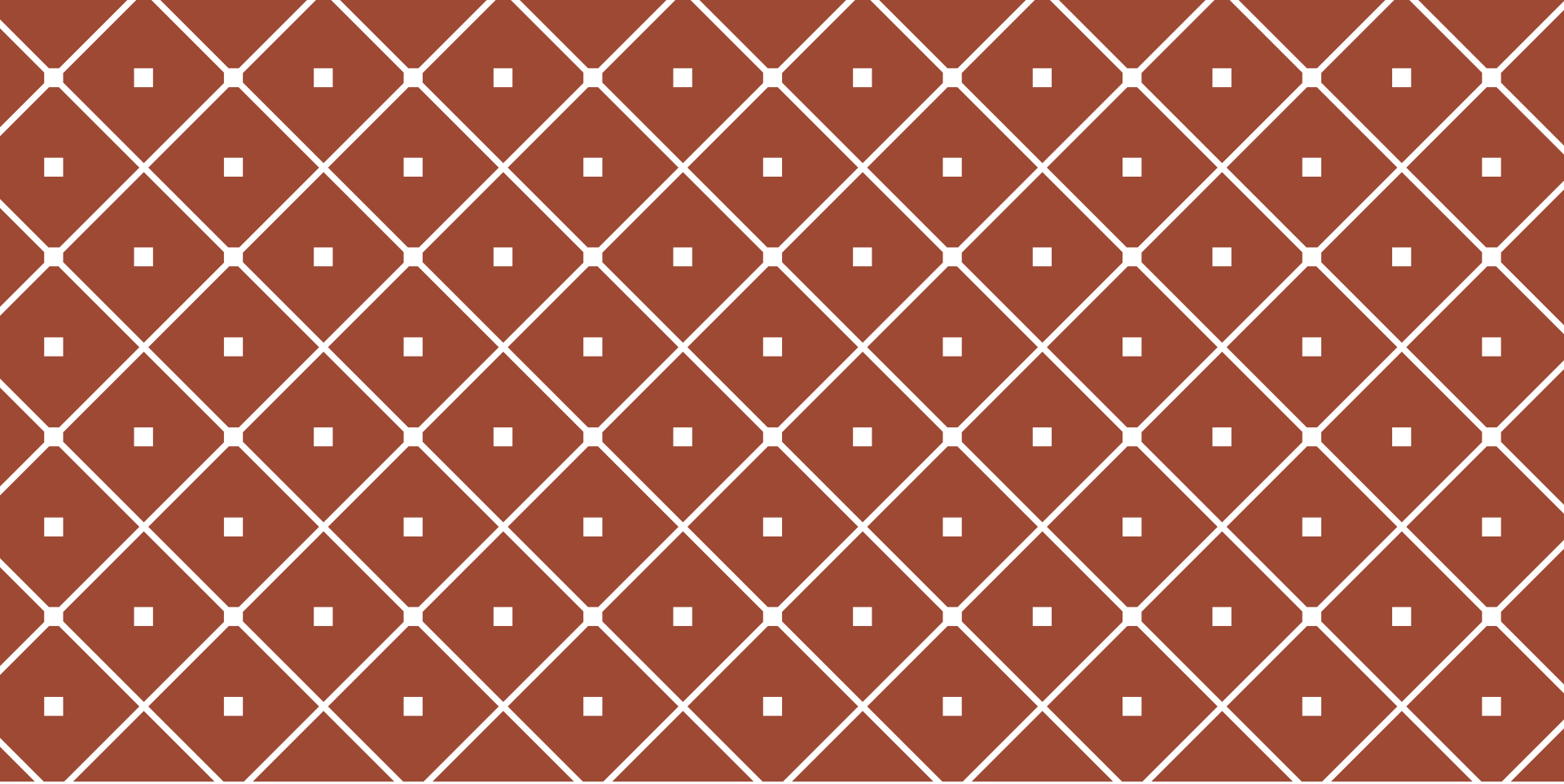

FIGHTING IN BROKEN FORMATION

THE COMPETITION BETWEEN THE GERMANIC STRONG ABLAUT CLASSES AND WEAK SUFFIX INFLECTION IN AN AGENT-BASED MODEL

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

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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 subm.)

PROPOSALS

1. General applicability of the dental suffix

2. Restrictions on the strong system

3. Irregularization of the strong system

(Ball 1968: 164; Bailey 1997: 17)

PROPOSALS

1. **General applicability of the dental suffix**
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(Ball 1968: 164; Bailey 1997: 17)

PROPOSALS

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

⇨ Irregularization may be result, rather than cause

OVERVIEW

- Simulation Design: what do we put in?
  - Conceptual level
  - Implementational level
- Results: what comes out?
- Conclusions

SIMULATION DESIGN: CONCEPTUAL LEVEL

- Agent-based simulation rather than 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)

- Acquisition of the Germanic past tense in models of iterated learning

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)

SIMULATION DESIGN: CONCEPTUAL LEVEL

- What do we put in?

PROPOSALS

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

(Ball 1968: 164; Bailey 1997: 17)

SIMULATION DESIGN: CONCEPTUAL LEVEL

- What do we put in?
  - Single, generally applicable weak suffix vs. multiple strong classes
  - No restrictions on the strong system: each verb can be conjugated strongly
  - No irregular verbs, no ways to become irregular
  - Each separate strong class starts dominant in type and token frequency
  - Verbs show a realistic (Zipfian) frequency distribution
  - Agents age and are gradually replaced

SIMULATION DESIGN: CONCEPTUAL LEVEL

- Any other possible advantages for the weak inflection

⇨ Agents will never forget strong forms (↔ Taatgen and Anderson 2002: 124)

⇨ No advantage of linear segmentibility: Hearers recognize

- *vraag-de* 'asked'
- *vr-ie-g* 'asked'

⇨ Abstract away from language acquisition

⇨ No social structure or social preference

SIMULATION DESIGN: CONCEPTUAL LEVEL

- Keep It Simple Stupid (Landsbergen 2009: 18-19)
  - Only finite past tenses
  - No influence of phonetic resemblance

SIMULATION DESIGN: CONCEPTUAL LEVEL

- 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

SIMULATION DESIGN: 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

SIMULATION DESIGN: IMPLEMENTATIONAL LEVEL

- Verbs: extracted from Corpus of Spoken Dutch

  (all can be conjugated strongly, no irregulars, Zipfian 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

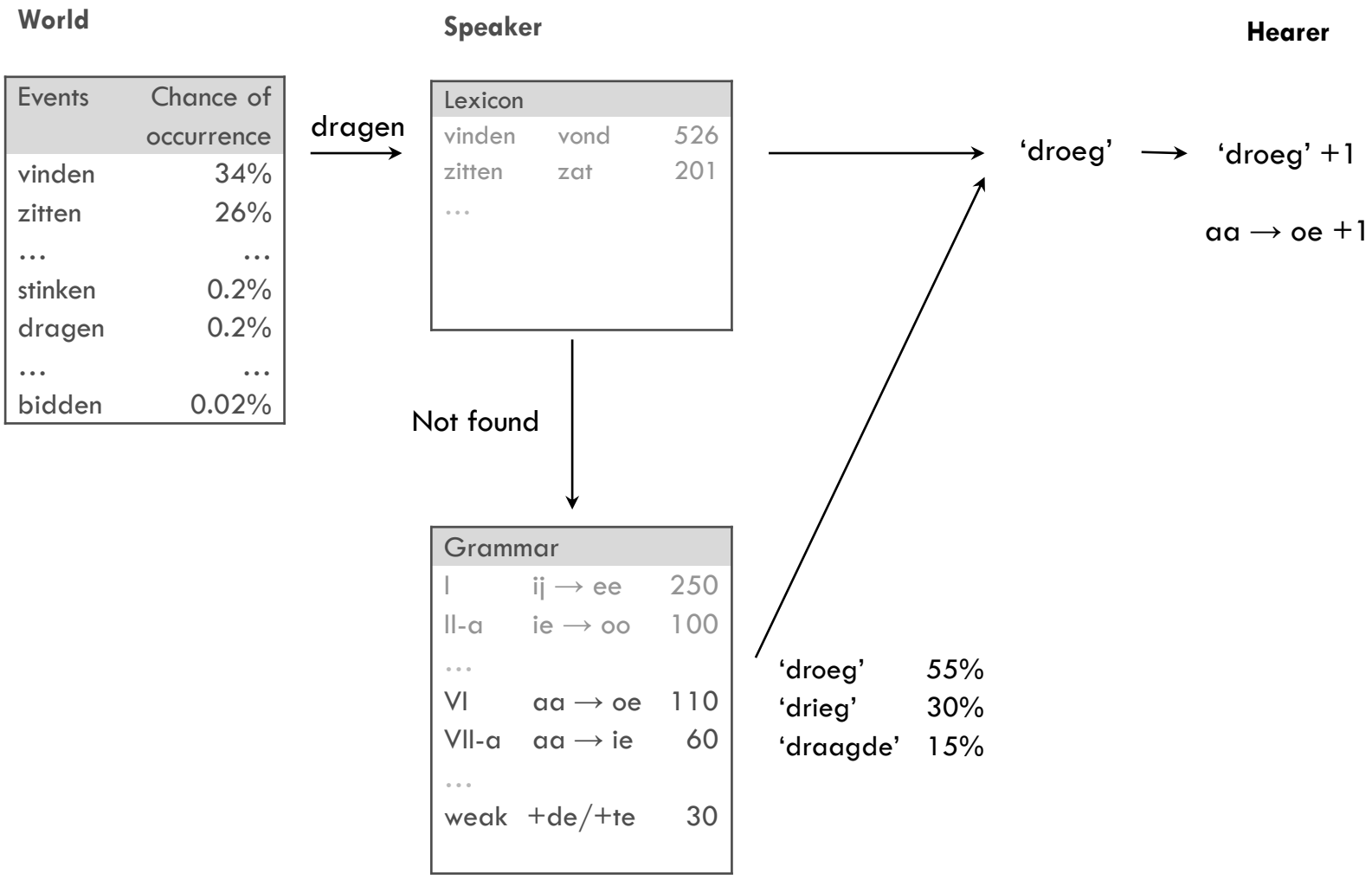
Lexicon		
vinden	vond	526
zitten	zat	201
…		
dragen	droeg	**9**
	draagde	**1**

