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WEAK VERSUS STRONG, DAVID VERSUS GOLIATH? A SIMULATION OF LANGUAGE USE

Dirk Pijpops, Katrien Beuls & Freek Van de Velde

GERMANIC PAST TENSE

- Strong inflection: classes of vowel alternations (Moonen 1706, p.140-141; Grimm 1819)

ij → ee	i → a	i → o	ee → a	….
kijk-keek	zit-zat	vind-vond	steek-stak	
lijd-leed	lig-lag	schrik-schrok	eet-at	
krijg-kreeg	bid-bad	zing-zong	breek-brak	
…		….	…	

- Weak inflection: dental suffix

+ de/te

lach-lachte
waai-waaide
praat-praatte
…

⇨ Both are regular

GERMANIC PAST TENSE

- Strong inflection
  - Oldest
  - Indo-European aspectual system
  - In decline
- Weak inflection
  - Youngest
  - Germanic innovation
  - On the rise
- Competition has been going on for thousands of years and still continues
  - *lach-loech, waai-woei, ? loop-loopte*
  - New verbs are conjugated weakly. Was not always the case: *schrijf-schreef*

GERMANIC PAST TENSE

- Clear why the weak inflection is winning now
  - Weak inflection has a much higher type frequency
  - Strong inflection is not all that regular

- However, neither was the case in Proto-Germanic

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)

EXPLANATIONS FOR THE SUCCESS OF THE WEAK SUFFIX

1. General applicability of the weak suffix

2. Restrictions on the strong system

3. Disintegration of the strong system

(Ball 1968: 164; Bailey 1997: 17)

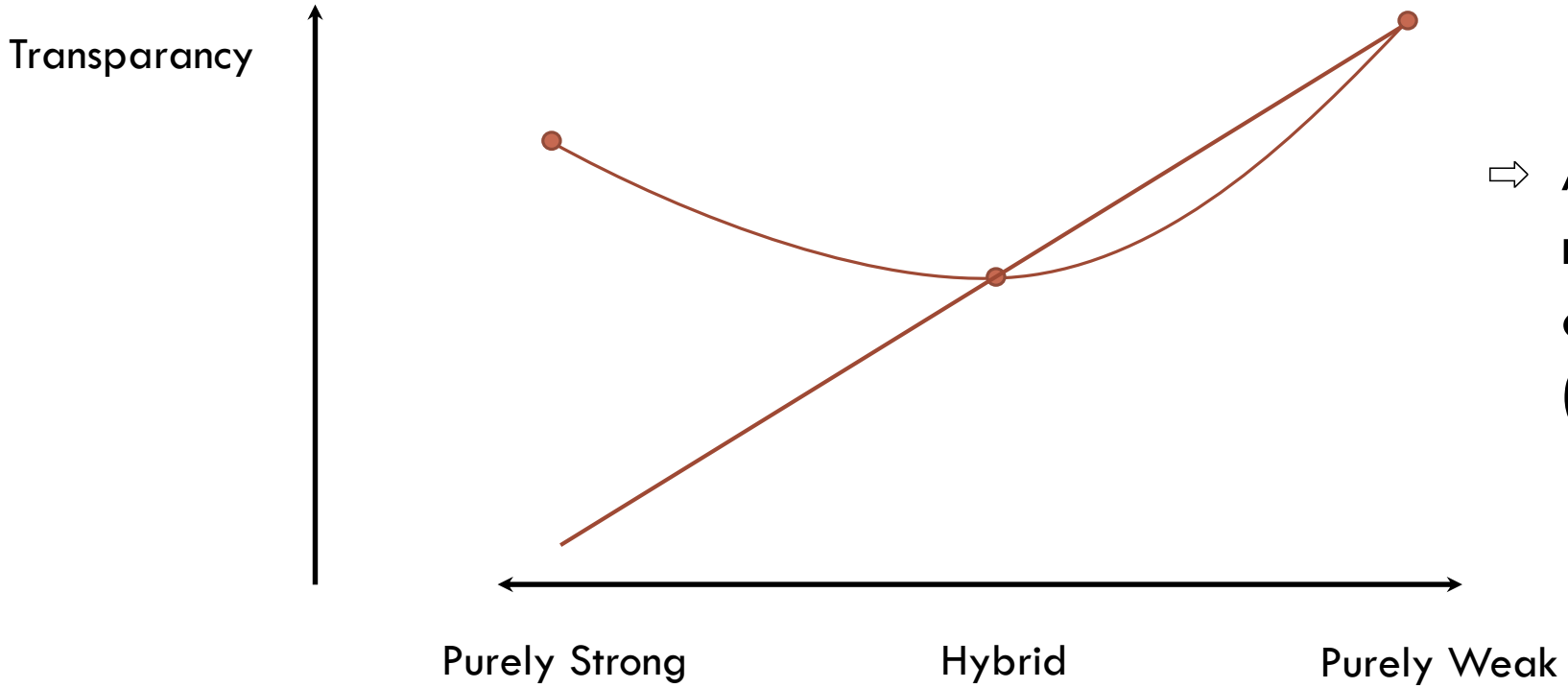
EXPLANATIONS FOR THE SUCCESS OF THE WEAK SUFFIX

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

(Ball 1968: 164; Bailey 1997: 17)

ARGUMENTS AGAINST GENERAL APPLICABILITY AS A SUFFICIENT EXPLANATION

1. What's the point of a special feature if you don't use it? The addition of the weak inflection only complicates our past tense system, e.g. *ijken* ('to calibrate')



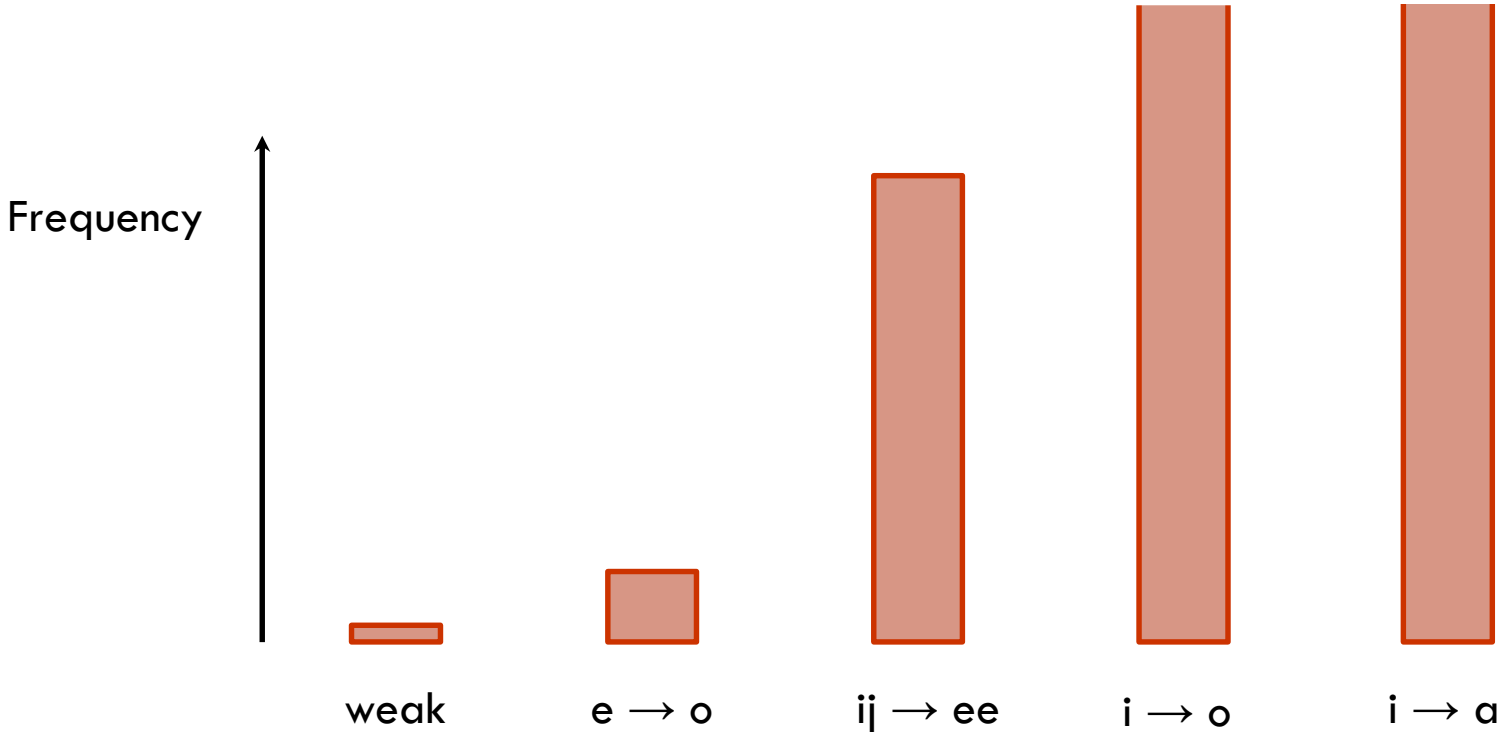
⇨ Additional assumption needed: disintegration of the strong system (e.g. *houd-hield)*

