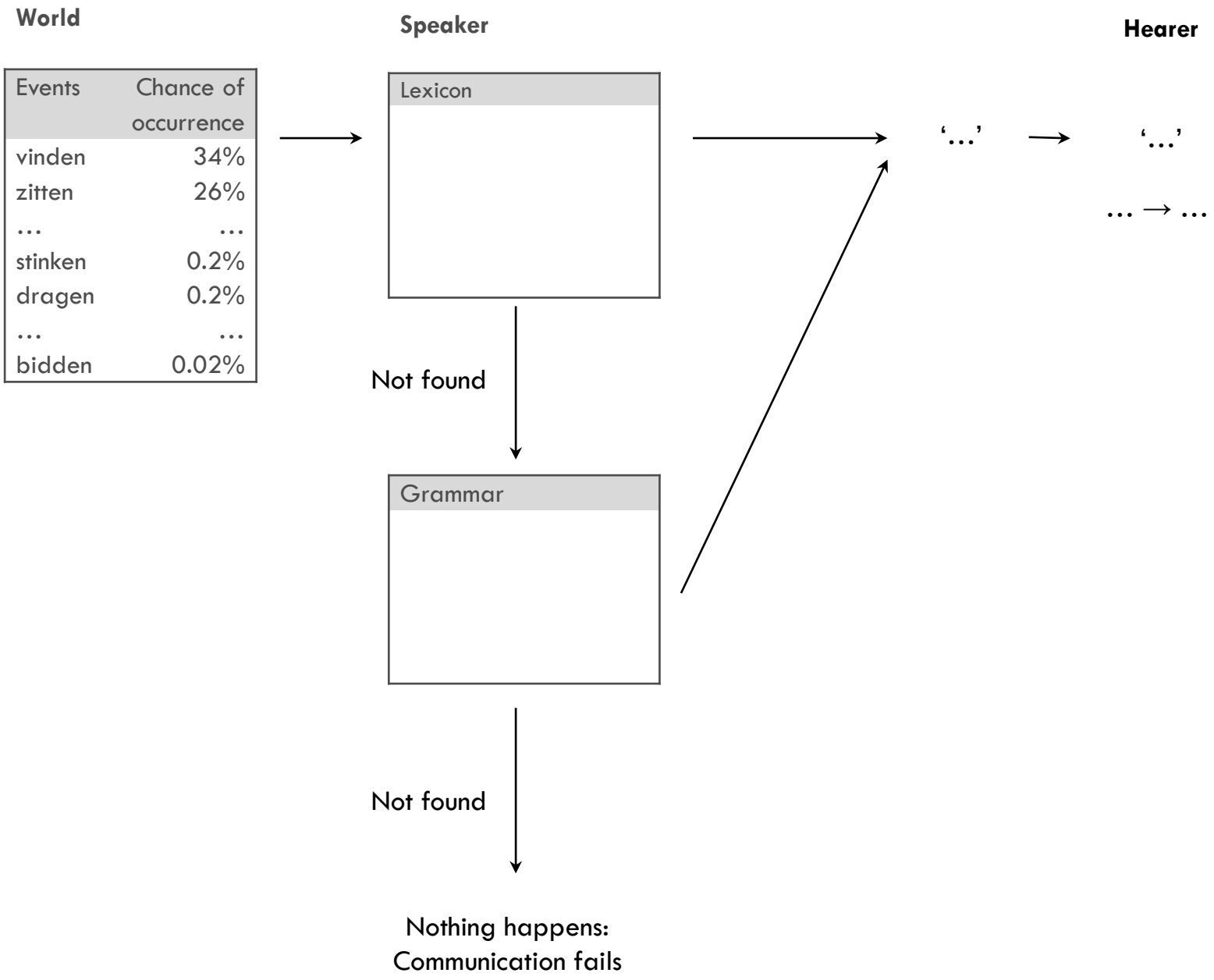
‘droeg’ → ‘droeg’ +1

aa → oe +1



Grammar implemented using Fluid Construction Grammar, see Steels (2011) and van Trijp et al. (2012)