‘droeg’ **90%**
‘draaagde’ **10%** →

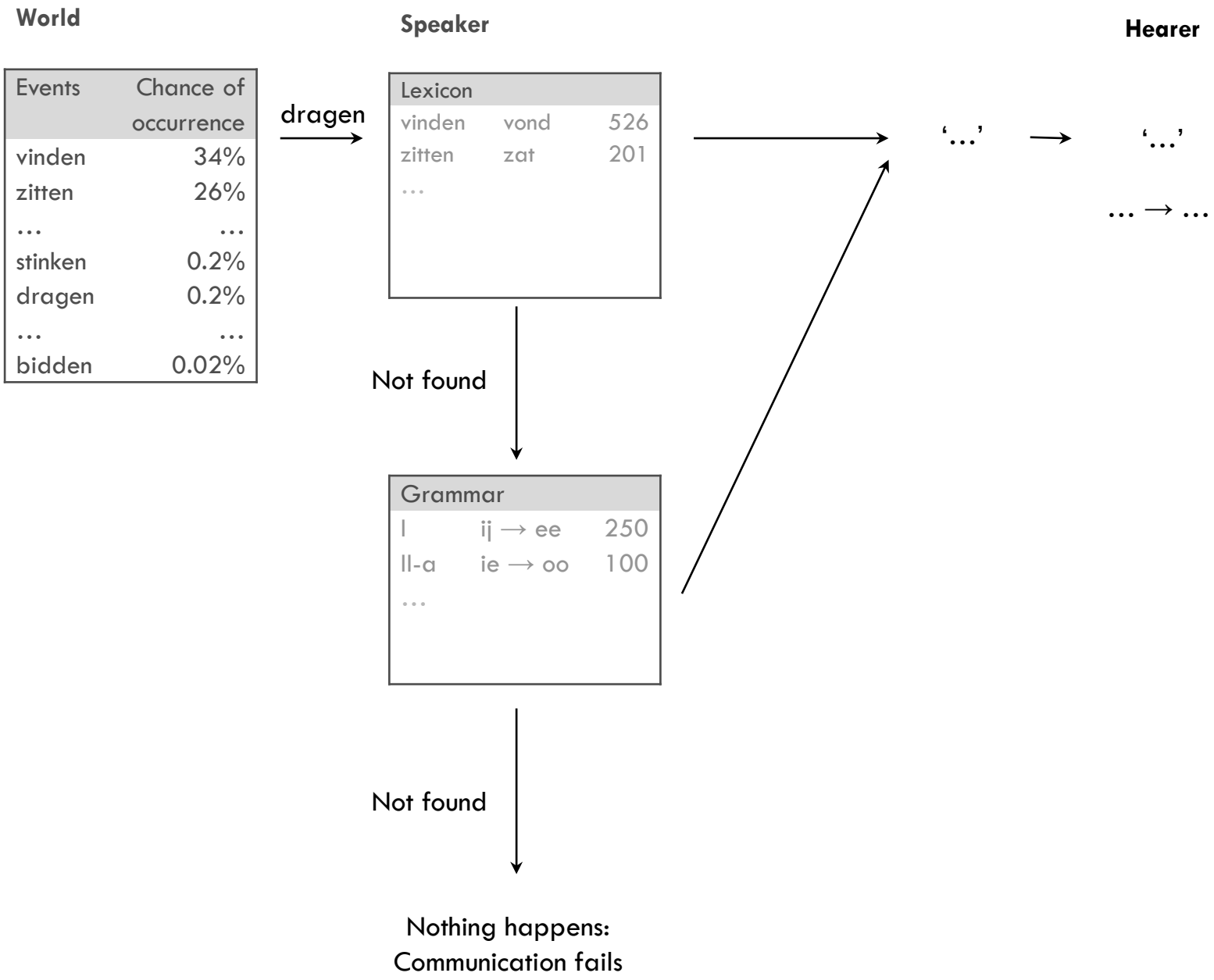
Hearer

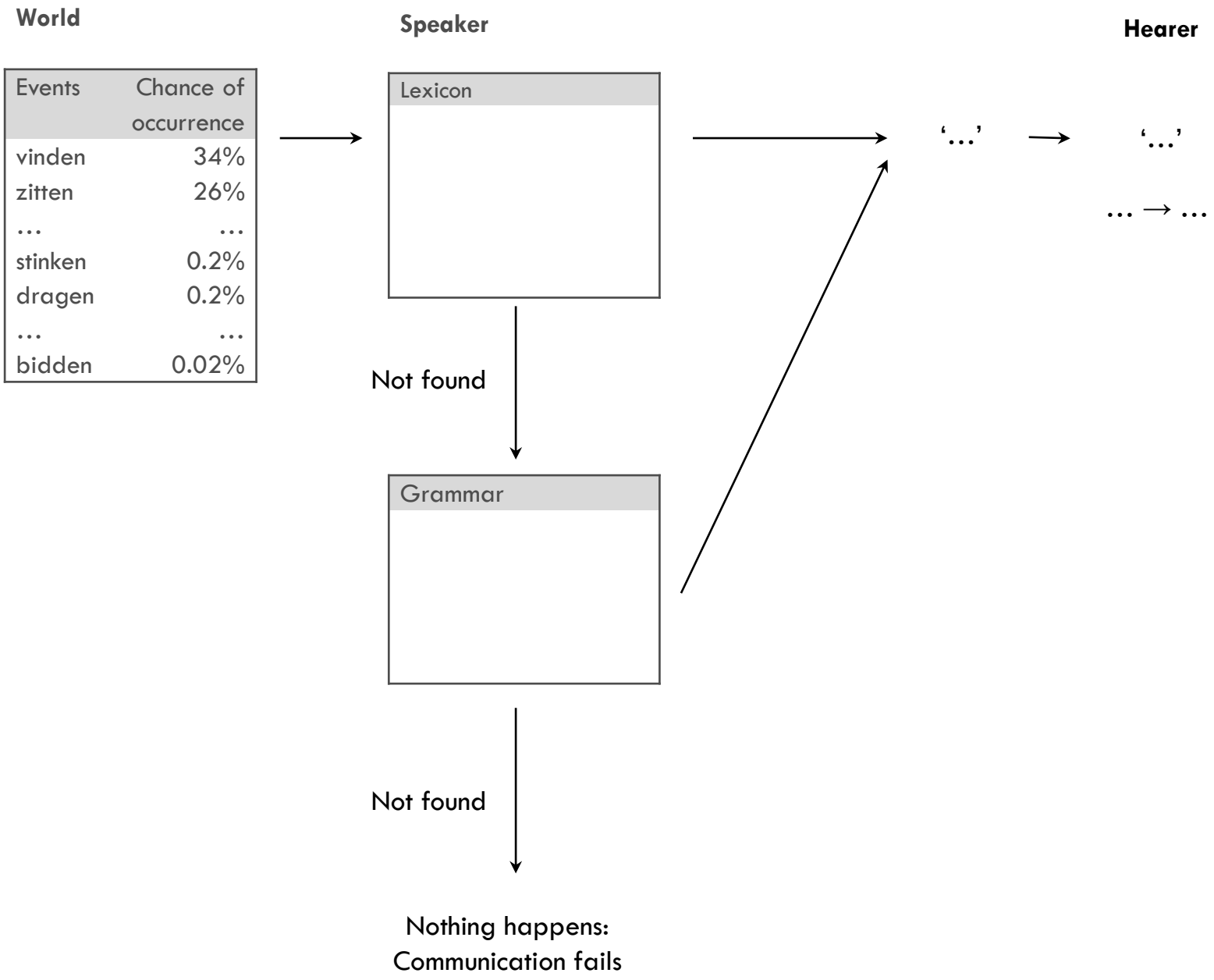
‘droeg’ → ‘droeg’ +1

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 perfectly know 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
VI/V-a	ee → a	239
Vb	i → a	1366
VI	aa →oe	185
VII-a	aa → ie	65
VII-b	a → I	34

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
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Not found

Grammar		
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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

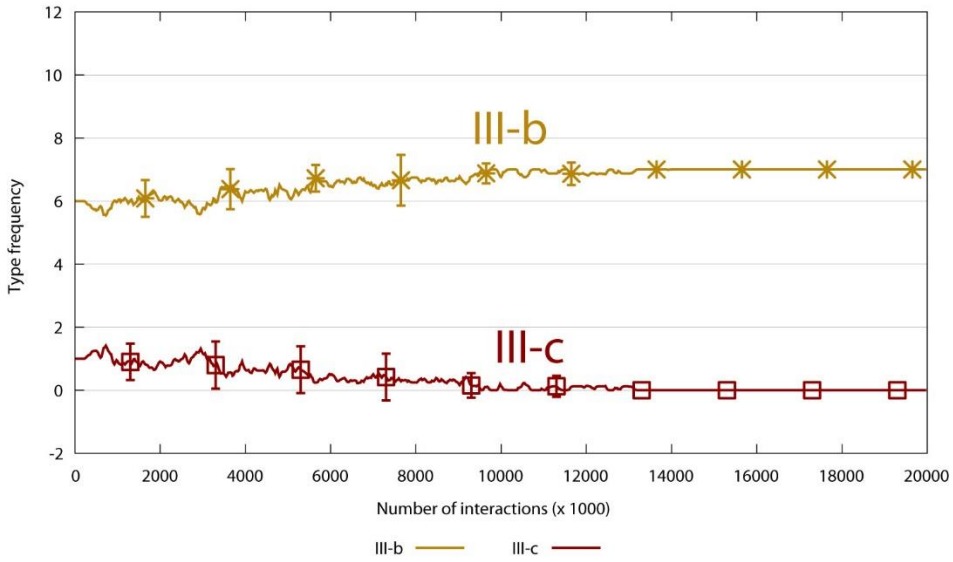
Nothing happens:
Communication fails

Hearer

"…" → ".." +1

… → … +1

RESULTS: COMPETING STRONG CLASSES



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

RESULTS: BRING IN THE WEAK INFLECTION

Starting position of the weak inflection

- ~~Preterito-presentia~~ (Bailey 1997: 578)
- Take the starting position of the feeblest strong class, i.e. III-c (e ⟶ *ie*)
  - Lowest type & token frequency of all classes
  - 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