WEAK SUFFIX

MAKE GERMANIC PAST TENSE FORMATION GREAT AGAIN!

ARGUMENTS AGAINST GENERAL APPLICABILITY AS A SUFFICIENT EXPLANATION

2. For a language user, general applicability is only useful if there are any verbs which he/she cannot (yet) conjugate strongly
   - And even in that case, if every strong class is still more frequent, it will always be preferred



⇨ Additional assumption needed: for some verbs, there was no strong alternative

How do we get out of this yes-no discussion?

Option 1: Give up

Option 2: Build a simulation

⇨ Build a simulation, assuming only that

1. The weak suffix is generally applicable

while not assuming that

2. There are any restrictions on the strong system
3. The strong system is disintegrating

⇨ Can we see a rise of the weak inflection in the simulation?

WOULD THIS PROVE THAT GENERAL APPLICABILITY ALONE CAUSED THE RISE OF THE WEAK INFLECTION?

NO

ABSOLUTELY NOT

The only thing a computer simulation can show, is whether something is possible, NOT whether something is real

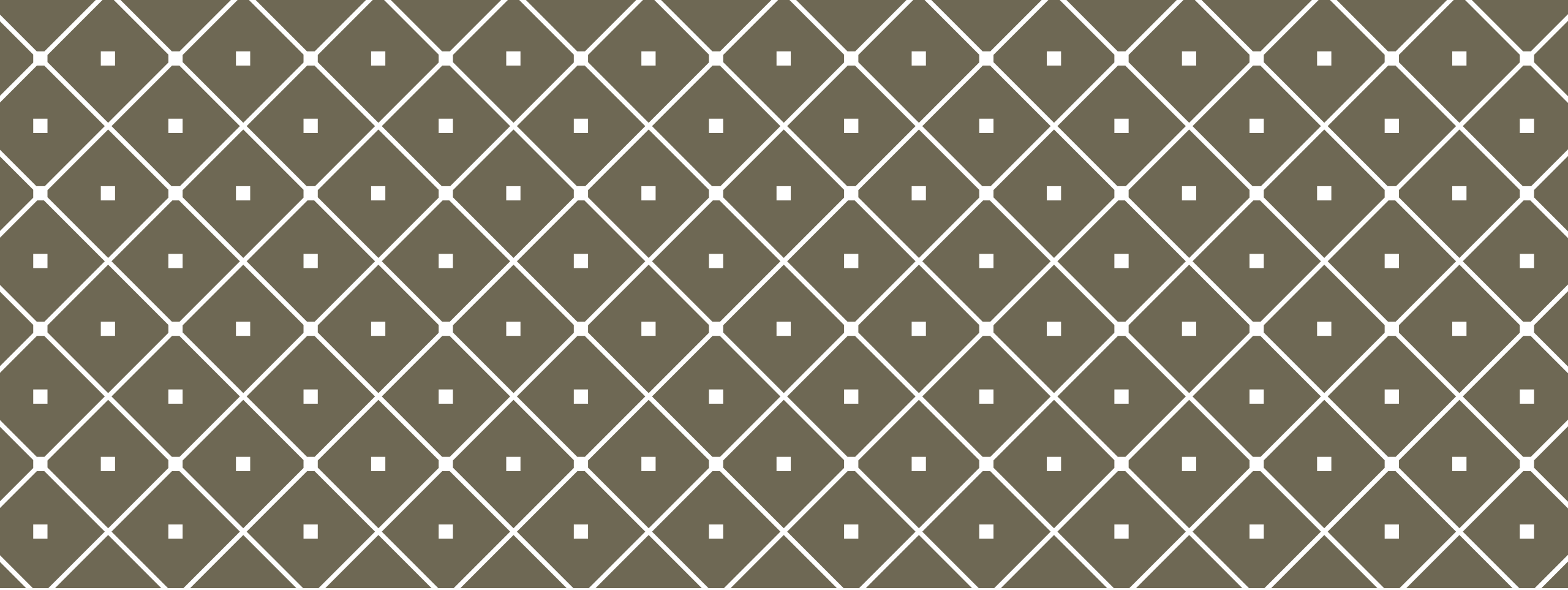
OCKHAM'S RAZOR

Heuristic: given two or more possible explanations for the same effect, choose the one that makes the fewest assumptions.

HOW TO REBUT OUR SIMULATION?

Build a simulation that

- Explains the same, using fewer assumptions
- Explains more, using the same assumptions



DESIGN THE SIMULATION: CONCEPTUAL LEVEL

DESIGN THE SIMULATION AT A CONCEPTUAL LEVEL

- What do we put it?
- What do we not put in?
- How do we decide whether it is succesful or not?

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 strong 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

    draag-de ‘draag + PAST’

    dr-ie-g ‘draag + PAST’
  - ↳ No social structure or social preference

IS ANY OF THIS REALISTIC?

ABSOLUTELY NOT

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

⇨ Goal is NOT to build a realistic simulation, but to explain as much as possible using as few assumptions as possible

KEEP IT SIMPLE STUPID

- Only finite past tenses
- No influence of phonetic resemblance

(Landsbergen 2009: 18-19)