World
Speaker
Hearer
Events
Chance of occurrence
vinden 34%
zitten 26%
… …
stinken 0.2%
dragen 0.2%
… …
bidden 0.02%
dragen
Lexicon
vinden vond 526
zitten zat 201
…
'…' → '…'
… → …
Not found
Grammar
l ij → ee 250
ll-a ie → oo 100
…
Not found
Nothing happens:
Communication fails


World
Speaker
Hearer
Events
Chance of occurrence
vinden 34%
zitten 26%
… …
stinken 0.2%
dragen 0.2%
… …
bidden 0.02%
Lexicon
Not found
Grammar
Not found
Nothing happens:
Communication fails
'…'
'…'
… → …

LET'S RUN A SIMULATION!

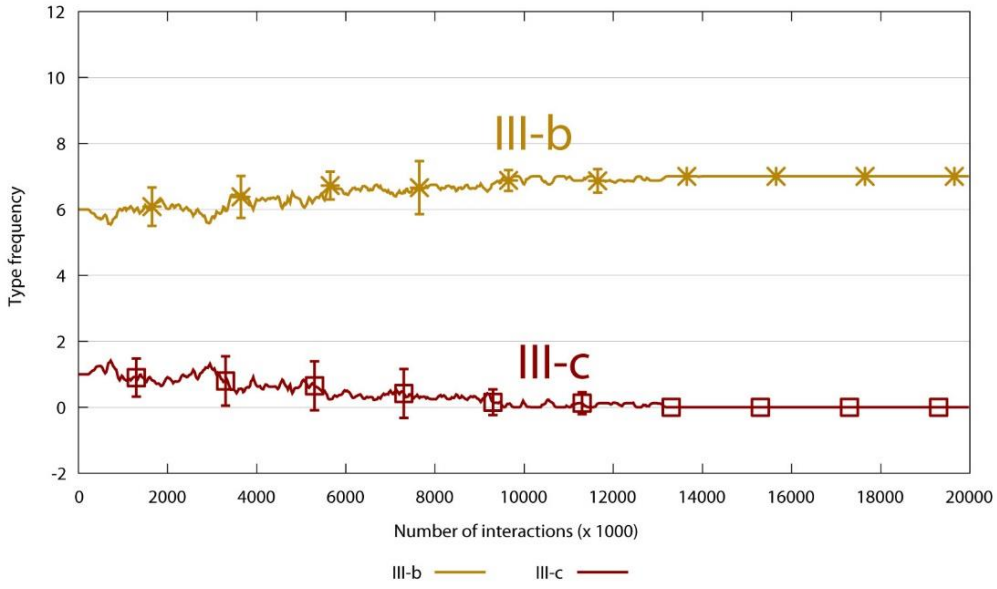
Starting situation: only strong classes

- All starting agents know perfectly how to conjugate each verb
- Have access to all strong classes

Lexicon		
vinden	vond	1518
zitten	zat	1157
…		
dragen	droeg	11
…		
bidden	bad	1

Grammar		
I	ij → ee	879
II-a	ie → oo	43
II-b	ui → oo	32
III-a	i → o	1633
III-b	e → o	33
III-c	e → ie	10
VI/V-a	ee → a	239
Vb	i → a	1366
VI	aa → oe	185
VII-a	aa → ie	65
VII-b	a → i	34

RESULTS: COMPETING STRONG CLASSES



- Either both competing classes hold each other in balance
- Or the initially most frequent one prevails

RESULTS: BRING IN THE WEAK INFLECTION

Starting position of the weak inflection

- Take the starting position of the feeblest strong class, i.e. III-c (e ⟶ *ie*)
  - Inferior in type & token frequency to any other class
  - Direct competition with more frequent III-b class (e ⟶ o)
  - Went extinct in the previous simulation

World

Events	Chance of occurrence
vinden	34%
zitten	26%
…	…
stinken	0.2%
dragen	0.2%
…	…
bidden	0.02%