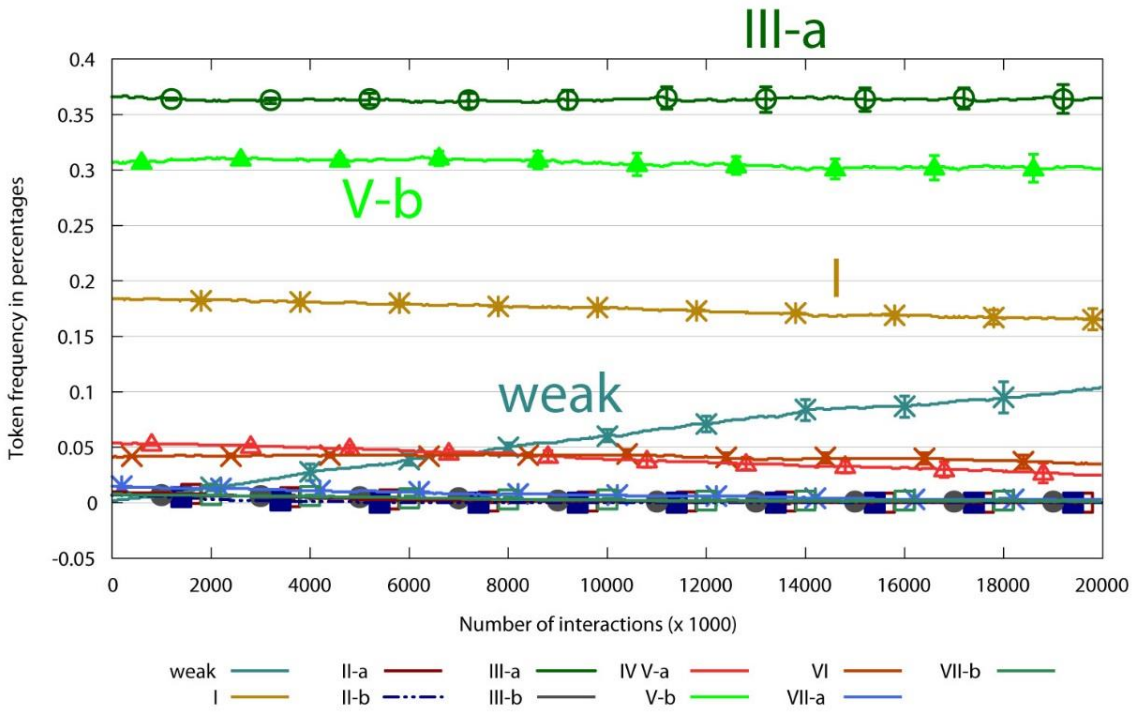
Hearer

"…" → ".." +1

… → … +1

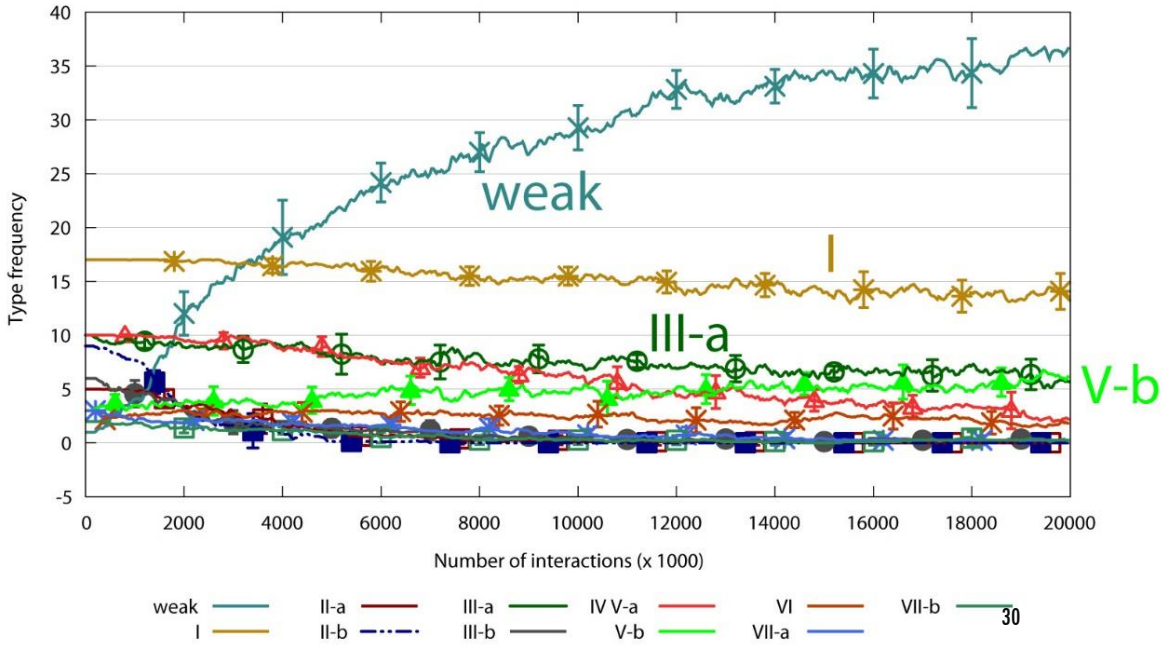
Only difference with the III-c class is that the weak inflection can in principle be applied to all verbs

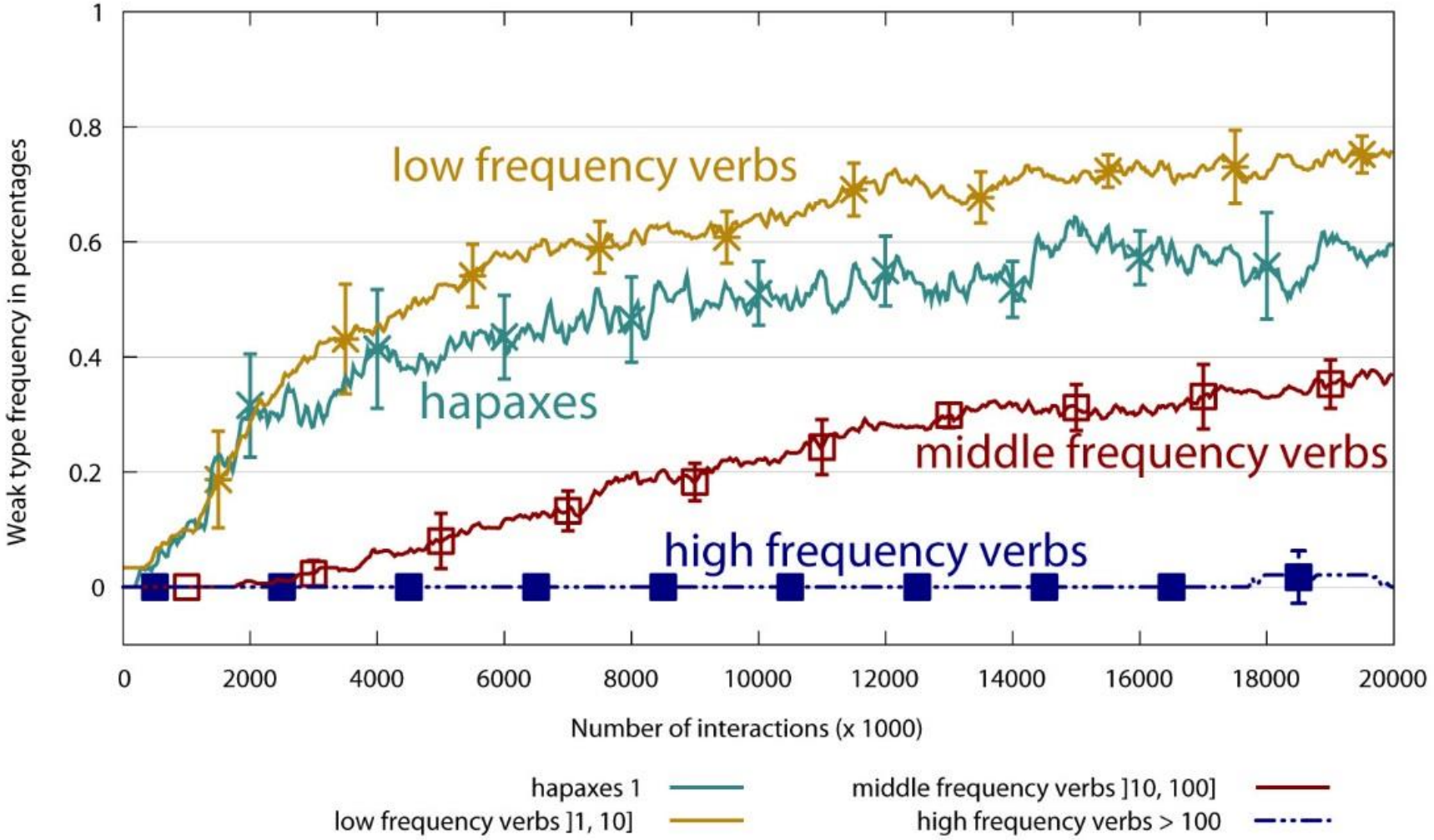
- Token frequency



- Type frequency

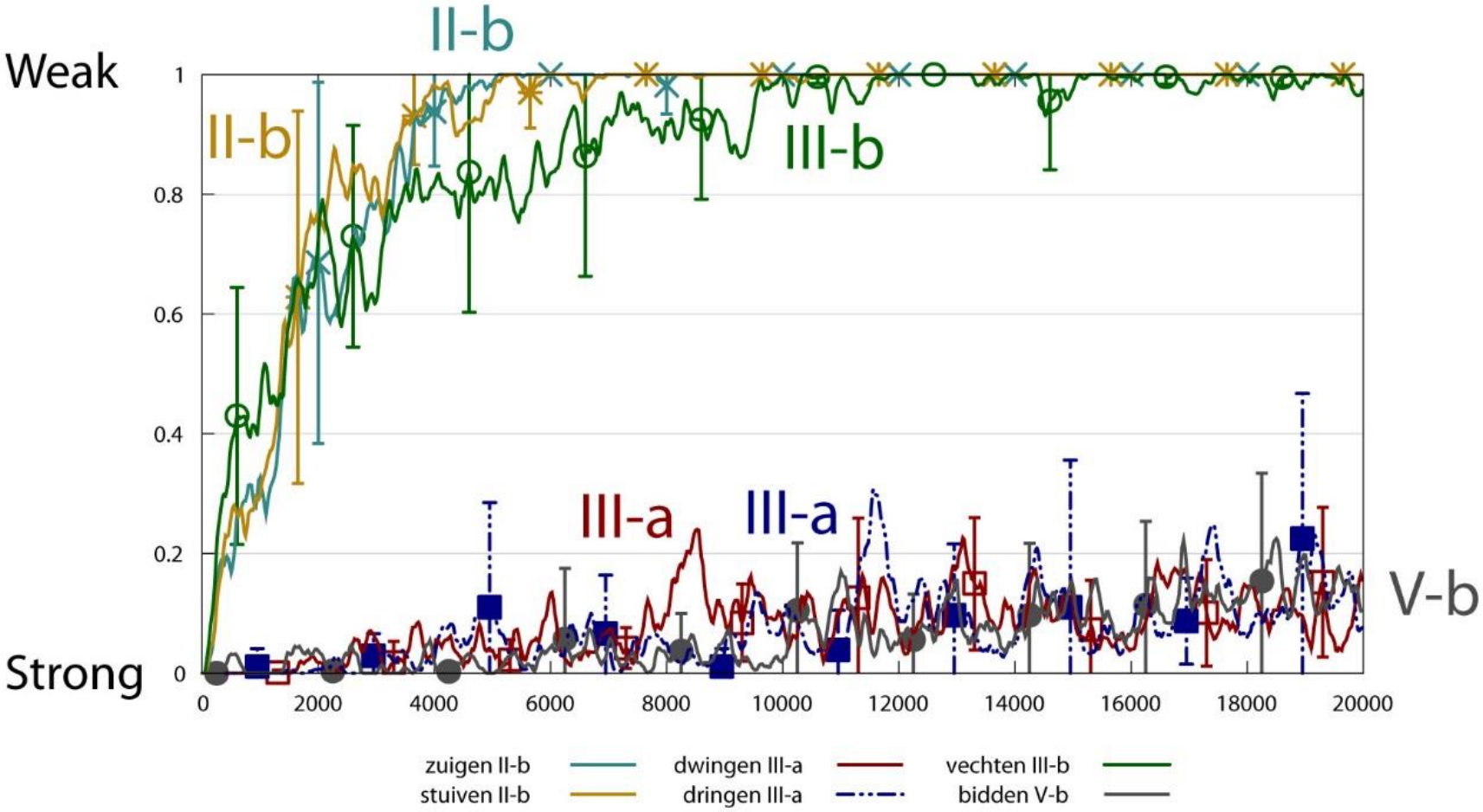
1. Rise of the Weak Inflection
2. Gradual Rise





3. Conserving Effect

- Development of a number of hapaxes



4. Class Resilience

RESULTS: 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. Irregularization of the strong system

(Ball 1968: 164; Bailey 1997: 17)

CAUSES OF THE RISE OF THE WEAK INFLECTION

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

(Ball 1968: 164; Bailey 1997: 17)

Starting point

Low frequency verbs become weak
&
Regularity is primarily needed by
low frequency verbs

Less need to maintain
the regularity of the
strong system

Irregularization of the
Strong Inflection

REMAINING QUESTIONS

- Origin of the dental suffix

(o.a. Loewe 1898; Collitz 1912; Ball 1968; Meid 1971; Tops 1974; Shields 1982; Ringe 2006: 179-785; Hill 2010)

- What originally made the strong system so succesful?
  - Shorter verb forms
  - Germanic first-syllable stress
  - ⇨ Influx of L2-learners: advantages of the weak inflection – general applicability and greater linear segmentability – proved more decisive

(cf. O'Neil 1978; Roberge 2010; Lupyan and Dale 2010; Bentz and Winter 2013)

FOR FURTHER INFORMATION

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EXTRA SLIDES

4 series of 20.000.000 interactions, 10 agents, replacement rate of 1/20.000

WHY A CORPUS OF MODERN DUTCH?