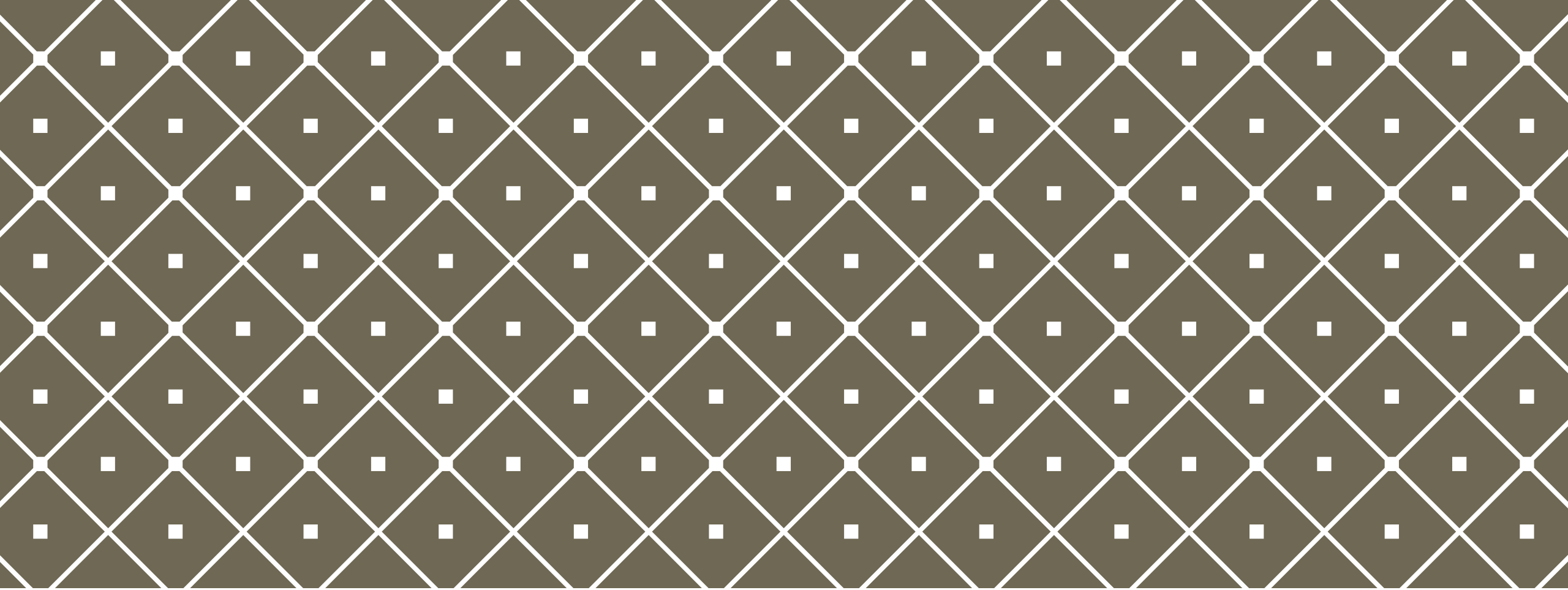
HOW DO WE DECIDE WHETHER IT IS SUCCESSFUL OR NOT?

Evaluation criteria: General applicability can explain

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



DESIGN THE SIMULATION: IMPLEMENTATION

IMPLEMENT THE SIMULATION IN COMPUTER CODE

- Choose an environment/language
- Get a functioning strong system
- Get a number of verbs to be expressed
- Define an interaction between language users
- Define a starting situation

CHOOSE AN ENVIRONMENT/LANGUAGE

- Babel2: out-of-the-box framework for agent-based simulations of language (http://emergent-languages.org/Babel2/)