Speaker

Lexicon		
vinden	vond	1518
zitten	zat	1157
…		
trekken	trok	23
…		
sterven	**stierf**	**10**
…		

Not found

Grammar		
I	ij → ee	879
II-a	ie → oo	43
II-b	ui → oo	32
III-a	i → o	1633
III-b	e → o	33
III-c	**e → ie**	**10**
VI/V-a	ee → a	239
Vb	i → a	1366
VI	aa → oe	185
VII-a	aa → ie	65
VII-b	a → I	34

Not found

Nothing happens:
Communication fails

Hearer

"…" → ".." +1

… → … +1

World

Events	Chance of occurrence
vinden	34%
zitten	26%
…	…
stinken	0.2%
dragen	0.2%
…	…
bidden	0.02%

Speaker

Lexicon		
vinden	vond	1518
zitten	zat	1157
…		
trekken	trok	23
…		
sterven	**sterfde**	**10**
…		

Not found

Grammar		
I	ij → ee	879
II-a	ie → oo	43
II-b	ui → oo	32
III-a	i → o	1633
III-b	e → o	33
weak	**+de/te**	**10**
VI/V-a	ee → a	239
Vb	i → a	1366
VI	aa → oe	185
VII-a	aa → ie	65
VII-b	a → I	34

Not found

Nothing happens:
Communication fails

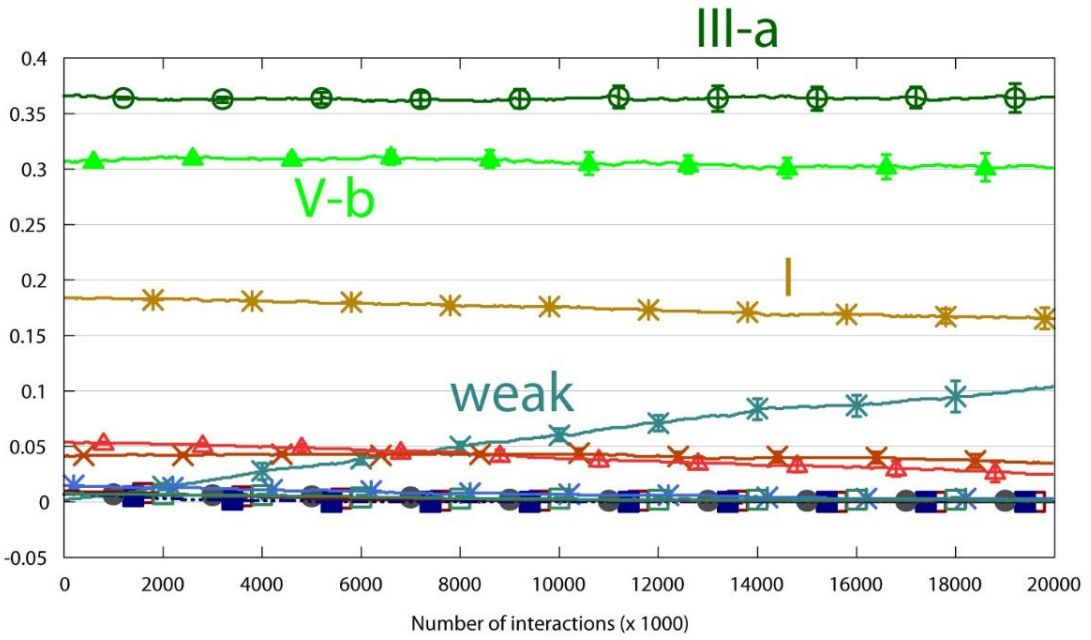
Hearer

"…" → ".." +1

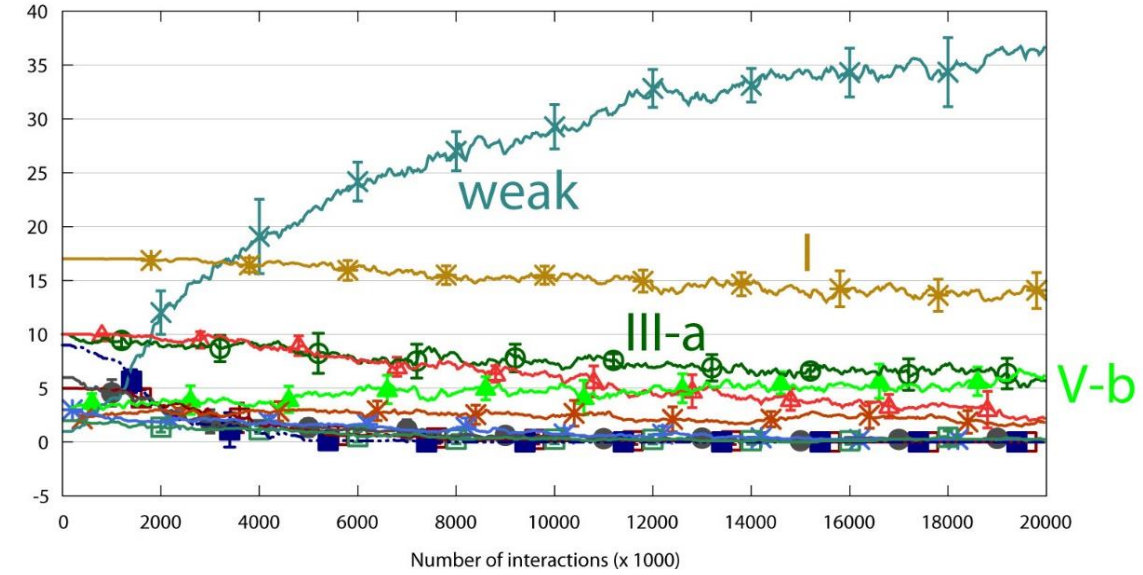
… → … +1

Only difference with the III-c class is that the weak suffix can in principle be applied to all verbs