- No corpora of Proto-Germanic, corpora of Middle-Dutch or Gothic arguably as 'bad' as one from Modern Dutch
- CGN is annotated and more representative of frequency distributions in spoken language
- In principle, any model which complies to the building blocks (slide 14-16) and leads to the emergence of the 4 evaluation criteria will do
    - ⇨ Realistic frequency distributions important
- Intuitively interpretable, but explicitly not a realistic model of Proto-Germanic

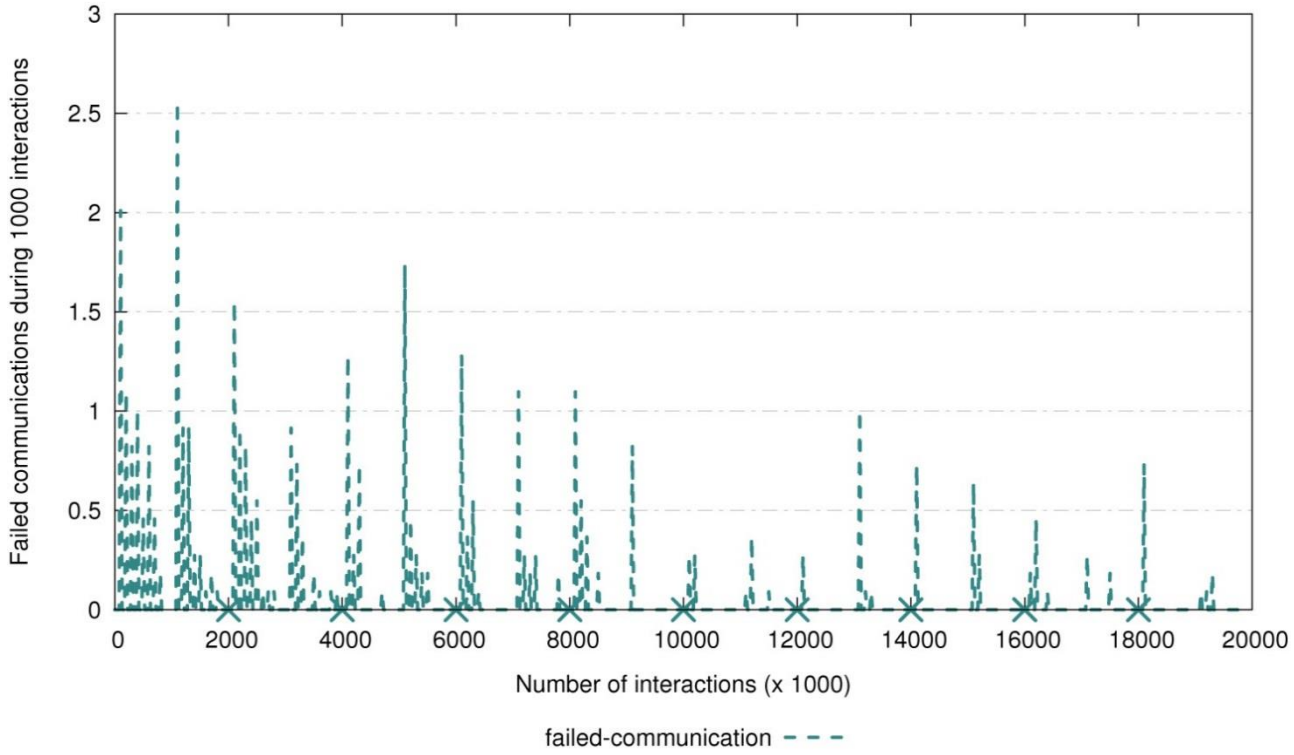
WHY IS THE STRENGTH OF A CLASS DETERMINED BY TOKEN INSTEAD OF TYPE FREQUENCY?

- No Advantages for the weak inflection:
  Type frequency would be more beneficial for the weak inflection than token frequency (Conserving Effect)

- KISS:
  More design choices need to be made for type frequency

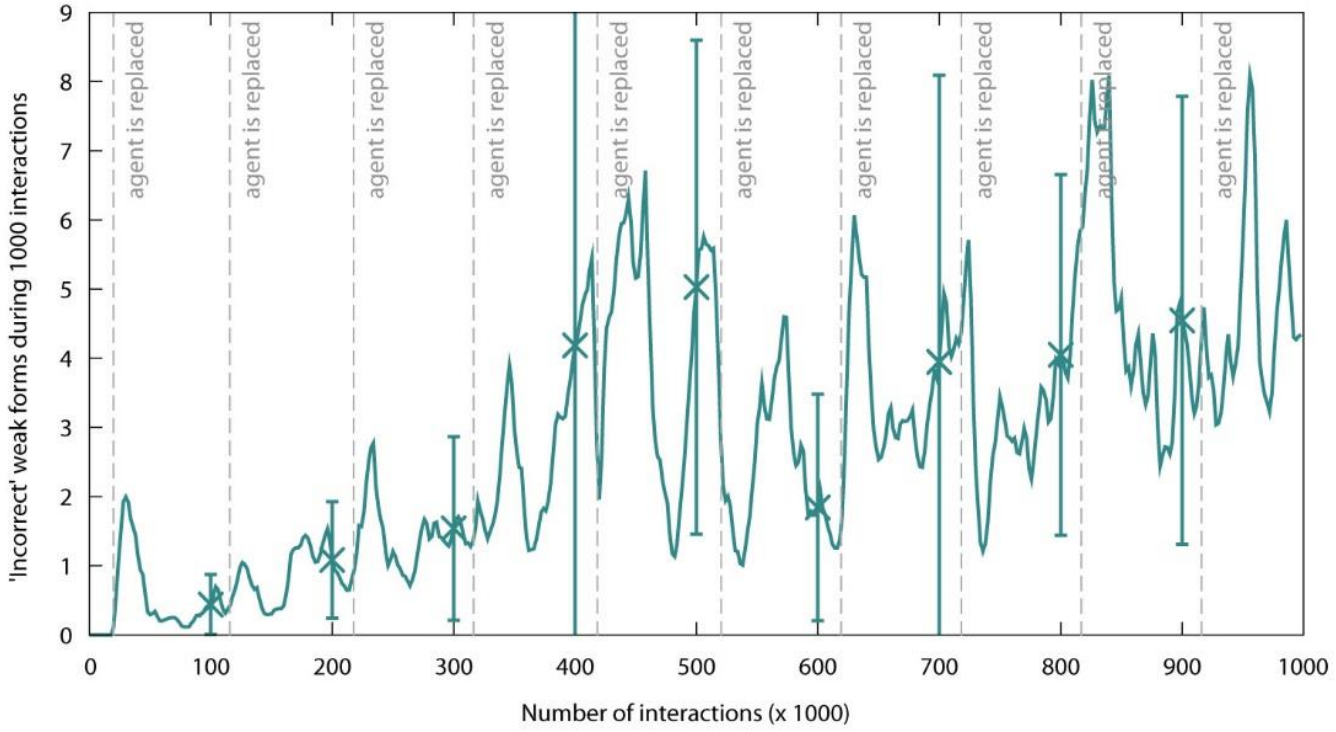
ARGUMENTS AGAINST GENERAL APPLICABILITY

1. Addition of the weak inflection only complicates past tense formation: only makes it harder to learn & use



ARGUMENTS AGAINST GENERAL APPLICABILITY

2. General applicability is only useful if you haven't acquired all strong classes yet. Moreover, each separate strong class is initially more frequent and thus more quickly acquired than the weak dental suffix.



WORLD

Rank	Event	Chance of occurrence
1	vinden	0.340435
2	zitten	0.259475
3	krijgen	0.080511
4	liggen	0.046647
5	vragen	0.039022
6	kijken	0.023324
7	lijken	0.019287
8	blijken	0.017268
9	blijven	0.016596
10	geven	0.015026
11	nemen	0.014802
12	rijden	0.013232
13	lezen	0.011213
14	laten	0.010316
15	schrikken	0.007176
16	hangen	0.007176
17	spreken	0.007176
18	schrijven	0.005607
19	trekken	0.005158
20	vliegen	0.004485
21	zingen	0.004485
22	winnen	0.004261
23	slapen	0.003813
24	klinken	0.00314
25	schijnen	0.002915
26	schieten	0.002467
27	stinken	0.002467
28	dragen	0.002467
29	eten	0.002243
30	sterven	0.002243
31	drinken	0.002018
32	springen	0.001794
33	kruipen	0.001346
34	steken	0.001346
35	rieken	0.001121
36	bieden	0.001121
37	spuiten	0.001121
38	ruiken	0.001121
39	sluiten	0.001121
40	schuiven	0.000897
41	gelden	0.000897
42	breken	0.000897
43	snijden	0.000897
44	grijpen	0.000673
45	bijten	0.000673
46	knijpen	0.000673
47	wijzen	0.000673
48	duiken	0.000673
49	lijden	0.000449
50	zwijgen	0.000449
51	kiezen	0.000449
52	sluipen	0.000449
53	treffen	0.000449
54	zwemmen	0.000449
55	treden	0.000449
56	blazen	0.000449
57	vangen	0.000449
58	rijgen	0.000224
59	glijden	0.000224
60	zuigen	0.000224
61	stuiven	0.000224
62	dwingen	0.000224
63	dringen	0.000224
64	schelden	0.000224
65	vechten	0.000224
66	stelen	0.000224
67	vreten	0.000224
68	bidden	0.000224

INITIAL LEXICON

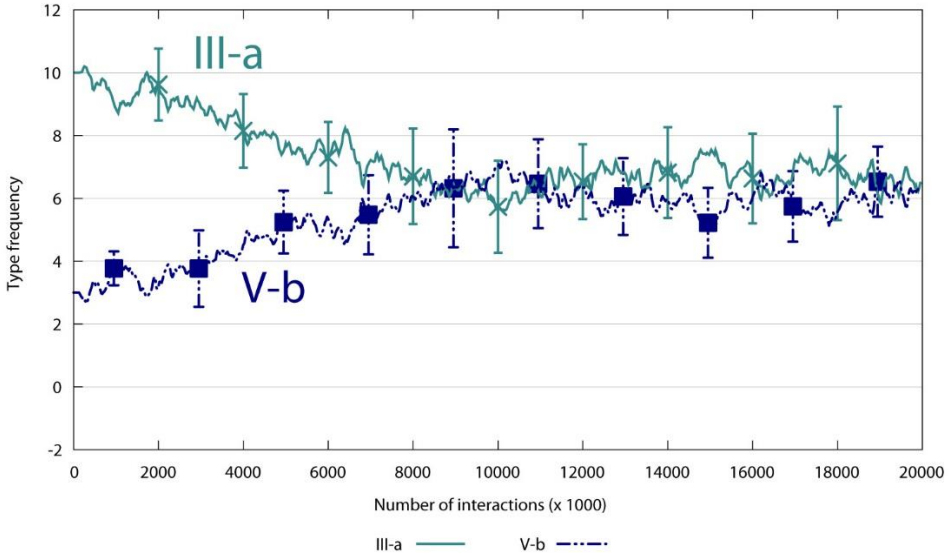
Event	Verb forms	Counts
vinden	vond	1518
zitten	zat	1157
krijgen	kreeg	359
liggen	lag	208
vragen	vroeg	174
kijken	keek	104
lijken	leek	86
blijken	bleek	77
blijven	bleef	74
geven	gaf	67
nemen	nam	66
rijden	reed	59
lezen	las	50
laten	liet	46
schrikken	schrok	32
hangen	hing	32
spreken	sprak	32
schrijven	schreef	25
trekken	trok	23
vliegen	vloog	20
zingen	zong	20
winnen	won	19
slapen	sliep	17
klinken	klonk	14
schijnen	scheen	13
schieten	schoot	11
stinken	stonk	11
dragen	droeg	11
eten	at	10
sterven	stierf; sterfde	10
drinken	dronk	9
springen	sprong	8
kruipen	kroop	6
steken	stak	6
rieken	rook	5
bieden	bood	5
spuiten	spoot	5
ruiken	rook	5
sluiten	sloot	5
schuiven	schoof	4
gelden	gold	4
breken	brak	4
snijden	sneed	4
grijpen	greep	3
bijten	beet	3
knijpen	kneep	3
wijzen	wees	3
duiken	dook	3
lijden	leed	2
zwijgen	zweeg	2
kiezen	koos	2
sluipen	sloop	2
treffen	trof	2
zwemmen	zwom	2
treden	trad	2
blazen	blies	2
vangen	ving	2
rijgen	reeg	1
glijden	gleed	1
zuigen	zoog	1
stuiven	stoof	1
dwingen	dwong	1
dringen	drong	1
schelden	schold	1
vechten	vocht	1
stelen	stal	1
vreten	vrat	1
bidden	bad	1