GET A FUNCTIONING STRONG SYSTEM

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

GET A NUMBER OF VERBS TO BE EXPRESSED

Verbs: extracted from Corpus of Spoken Dutch

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

vind	1518
zit	1157
krijg	359
lig	208
…	
stink	11
draag	11
eet	10
…	
bid	1

DEFINE AN INTERACTION BETWEEN LANGUAGE USERS

World	
vind	34%
zit	26%
…	…
draag	**0.25%**
sterf	0.20%
…	…
bid	0.02%

vind → vond 233

zit → zat 162

draag → droeg 9

draag → draagde 1

bid → bad 1

sterf → sterfde 3

droeg +1

droeg 90%

draagde 10%

droeg

speaker

hearer

World	
vind	34%
zit	26%
…	…
draag	**0.25%**
sterf	0.20%
…	…
bid	0.02%

vraag → vroeg 80

slaap → sliep 15

blaas → blies 3

sterf → sterfde 2

drieg +1

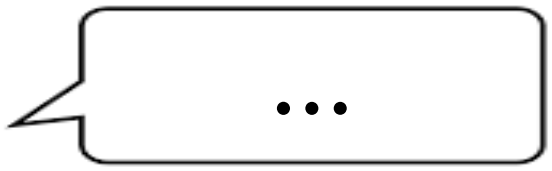
droeg 80%
drieg 18%
draagde 2%

drieg

speaker

hearer

World	
vind	34%
zit	26%
…	…
draag	**0.25%**
sterf	0.20%
…	…
bid	0.02%



speaker

hearer

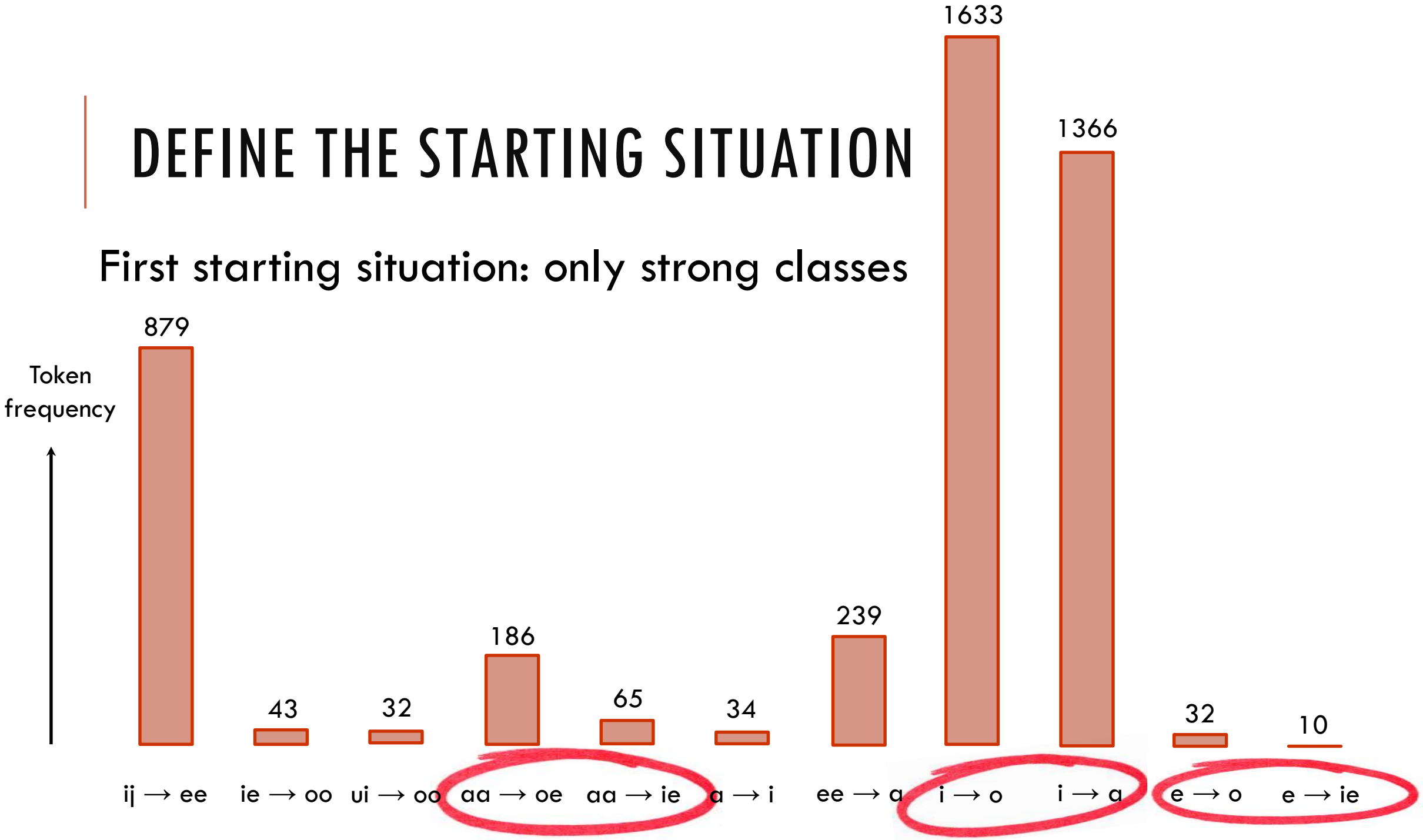
DEFINE THE STARTING SITUATION

First starting situation: only strong classes

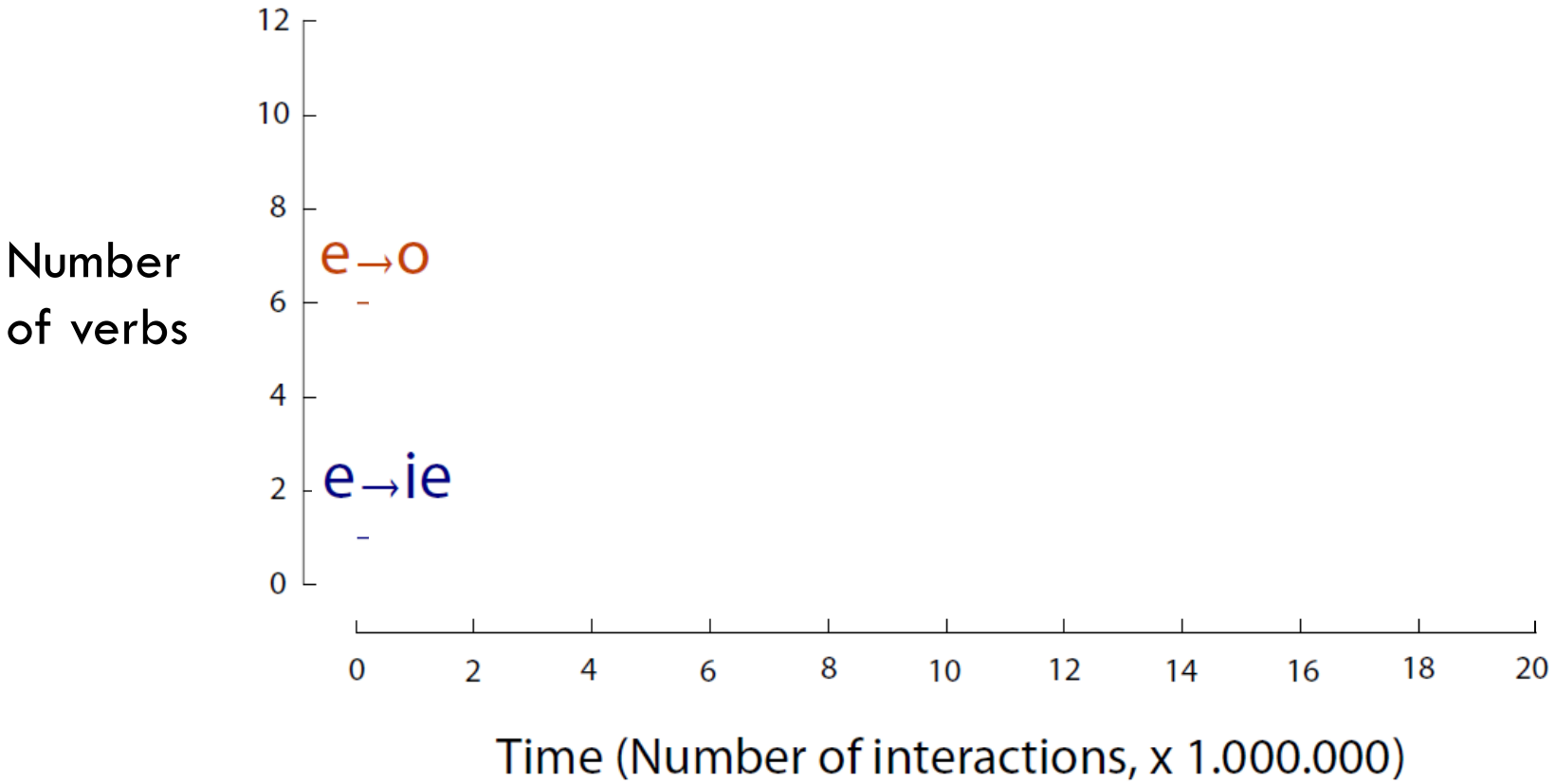
- All starting agents know perfectly how to conjugate each verb
- Have access to all strong classes
- Weak inflection does not exist

DEFINE THE STARTING SITUATION

First starting situation: only strong classes



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



⇨ Initial frequency fully determines outcome

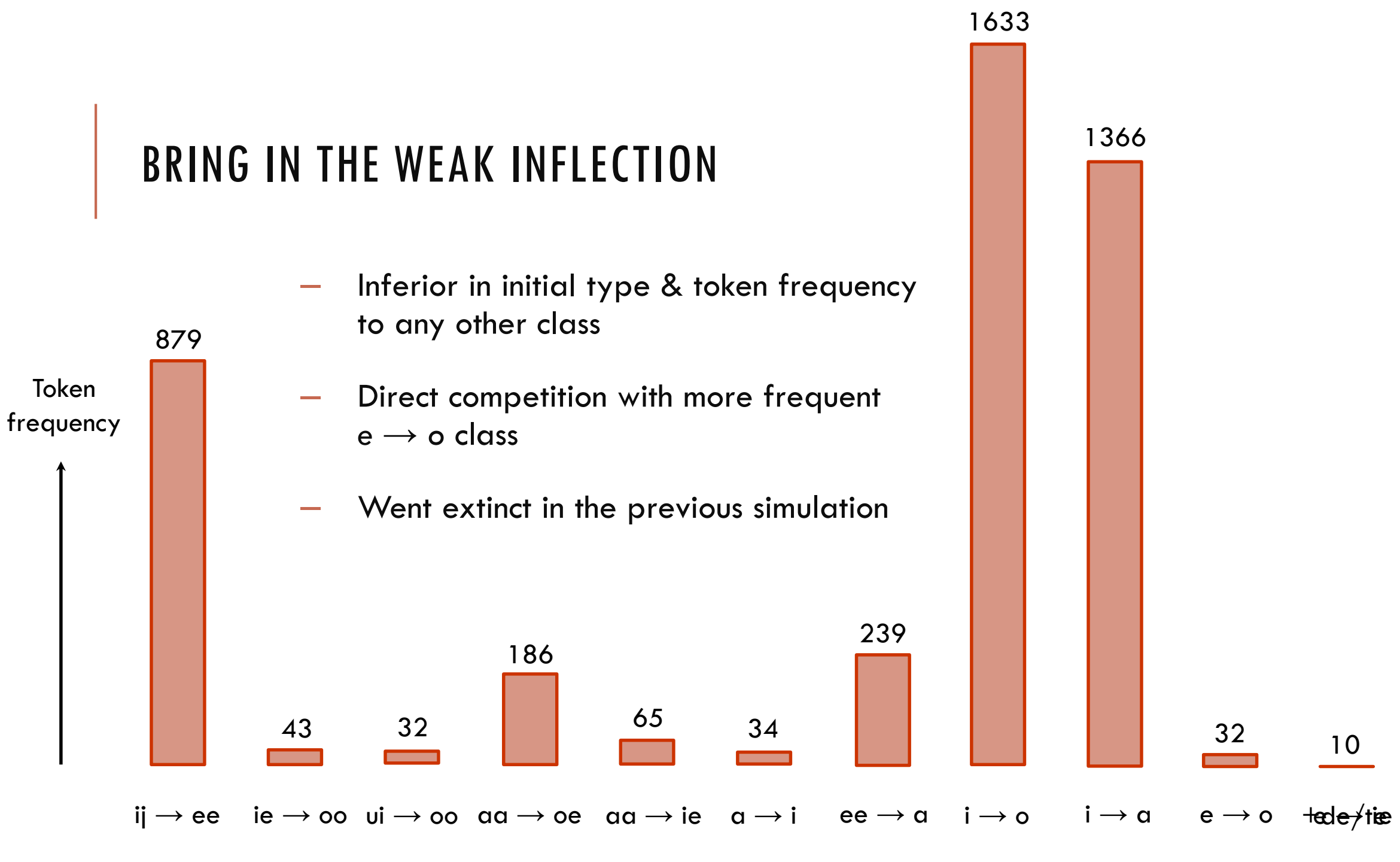
BRING IN THE WEAK INFLECTION

Starting position of the weak inflection

- ~~Preterito-presentia~~ (Bailey 1997: 578)
- Take the starting position of the feeblest strong class, i.e. e → *ie*