Token frequency

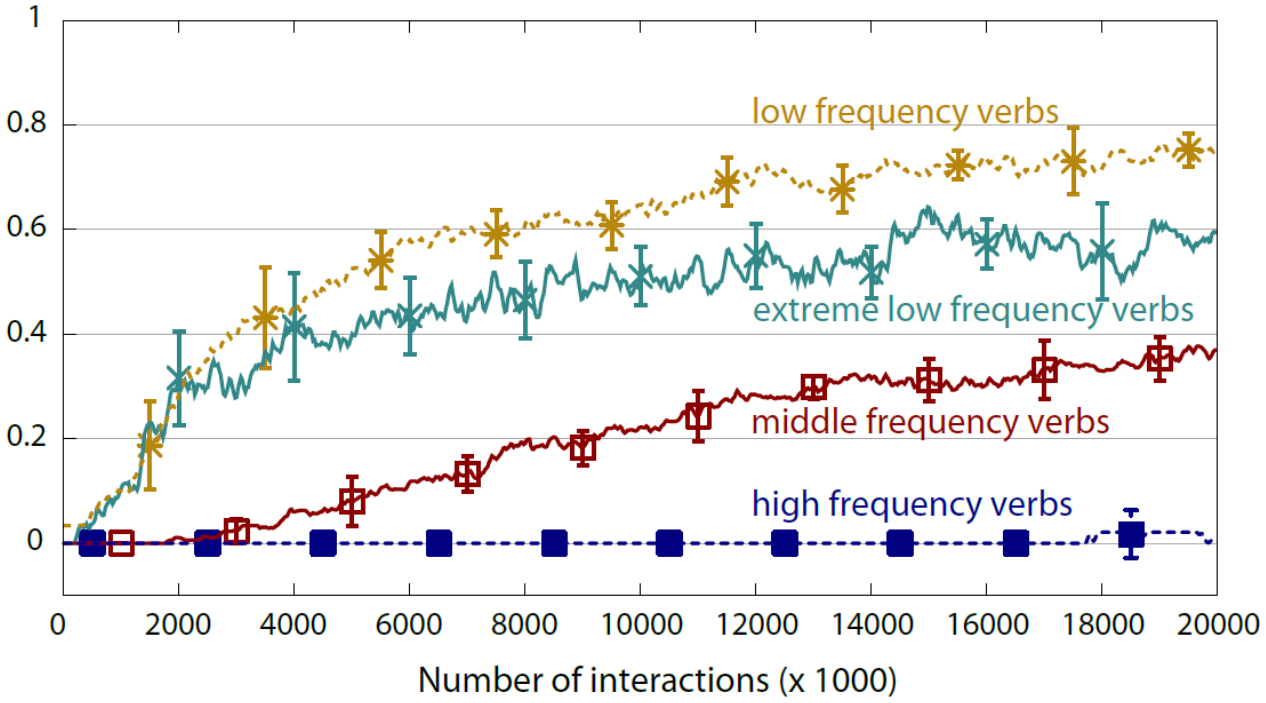


Type frequency

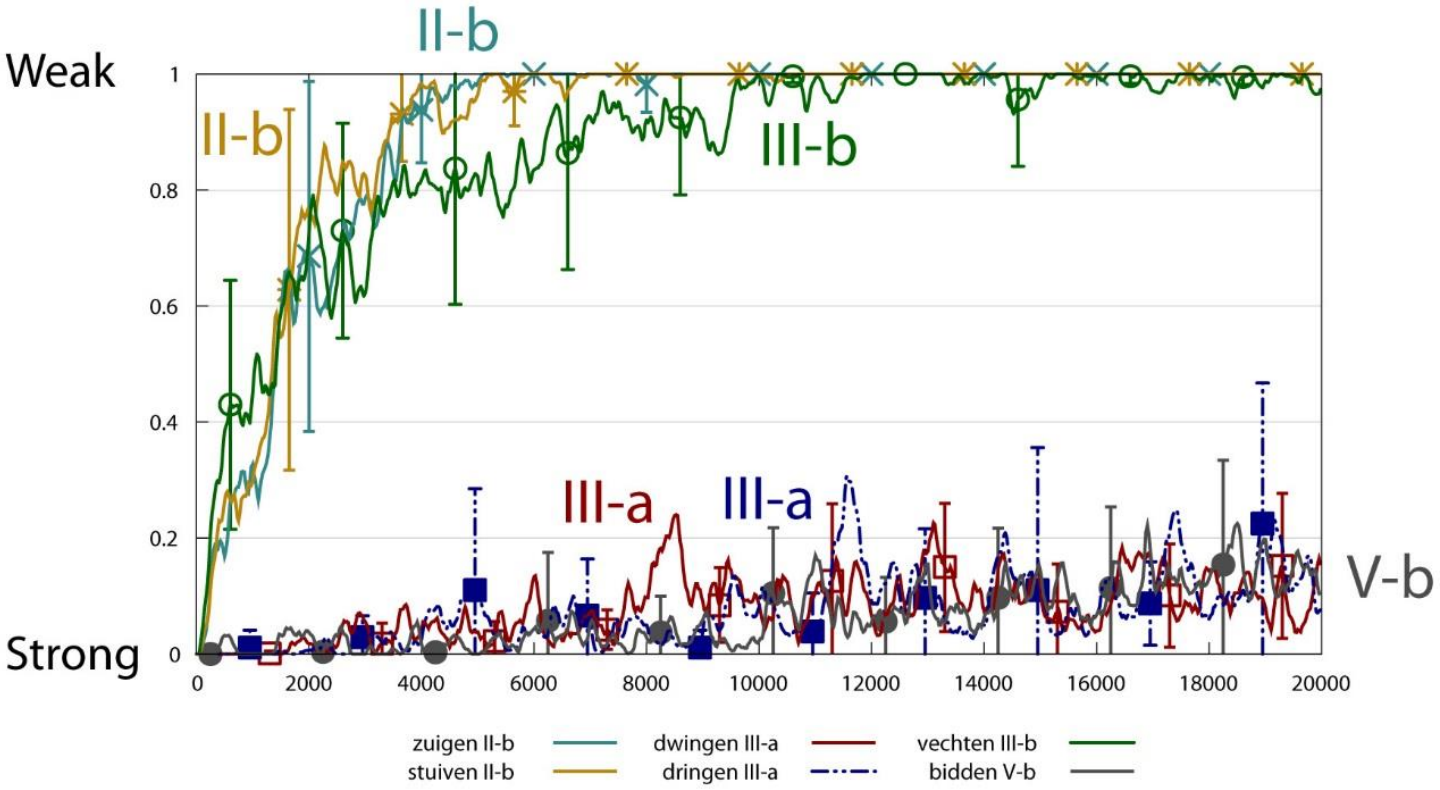


1. Rise of the Weak Inflection
2. Gradual Rise

Weak type frequency



3. Conserving Effect



4. Class Resilience

EFFECTS OF THE PARAMETERS

- Number of agents: more agents, slower rise