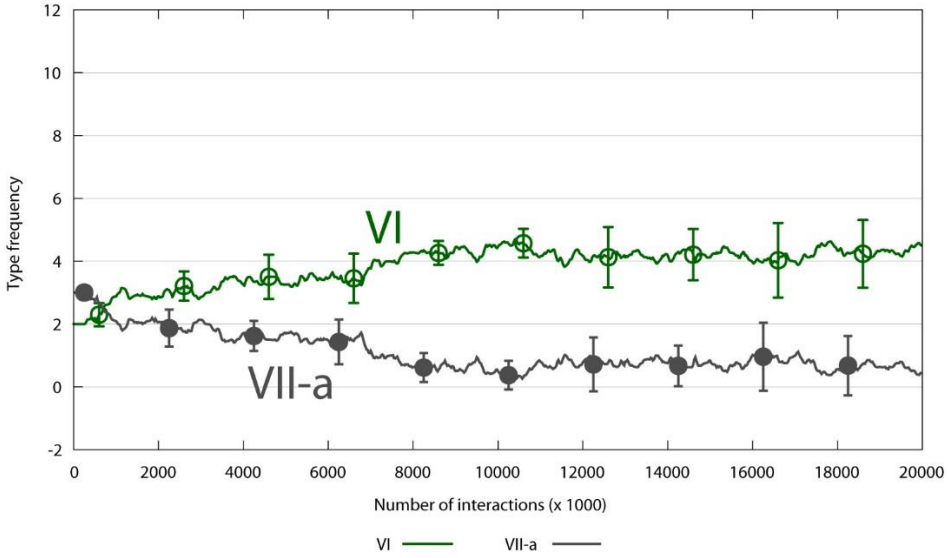
INITIAL GRAMMAR

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

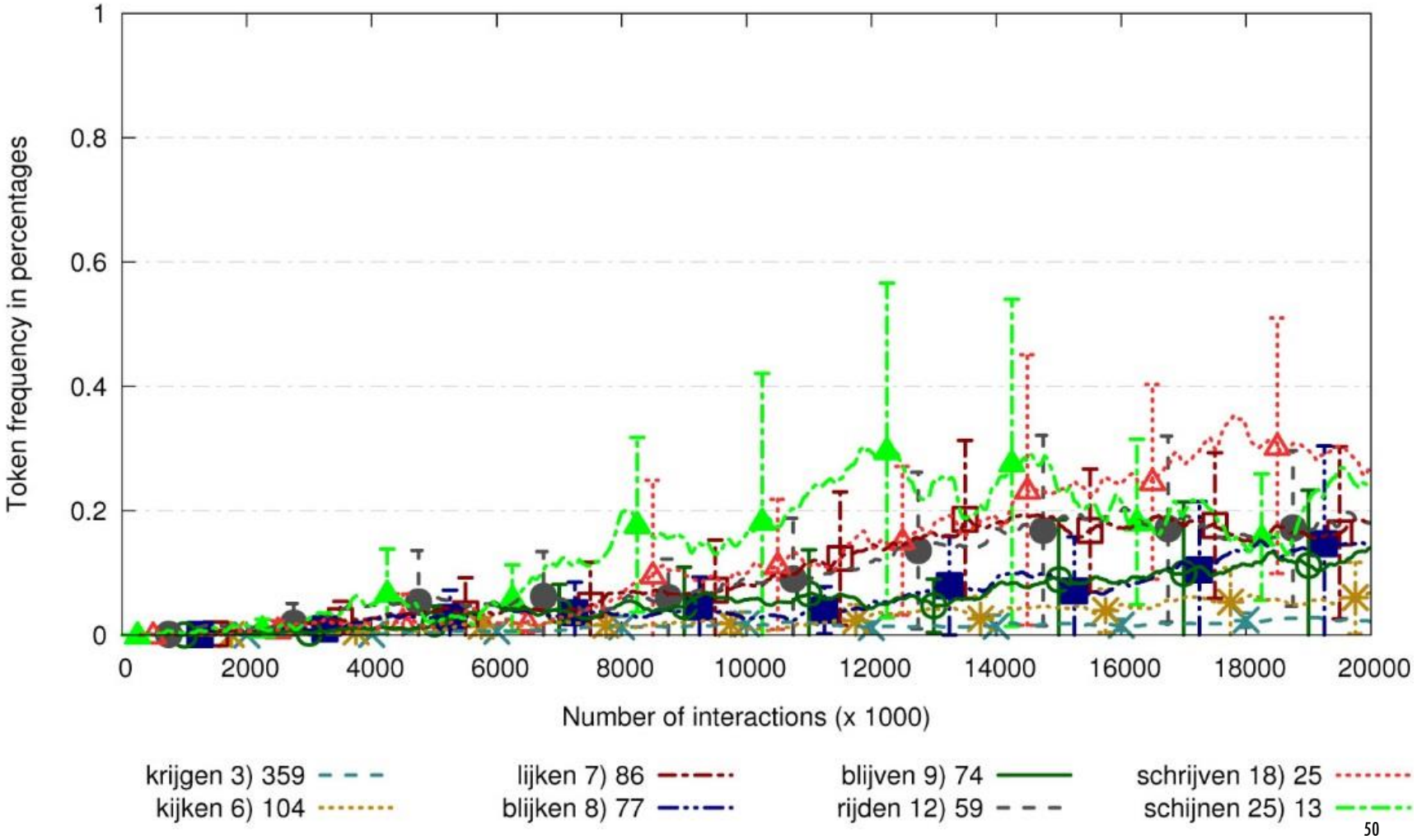
Grammar		
I	ij → ee	879
II-a	ie → oo	43
II-b	ui → oo	32
III-a	i → o	1633
III-b	e → o	33
weak	**+de/te**	**10**
VI/V-a	ee → a	239
Vb	i → a	1366
VI	aa →oe	185
VII-a	aa → ie	65
VII-b	a → I	34