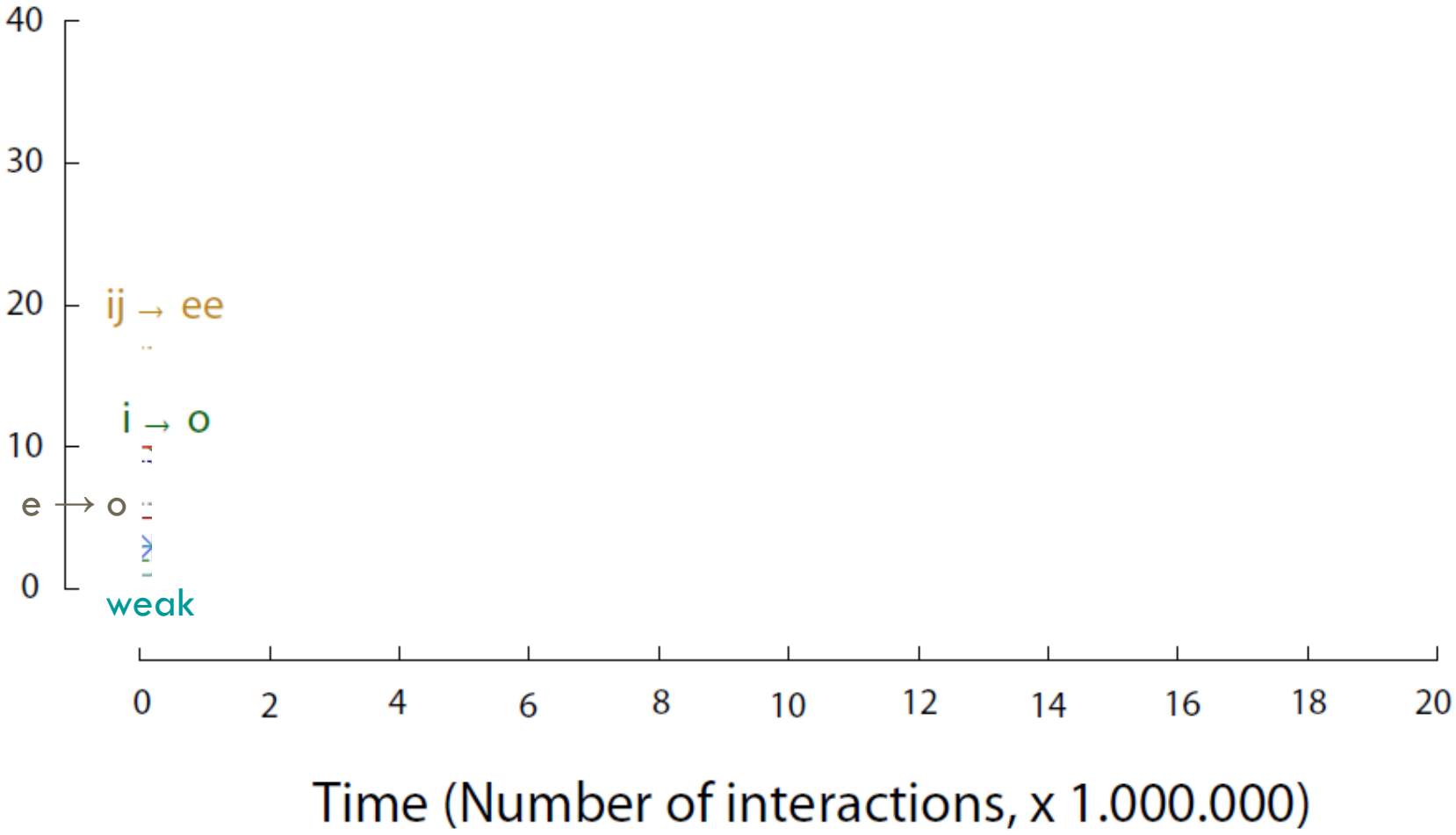
BRING IN THE WEAK INFLECTION

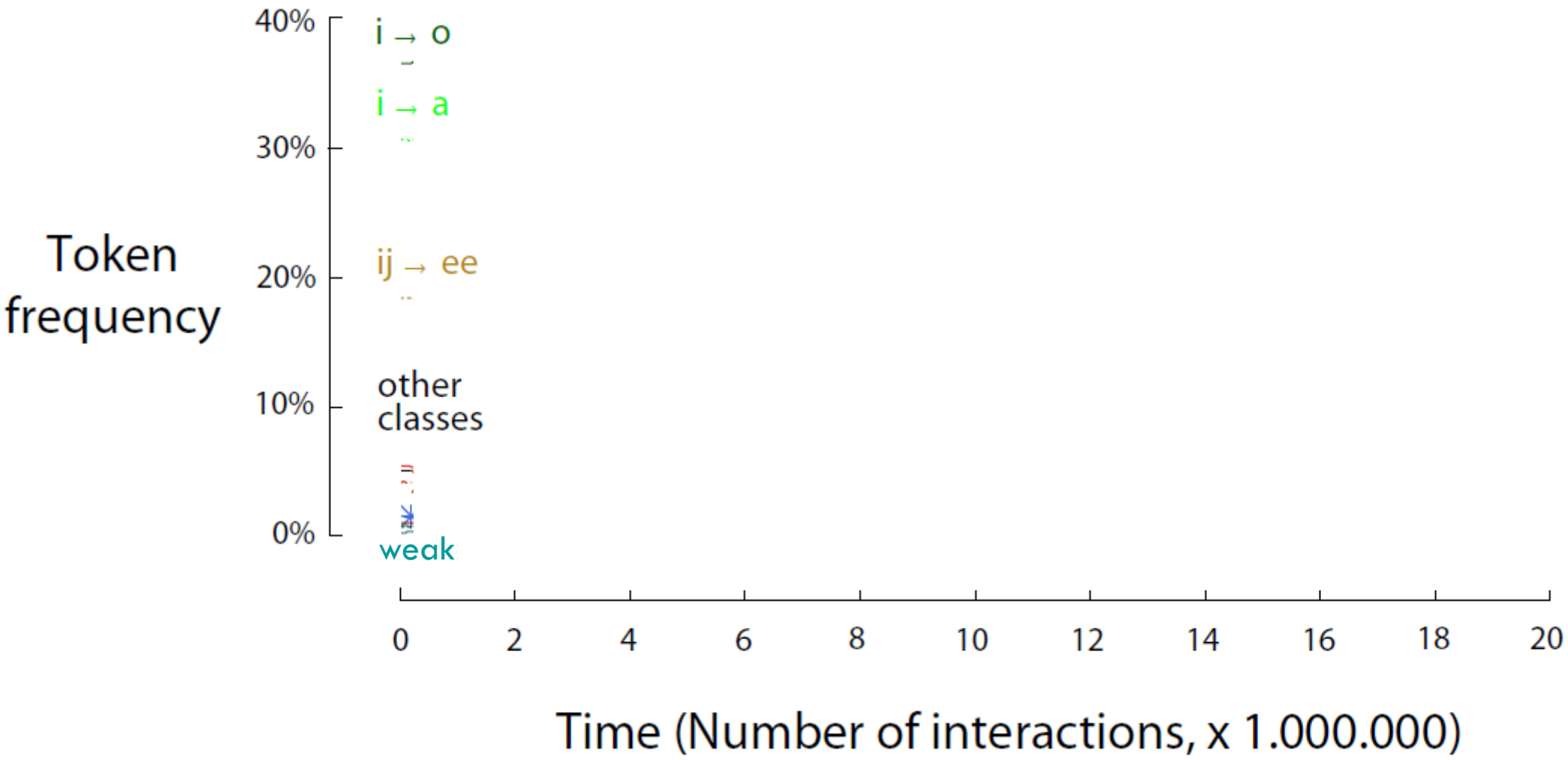
- Inferior in initial type & token frequency to any other class
- Direct competition with more frequent e → o class
- Went extinct in the previous simulation