- Replacement rate: lower replacement rate, slower rise
  - ⇨ Emergence of the evaluation criteria is not dependent upon specific parameter settings
  - ⇨ To kill off the weak inflection, the replacement rate needs to be set extremely high

CONCLUSIONS

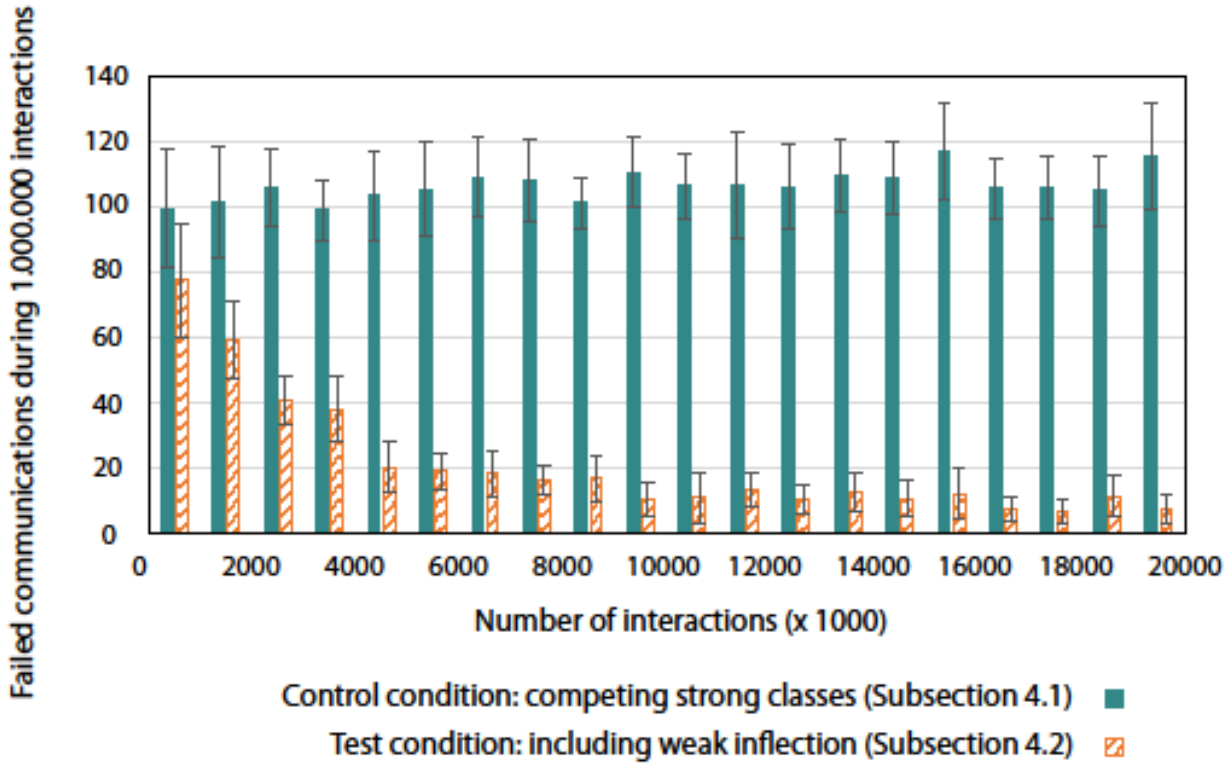
- The only thing that set the weak inflection apart from the strong classes in our simulation was its general applicability
- This suffices to explain
    1. Rise of the Weak Inflection
    2. Gradual Rise
    3. Conserving Effect
    4. Class Resilience