COMPETING STRONG CLASSES

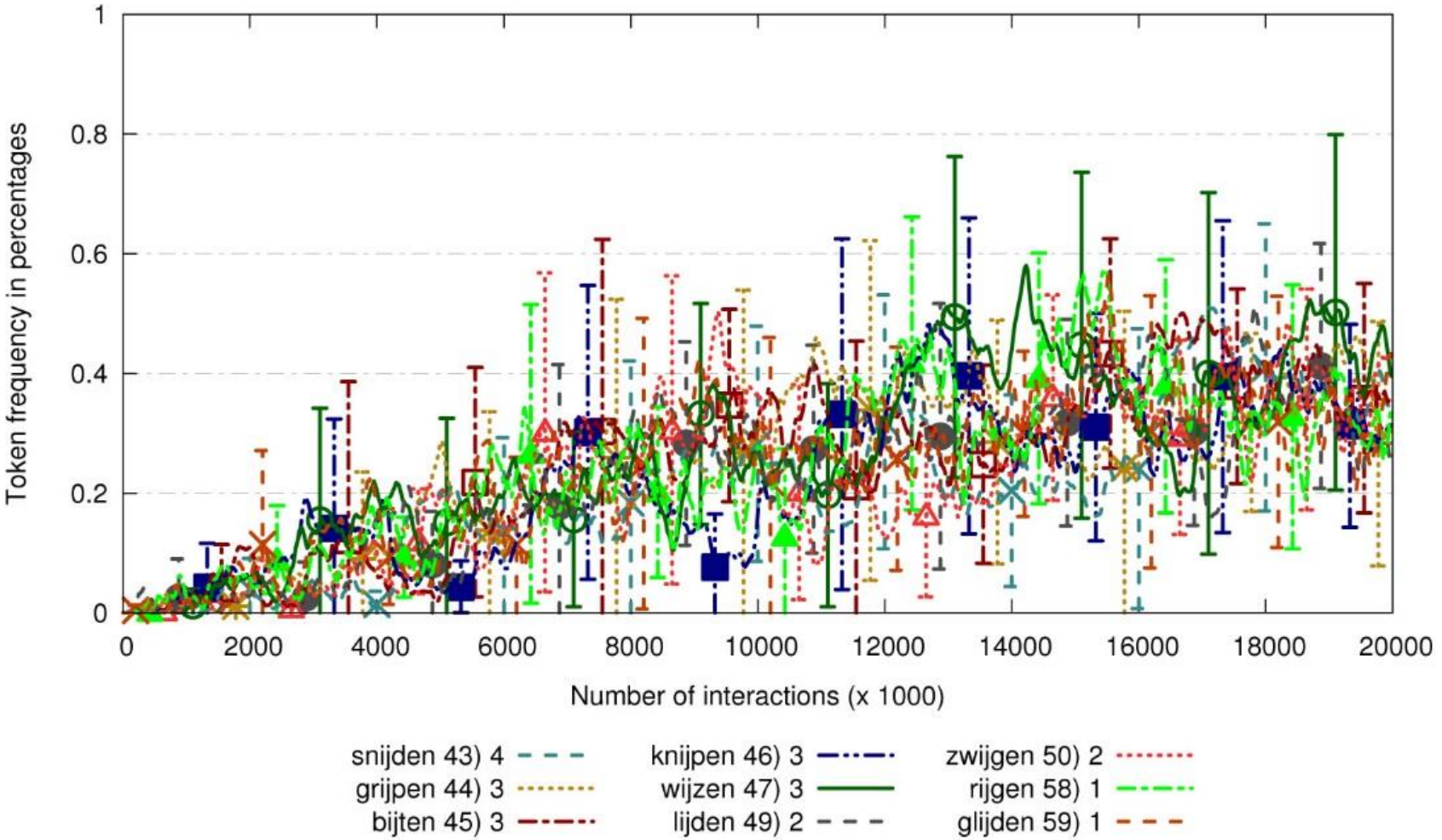




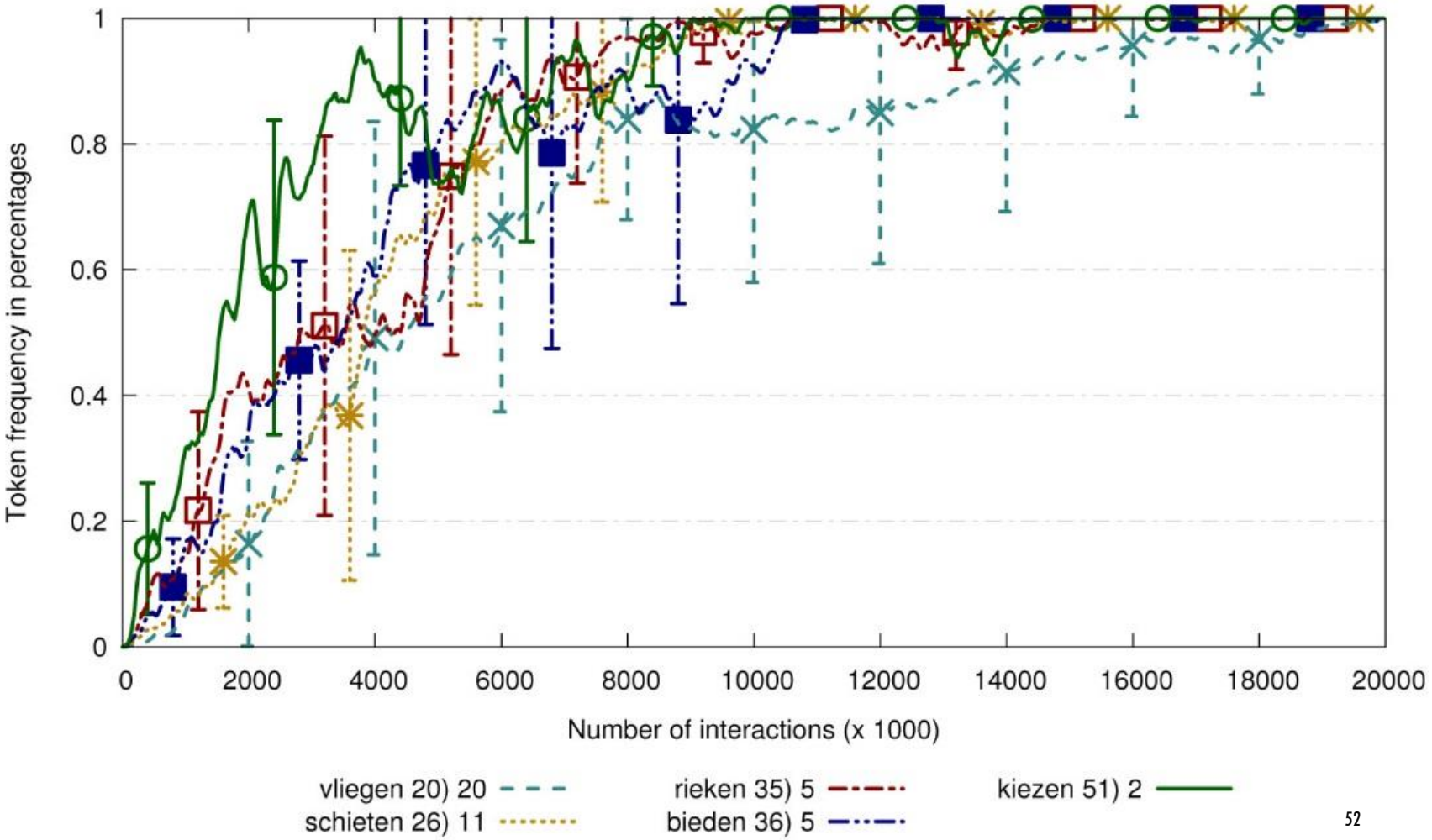
CLASS I, HIGHER FREQUENCY VERBS



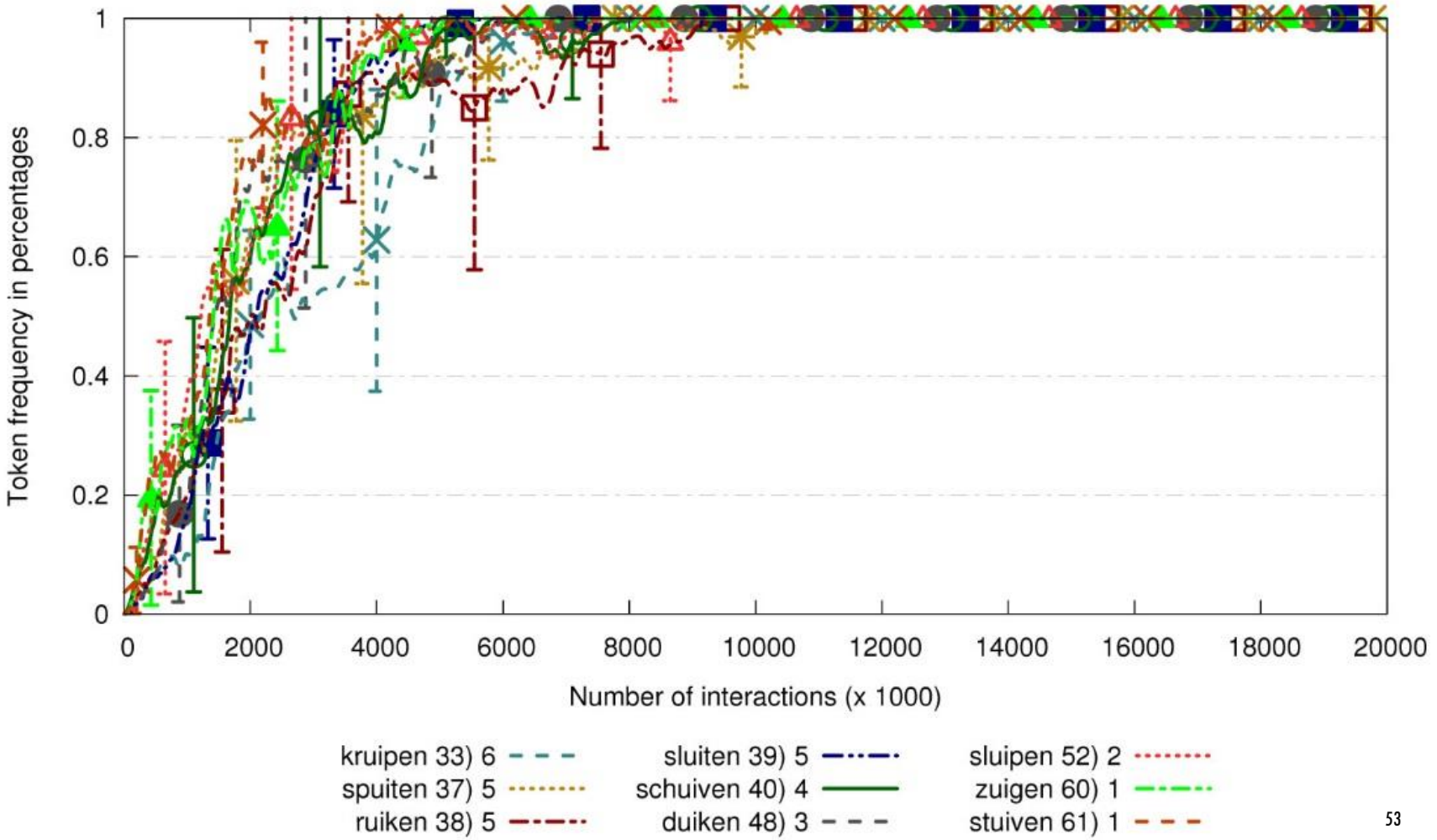
CLASS I, LOWER FREQUENCY VERBS



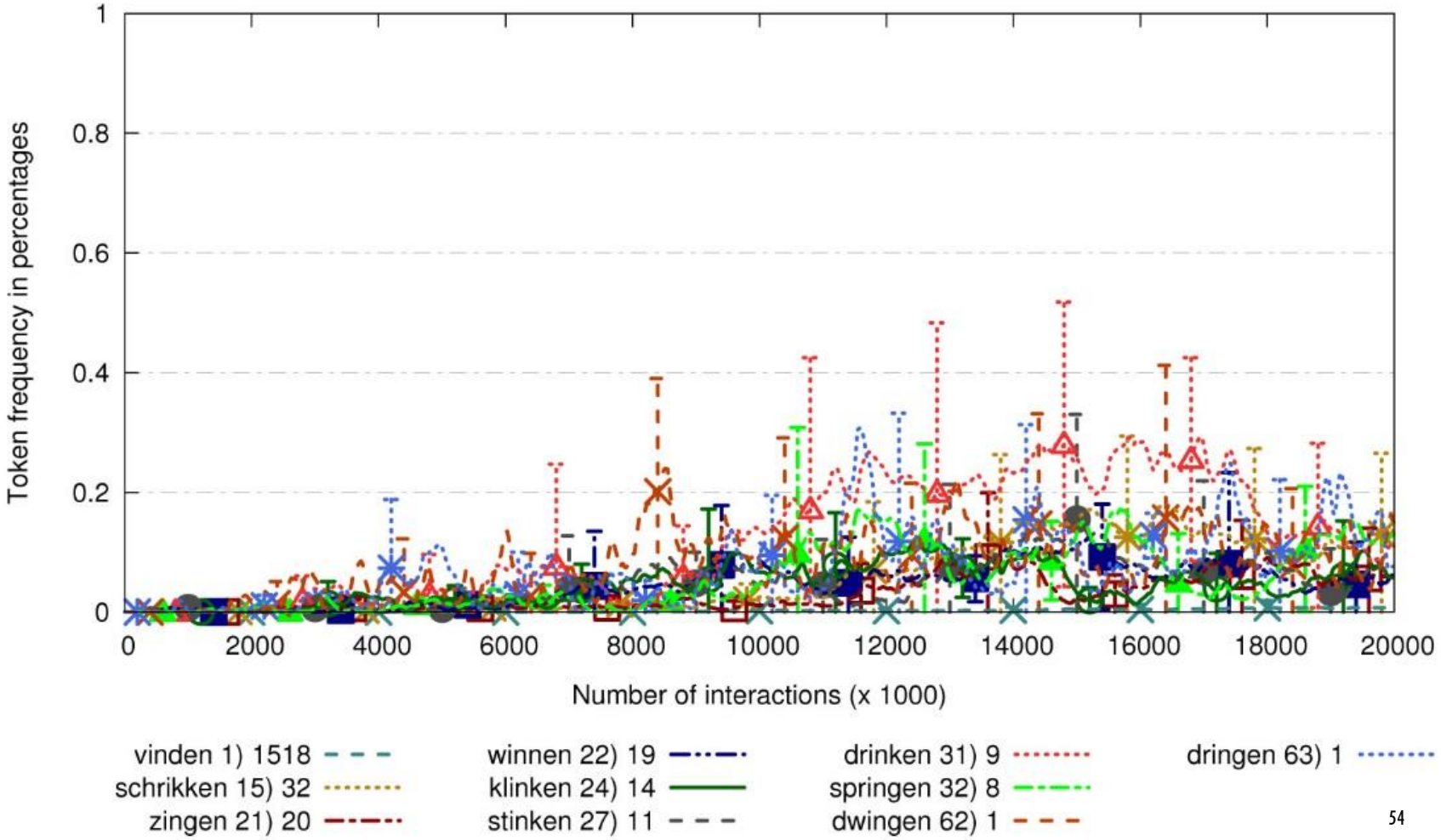
CLASS II-A


Token frequency in percentages
0
0.2
0.4
0.6
0.8
1
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Number of interactions (x 1000)
vliegen 20) 20
schieten 26) 11
rieken 35) 5
bieden 36) 5
kiezen 51) 2