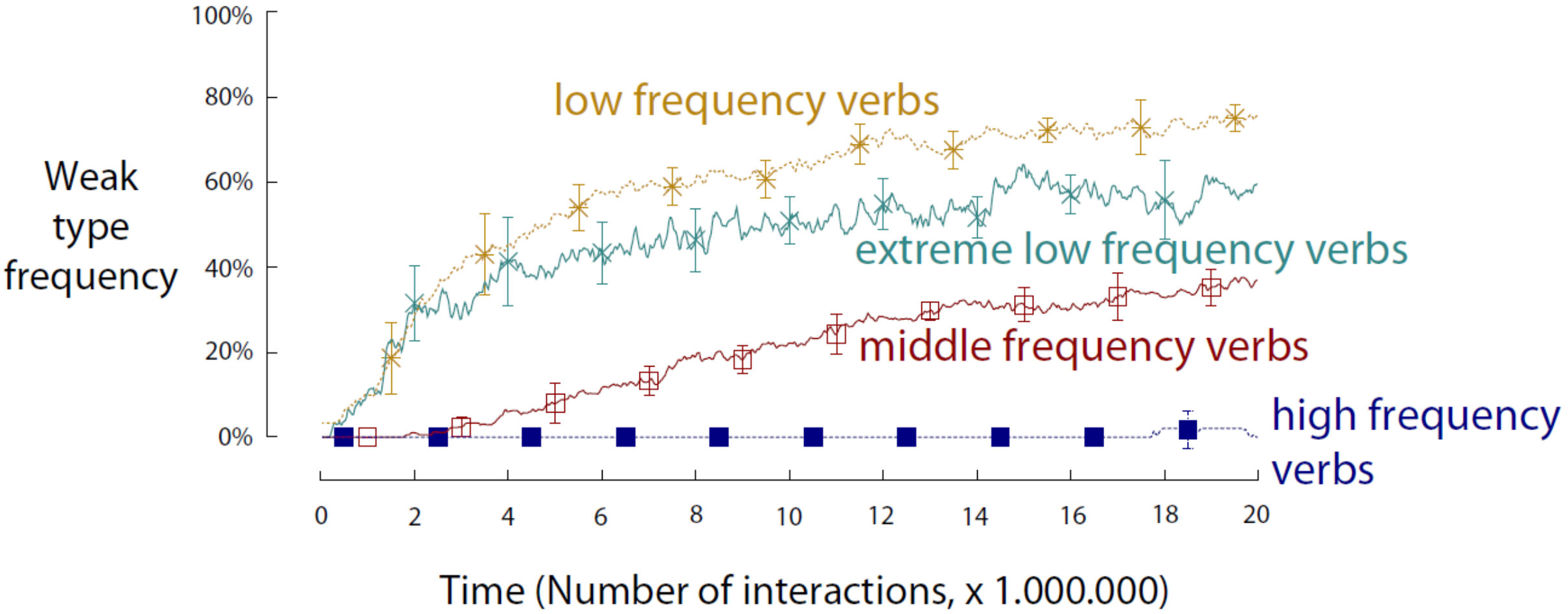
The only difference between the weak suffix and the e → *i*e class is that the weak suffix can in principle be applied to all verbs