CAUSES OF THE RISE OF THE WEAK INFLECTION

1. **General applicability of the dental suffix**
2. Restrictions on the strong system
3. Desintegration of the strong system

(Ball 1968: 164; Bailey 1997: 17)

FUNCTIONAL ADVANTAGE OF GENERAL APPLICABILITY: IT'S REAL



FOR FURTHER INFORMATION

Pijpops, Dirk, Katrien Beuls and Freek Van De Velde. 2015. The rise of the verbal weak inflection in Germanic. An agent-based model. *Computational Linguistics in the Netherlands Journal* 5. 81–102.

Tutorials FCG: https://www.fcg-net.org/tutorial/lectures/

Babel2 Software for evolutionary experiments: http://emergent-languages.org/Babel2/index.html

Summerschool (Lake Como): http://caes.lakecomoschool.org/

REFERENCES

Bailey, Christopher Gordon. 1997. The Etymology of the Old High German Weak Verb. University of Newcastle upon Tyne.

Ball, Christopher. 1968. The Germanic dental preterite. *Transactions of the Philological Society* 67. 162–188.

Beckner, Clay, Joan Bybee, William Croft, Richard Blythe, Morten H Christiansen, Nick C Ellis, Jinyun Ke, Diane Larsen-Freeman, John Holland and Tom Schoenemann. 2009. Language is a complex adaptive system: Position paper. *Language Learning* 59(1). 1–26. doi:10.1111/j.1467-9922.2009.00533.x.

Bentz, Christian and Bodo Winter. 2013. Languages with More Second Language Learners Tend to Lose Nominal Case. *Language Dynamics and Change* 3(1). 1–27.

Bybee, Joan. 2006. From Usage to Grammar: The Mind's Response to Repetition. *Language* 82(4). 711–733.

Bybee, Joan. 2010. *Language, usage and cognition*. Cambridge: Cambridge University Press.

Carroll, Ryan, Ragnar Svare and Joseph Salmons. 2012. Quantifying the evolutionary dynamics of German verbs. *Journal of Historical Linguistics* 2(2). 153–172.

Colaiori, Francesca, Claudio Castellano, Christine Cuskley, Vittorio Loreto, Martina Pugliese and Francesca Tria. 2015. General three-state model with biased population replacement: Analytical solution and application to language dynamics. *Physical review. E, Statistical, nonlinear, and soft matter physics* 91(1-1). 12808.

Collitz, Hermann. 1912. *Das schwache Praeteritum und seine Vorgeschichte*. Göttingen: Vandenhoeck and Ruprecht.

Croft, William. 2000. *Explaining language change: An evolutionary approach*. Essex: Pearson Education Limited.

Cuskley, Christine, Martina Pugliese, Claudio Castellano, Frascesca Colaiori, Vittorio Loreto and Franscesca Tria. 2014. Internal and External Dynamics in Language: Evidence from Verb Regularity in a Historical Corpus of English. *Plos One* 9(8). e102882.

Eerten, Laura van. 2007. Over het Corpus Gesproken Nederlands. *Nederlandse Taalkunde* 12(3). 194–215.

Gilbert, Nigel. 2008. *Agent-based models*. Los Angeles: Sage.

Hare, Mary and Jeffrey Elman. 1995. Learning and morphological change. *Cognition* 56(1). 61–98.

Hill, Eugen. 2010. A case study in grammaticalized inflectional morphology: Origin and development of the Germanic weak preterite. *Diachronica* 27(3). 411–458.

Landsbergen, Frank. 2009. Cultural evolutionary modeling of patterns in language change: exercises in evolutionary linguistics. Utrecht: LOT.