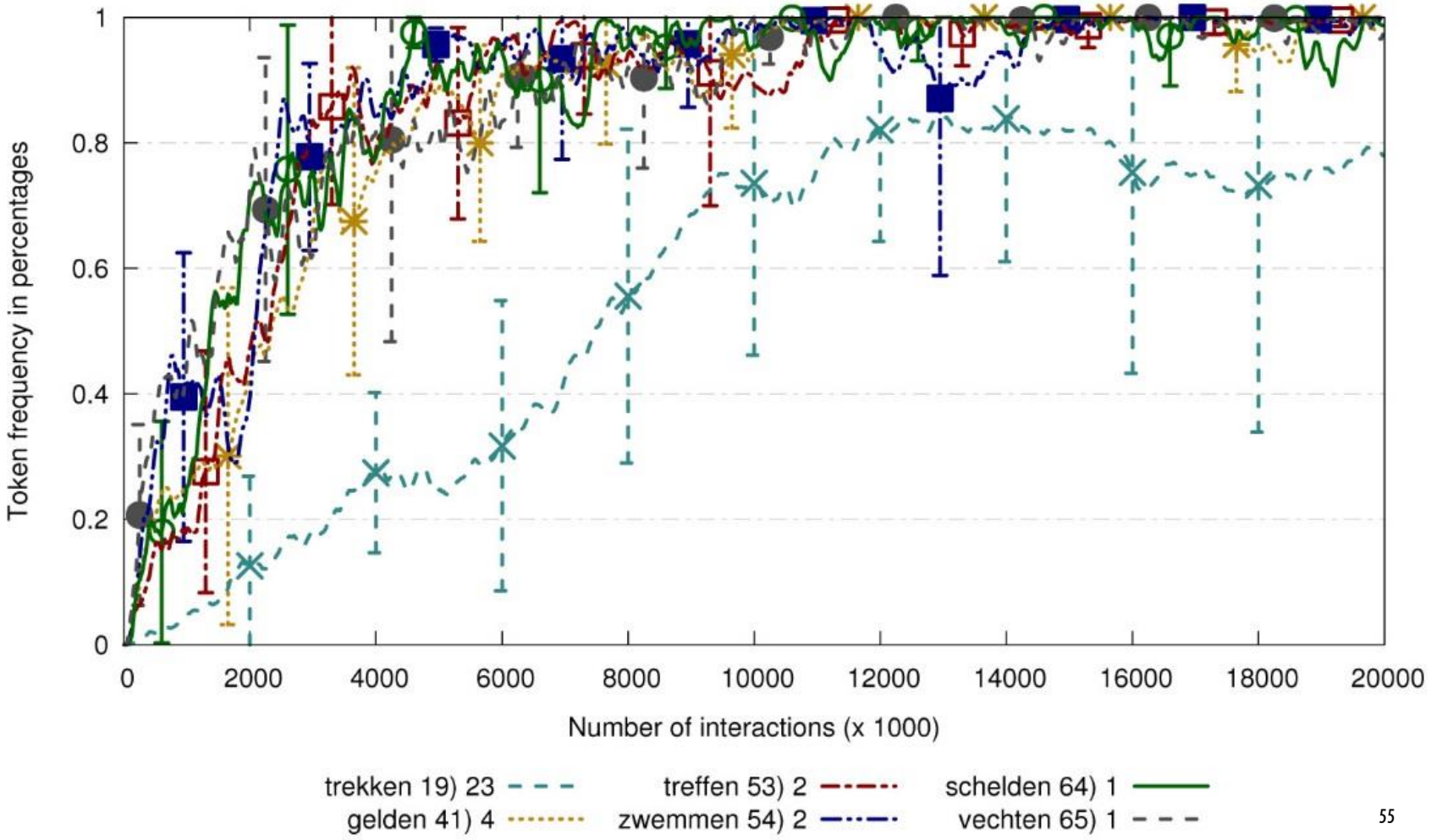
CLASS II-B


Token frequency in percentages
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Number of interactions (x 1000)
kruipen 33) 6
spuiten 37) 5
ruiken 38) 5
sluiten 39) 5
schuiven 40) 4
duiken 48) 3
sluipen 52) 2
zuigen 60) 1
stuiven 61) 1

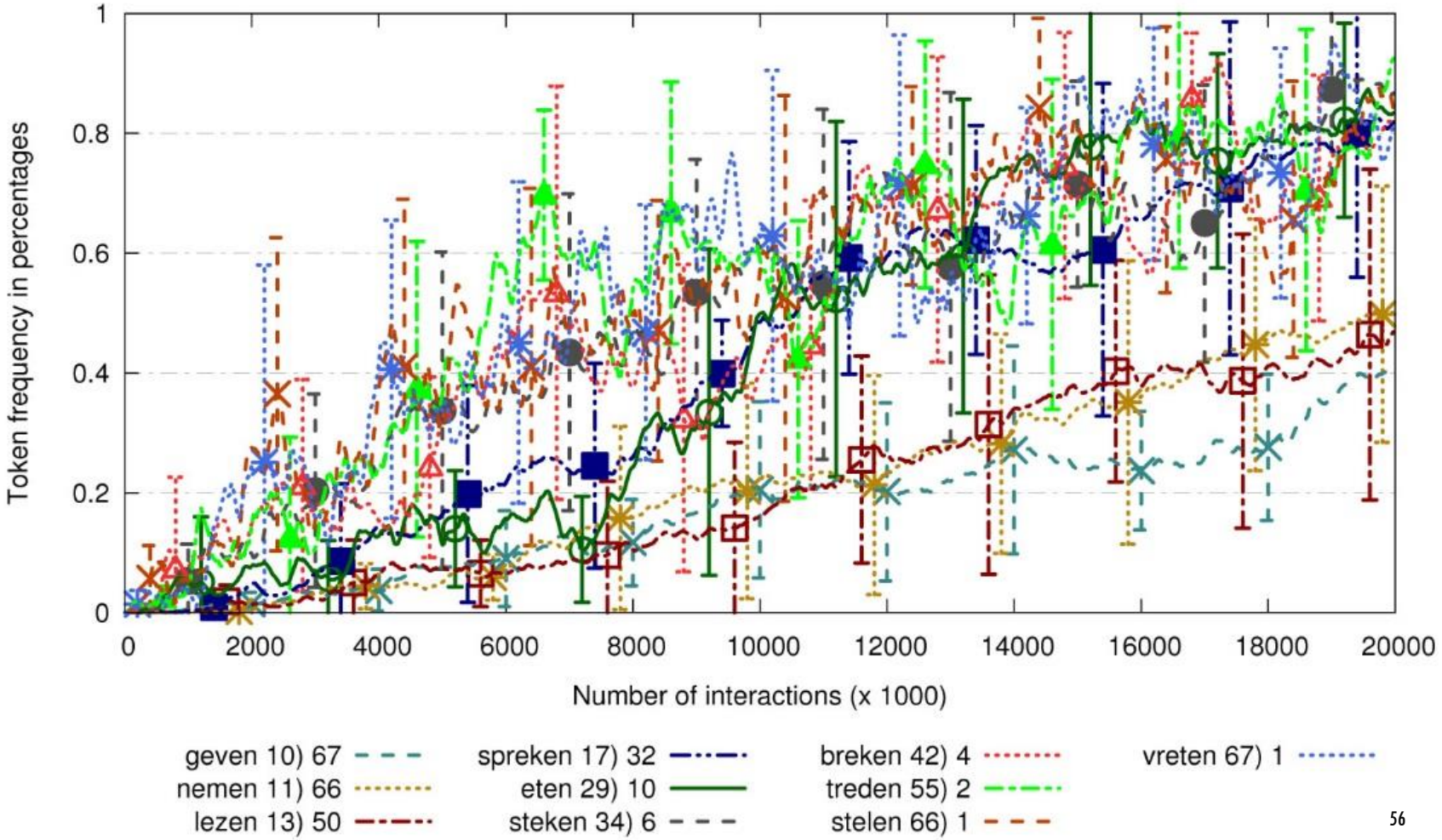
CLASS III-A


Token frequency in percentages
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Number of interactions (x 1000)
vinden 1) 1518
schrikken 15) 32
zingen 21) 20
winnen 22) 19
klinken 24) 14
stinken 27) 11
drinken 31) 9
springen 32) 8
dwingen 62) 1
dringen 63) 1

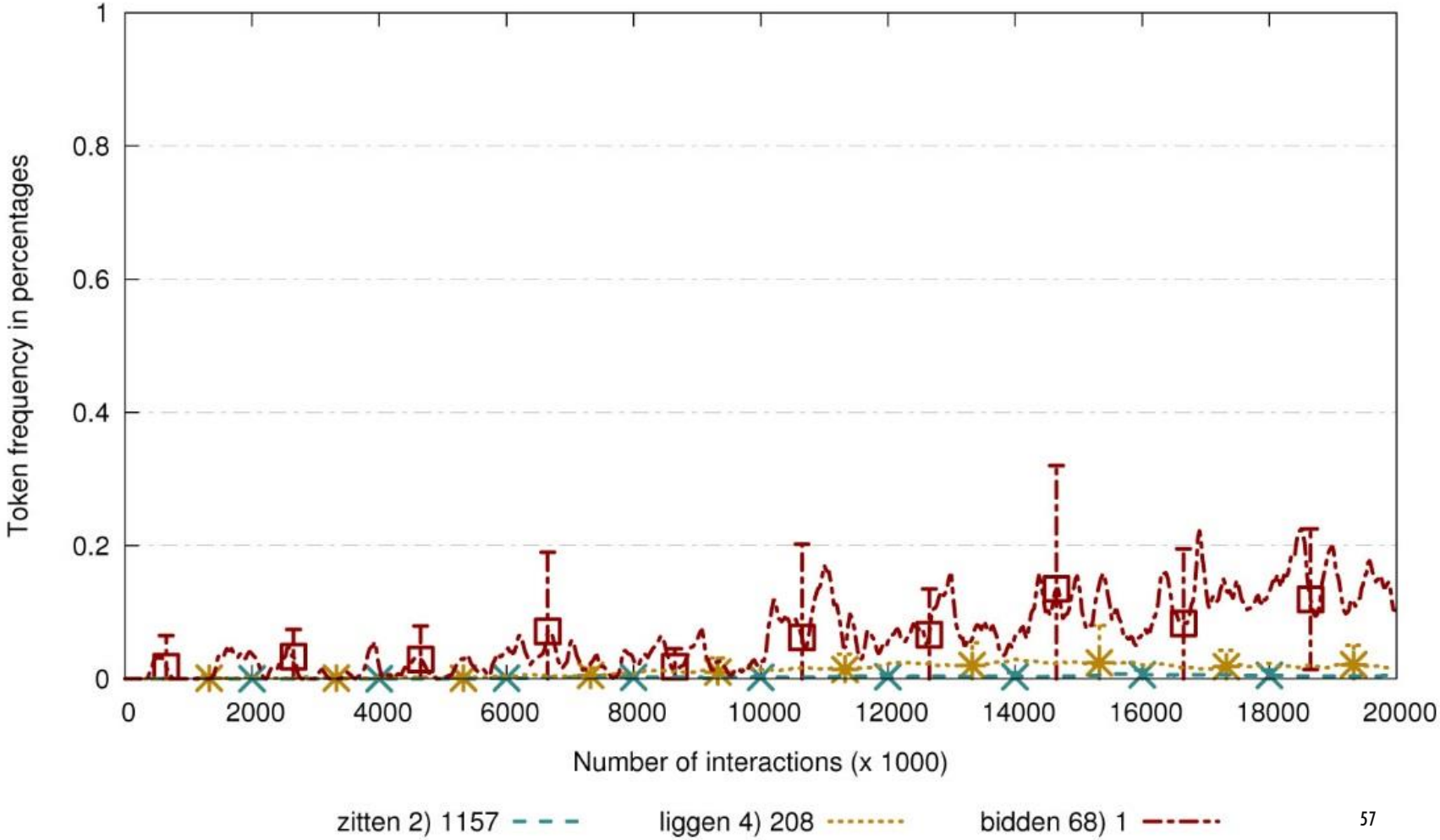
CLASS III-B


Token frequency in percentages
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Number of interactions (x 1000)
trekken 19) 23
gelden 41) 4
treffen 53) 2
zwemmen 54) 2
schelden 64) 1
vechten 65) 1