Number of verbs

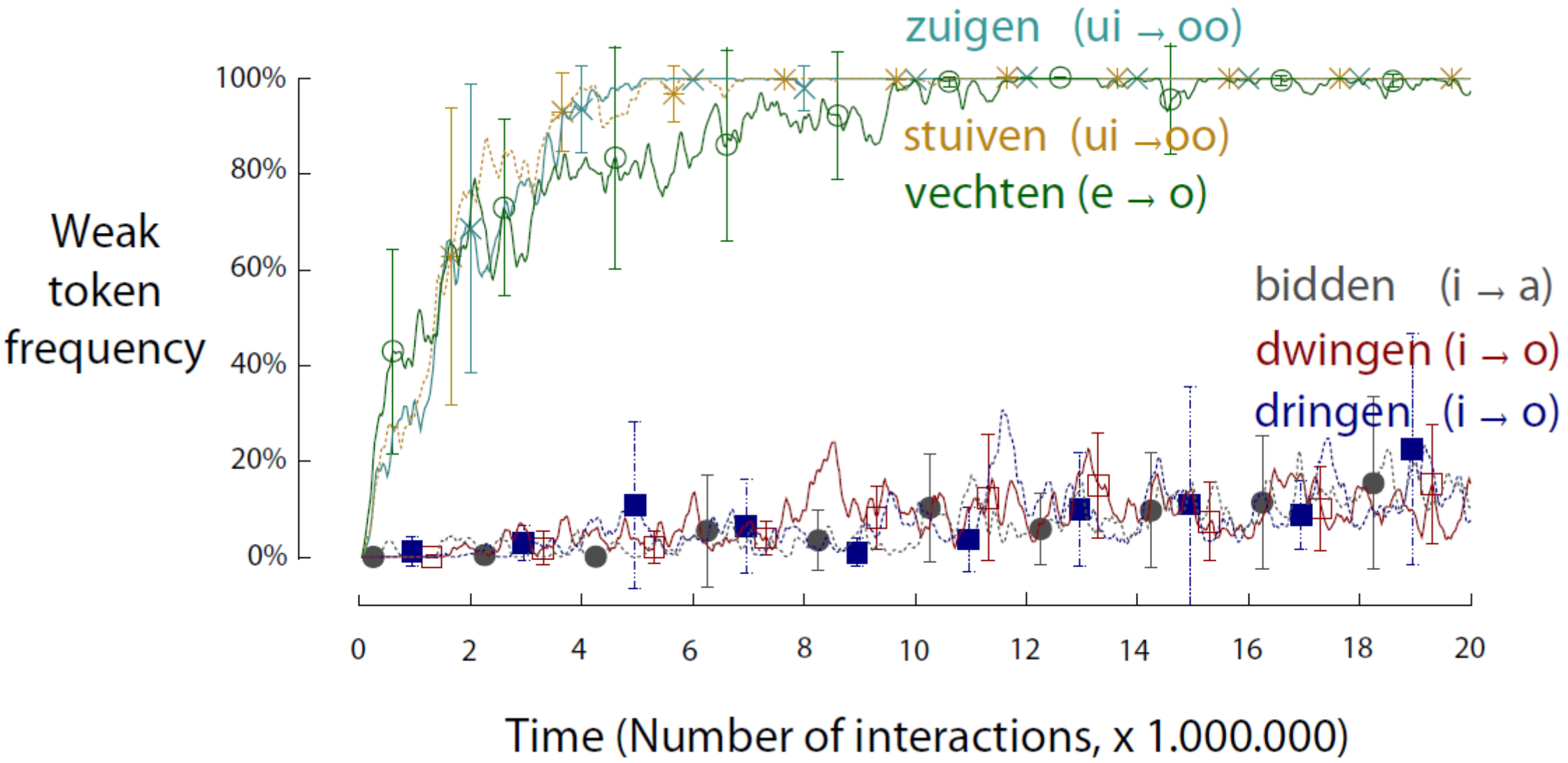




1. Rise of the Weak Inflection in type and token frequency
2. Gradual Rise



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

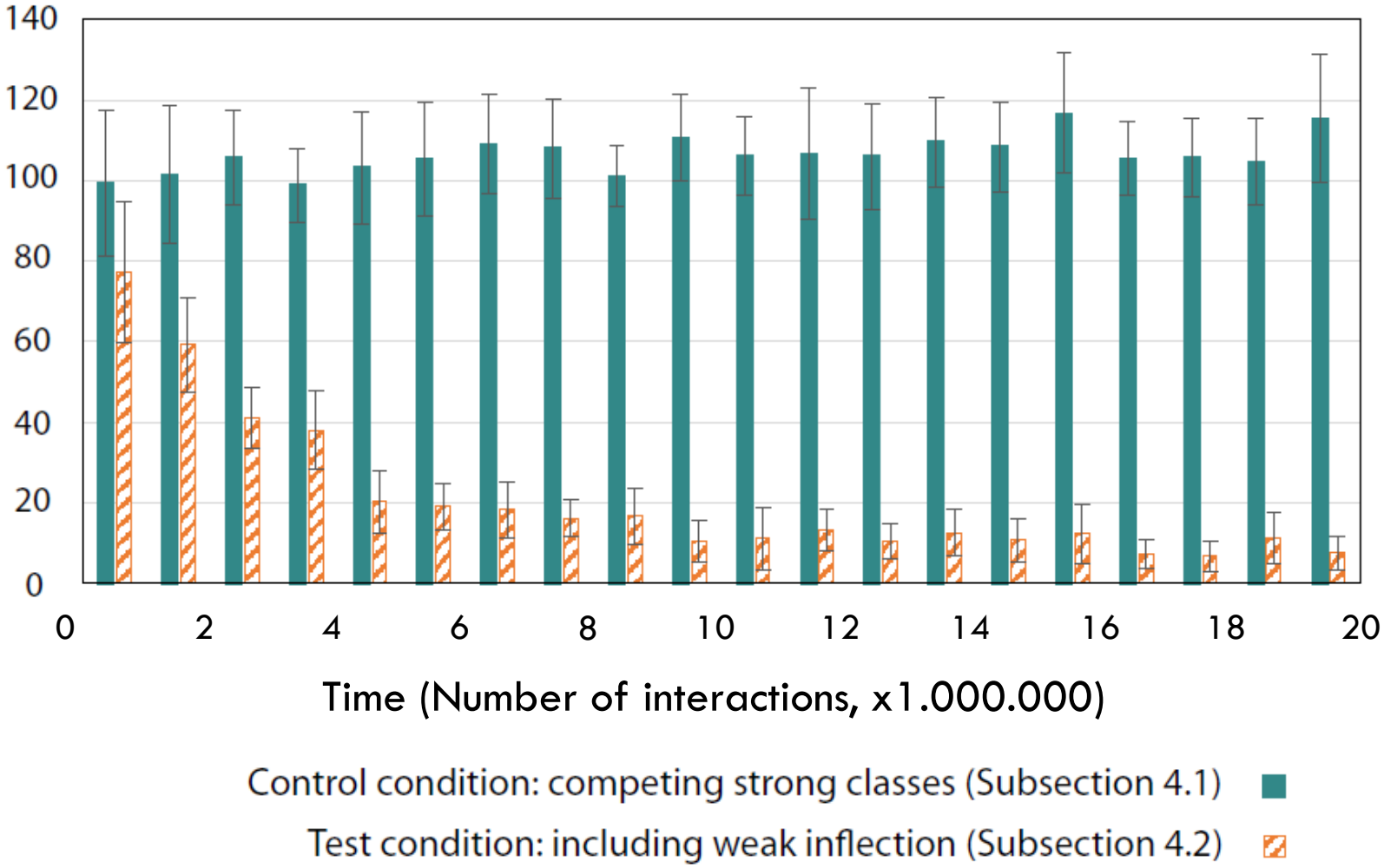
1. Addition of the weak inflection only complicates past tense inflection

Goal of language user ≠ to acquire the language flawlessly

= to communicate

1. Addition of the weak inflection only complicates past tense inflection

Failed communications during 1.000.000 interactions

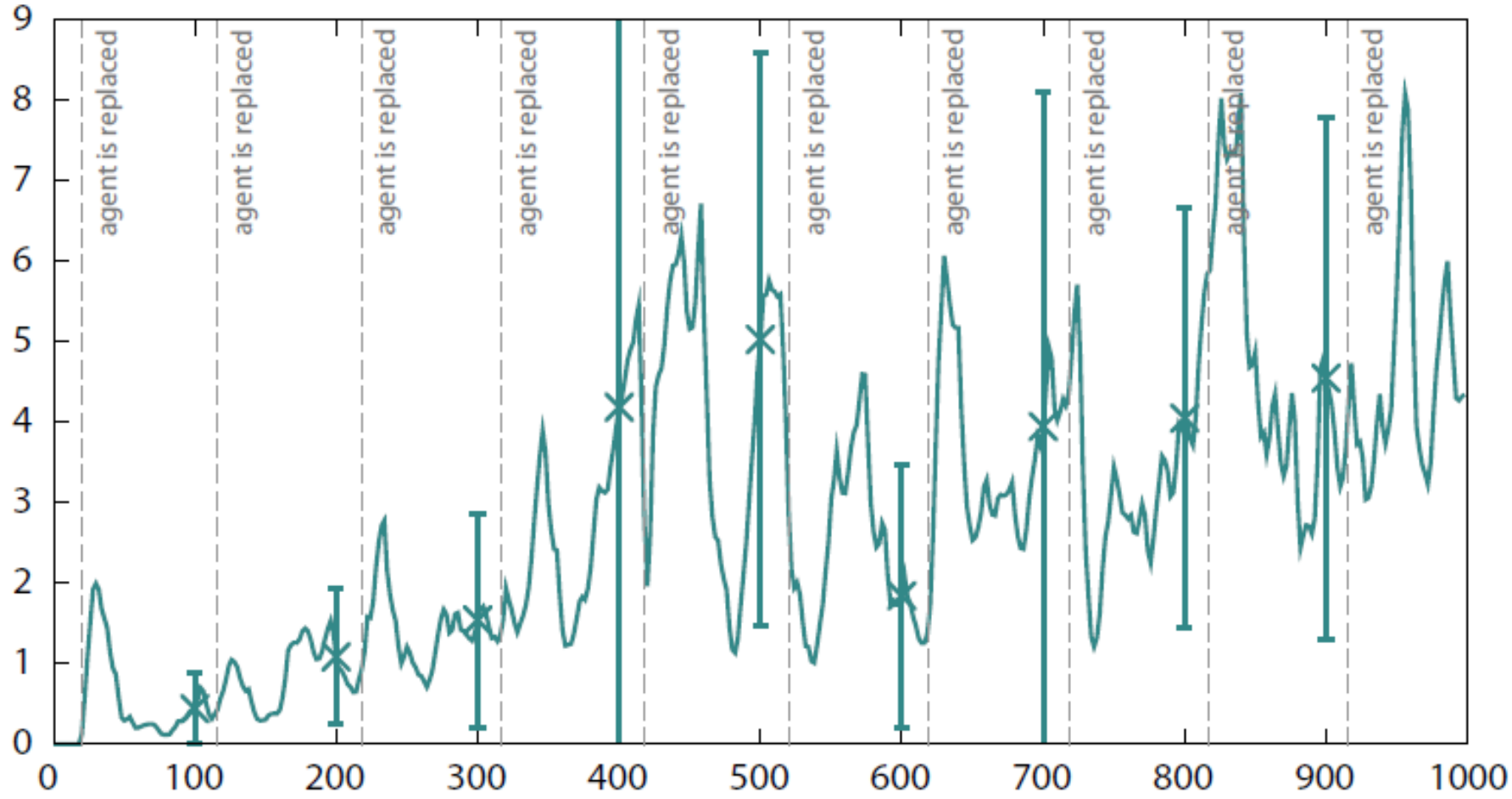


2. For a language user, general applicability is only useful if there are any verbs which he/she cannot (yet) conjugate strongly

True

2. For a language user, general applicability is only useful if there are any verbs which he/she cannot (yet) conjugate strongly

1 agent: 'incorrect' weak forms during 1000 interaction



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

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.