Lieberman, Erez, Jean-Baptste Michel, Joe Jackson, Tina Tang and Martin Nowak. 2007. Quantifying the evolutionary dynamics of language. *Nature* 449(7163). 713–716.

Ling, Charles and Marin Marinov. 1993. Answering the connectionist challenge: a symbolic model of learning the past tenses of English verbs. *Cognition* 49(3). 235–290.

Loewe, Richard. 1898. Das schwache Präteritum des Germanischen. *Indogermanische Forschungen* 8. 254–266.

Lupyan, Gary and Rick Dale. 2010. Language structure is partly determined by social structure. *PloS one* 5(1). e8559.

Macwhinney, Brian and Jared Leinbach. 1991. Implementations are not conceptualizations: revising the verb learning model. *Cognition* 40(1-2). 121.

Marcus, Gary, Ursula Brinkmann, Harald Clahsen, Richard Wiese and Steven Pinker. 1995. German inflection: the exception that proves the rule. *Cognitive Psychology* 29(3). 189.

Meid, Wolfgang. 1971. *Das germanische Praeteritum*. Innsbruck: Institut für vergleichende Sprachwissenschaft der Universität Innsbruck.

Noord, Rik van. 2015. Modeling the learning of the English past tense with memory-based learning. *Computational Linguistics in the Netherlands (CLIN)*. Antwerp, 6 February.

O'Neil, Wayne. 1978. The evolution of the Germanic Inflection Systems: A Study in the Causes of Language Change. *Orbis* 27. 248–286.

Pijpops, Dirk and Katrien Beuls. 2015 Agent-gebaseerde modellering in de historische taalkunde. Een model van regularisatiedruk op de Nederlandse werkwoorden. *Handelingen der Koninklijke Zuid-Nederlandse Maatschappij voor Taal- en Letterkunde en Geschiedenis*. 69. 5-23.

Pinker, Steven and Alan Prince. 1988. On language and connectionism: Analysis of a parallel distributed processing model of language acquisition. *Cognition* 28(1). 73–193.

Plunkett, Kim and Patrick Juola. 1999. A Connectionist Model of English Past Tense and Plural Morphology. *Cognitive Science* 23(4). 463–490.

Plunkett, Kim and Virginia Marchman. 1991. U-shaped learning and frequency effects in a multi-layered perception: Implications for child language acquisition. *Cognition* 38(1). 43–102.

Plunkett, Kim and Virginia Marchman. 1993. From rote learning to system building: acquiring verb morphology in children and connectionist nets. *Cognition* 48(1). 21–69.

Ringe, Don. 2006. A sociolinguistically informed solution to an old historical problem: the Gothic genitive plural. *Transactions of the Philological Society* 104(2). Oxford, UK. 167–206.

Roberge, Paul. 2010. Contact and the History of Germanic Languages. *The Handbook of Language Contact*, 406–431.

Rumelhart, David and James McClelland. 1986. On learning the past tense of English verbs. In David Rumelhart & James McClelland (eds.), *Parallel distributed processing: explorations in the microstructure of cognition*, 216–271. Cambridge: MIT Press.

Shields, Kenneth. 1982. The origin of the Germanic dental preterite: A new proposal. *Leuvense Bijdragen* 71. 427–440.

Steels, Luc. 2011. *Design Patterns in Fluid Construction Grammar*. Amsterdam: John Benjamins.

Taatgen, Niels and John Anderson. 2002. Why do children learn to say "Broke"? A model of learning the past tense without feedback. *Cognition* 86. 123–155.

Tops, Guy. 1974. *The origin of the Germanic dental preterit*. Leiden: Brill.

Trijp, Remi van, Luc Steels, Katrien Beuls and Pieter Wellens. 2012. Fluid construction grammar: The new kid on the block. *Proceedings of the 13th Conference of the European Chapter of the Association for Computational Linguistics*. Avignon: ACL.

Yang, Charles. 2002. *Knowledge and learning in natural language*. Oxford: Oxford University Press.