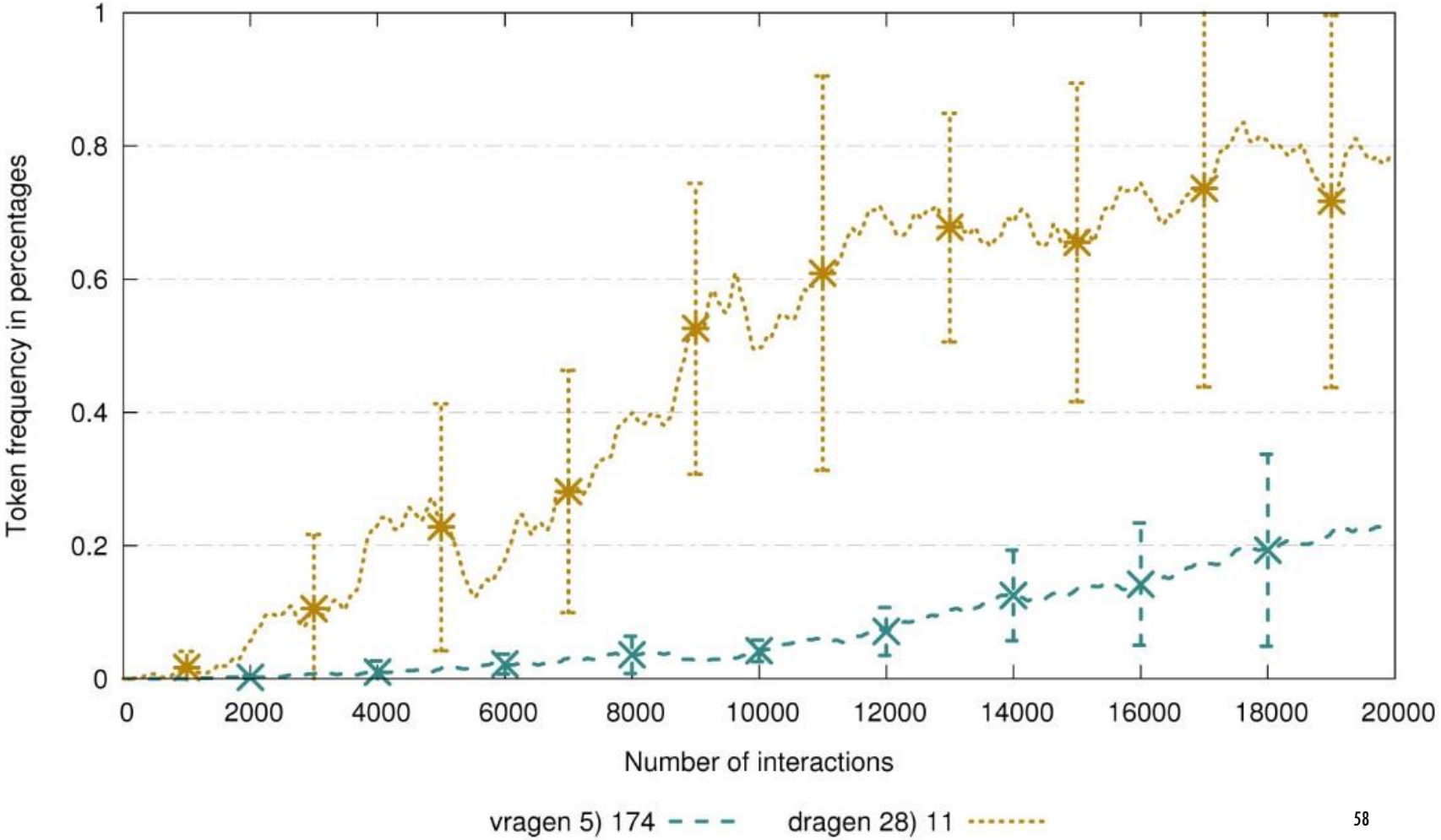
CLASS IV/V-A


Token frequency in percentages
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Number of interactions (x 1000)
geven 10) 67
nemen 11) 66
lezen 13) 50
spreken 17) 32
eten 29) 10
steken 34) 6
breken 42) 4
treden 55) 2
stelen 66) 1
vreten 67) 1

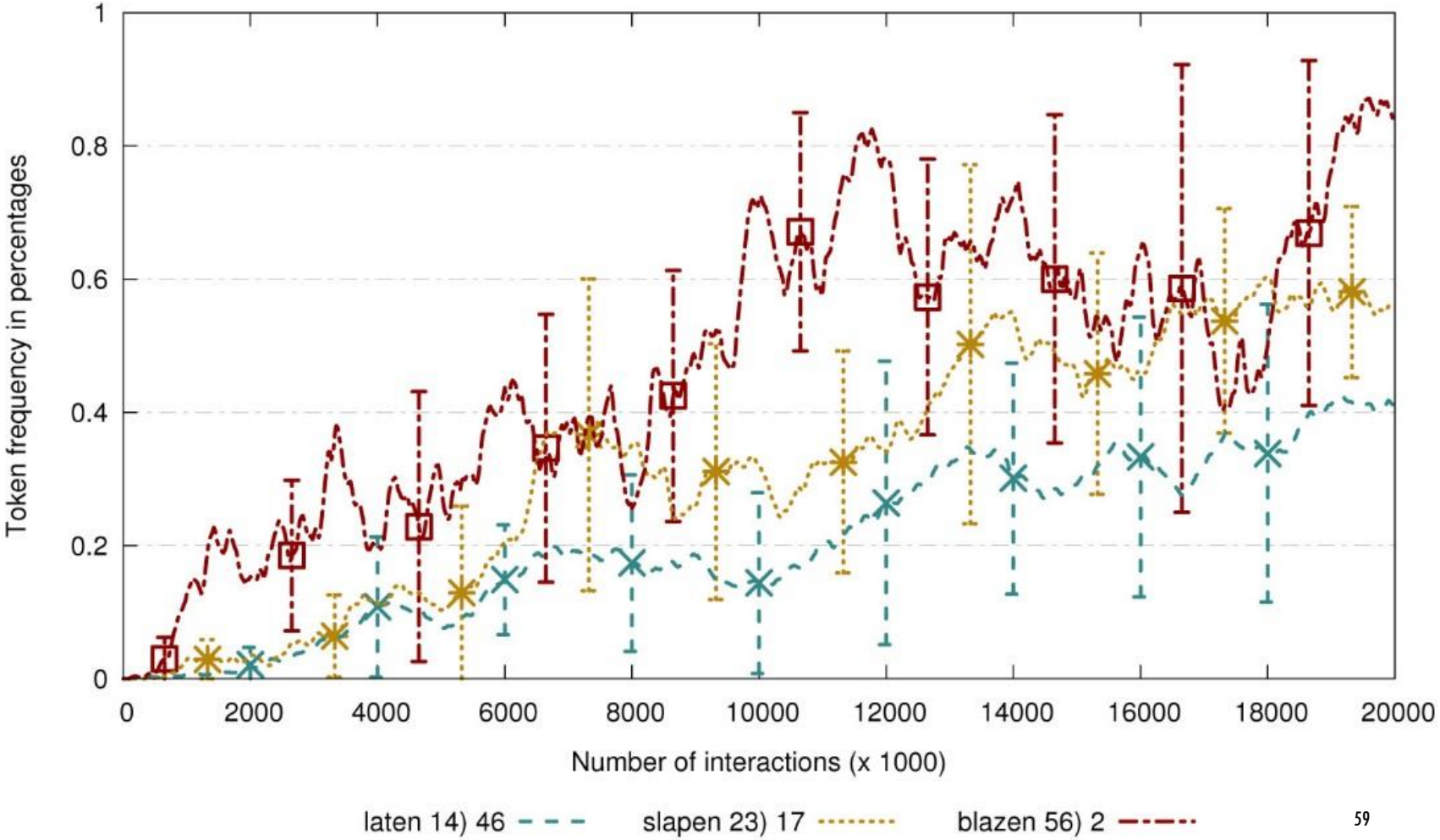
CLASS V-B


Token frequency in percentages
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Number of interactions (x 1000)
zitten 2) 1157
liggen 4) 208
bidden 68) 1

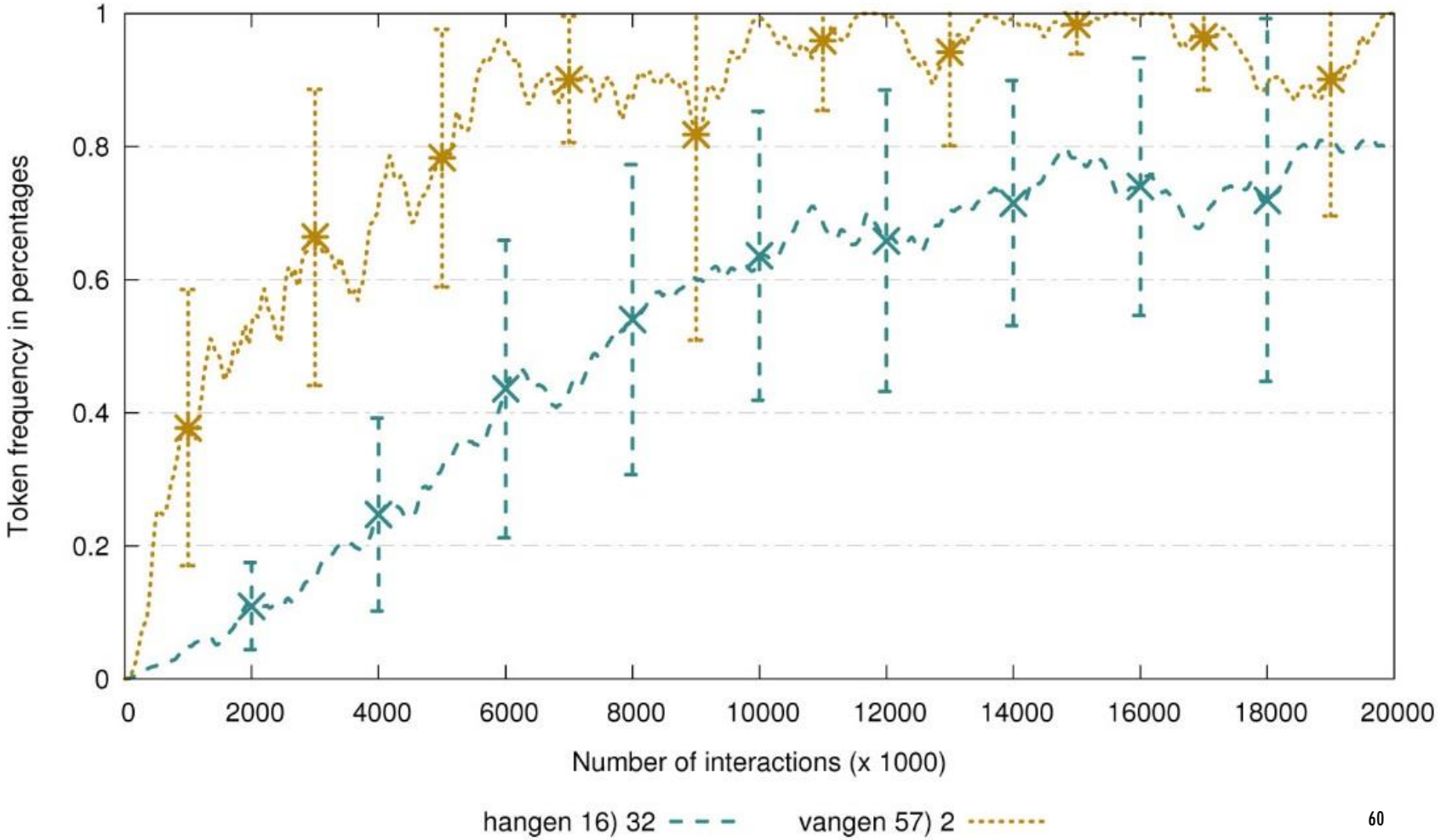
CLASS VI


Token frequency in percentages
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Number of interactions
vragen 5) 174
dragen 28) 11

CLASS VII-A


Token frequency in percentages
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Number of interactions (x 1000)
laten 14) 46
slapen 23) 17
blazen 56) 2

CLASS VII-B


Token frequency in percentages
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Number of interactions (x 1000)
hangen 16) 32
vangen 57) 2

WEAK INFLECTION