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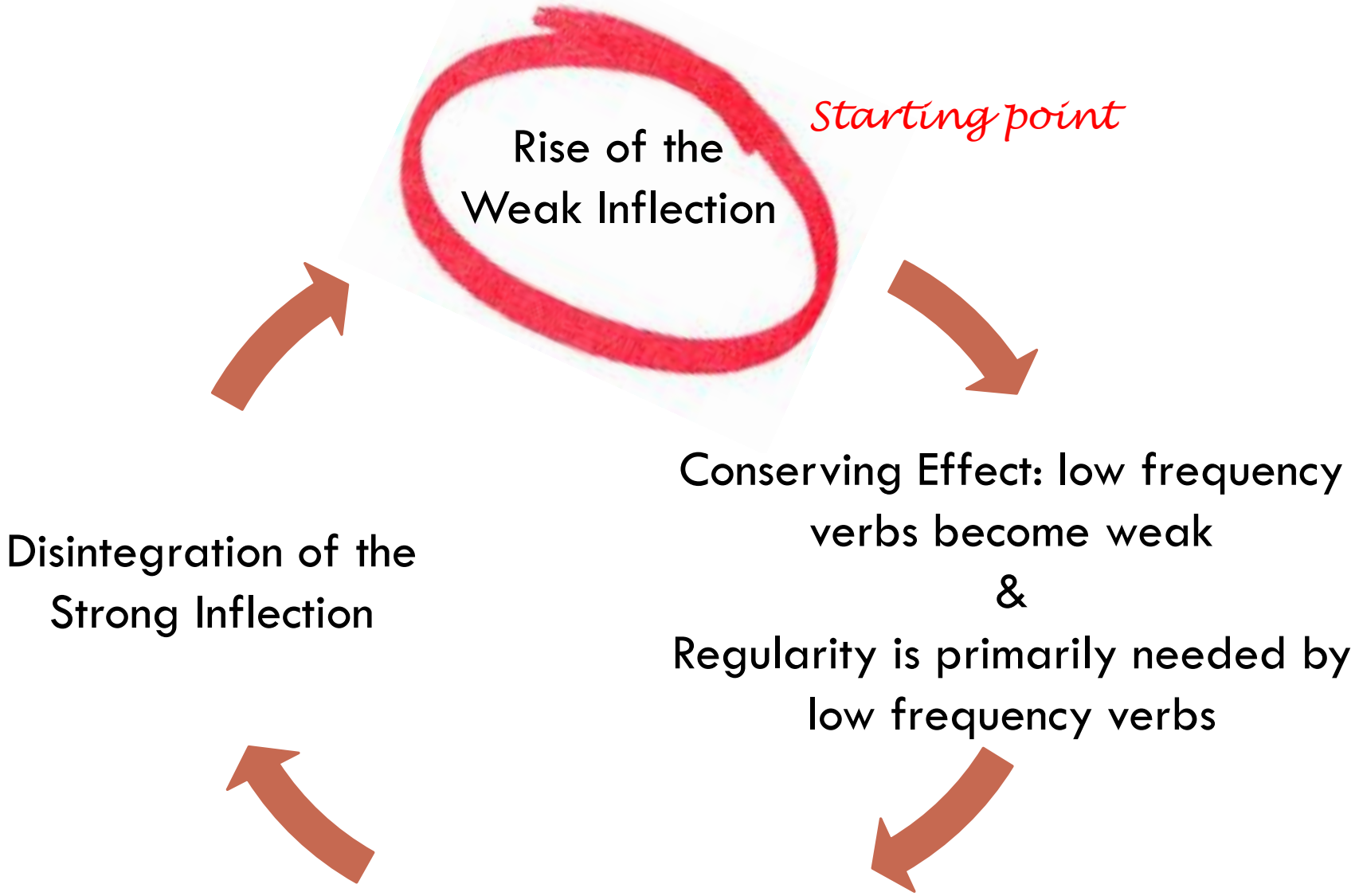
EXTRA SLIDES

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

PROPOSALS

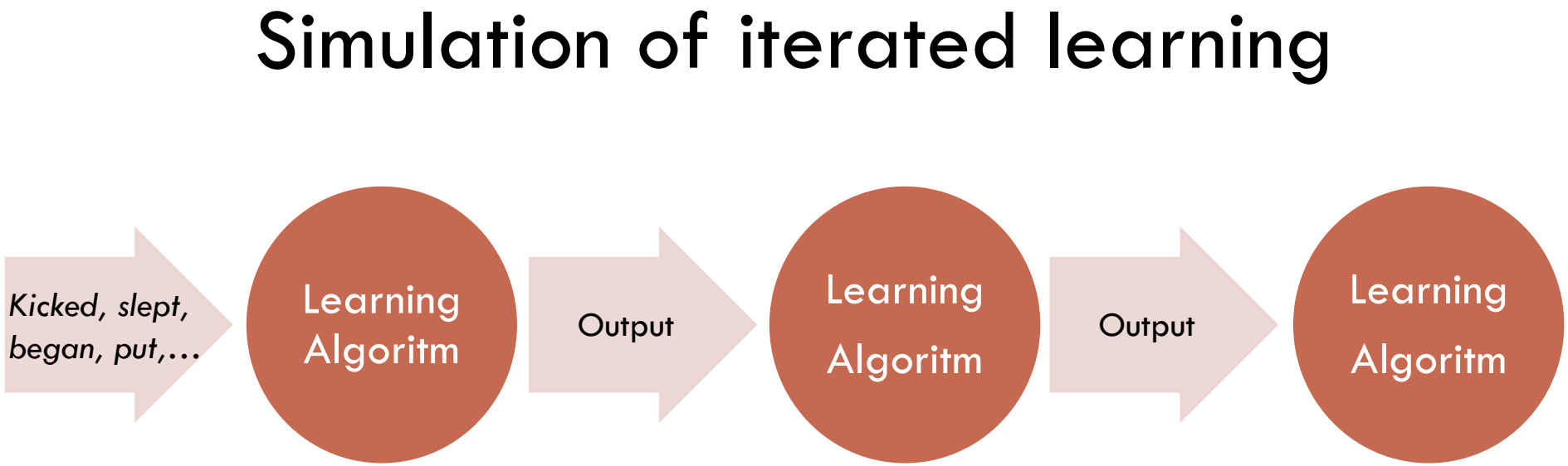
1. **General applicability of the dental suffix**
2. Restrictions on the strong system
3. Disintegration of the strong system

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


Rise of the
Weak Inflection
Starting point
Conserving Effect: low frequency
verbs become weak
&
Regularity is primarily needed by
low frequency verbs
Less pressure to
maintain the regularity
of the strong system
Disintegration of the
Strong Inflection

WHAT KIND OF SIMULATION DO WE WANT?

- Acquisition as the main driving force behind language change:



WHAT KIND OF SIMULATION DO WE WANT?

Goal: what kind of learning algoritm do we need in order to obtain realistic effects in

i. The mistakes that children make, e.g. U-shaped learning
ii. Language changes in the recent past

Connectionists: Neural Netwerk

Rumelhart & McClelland (1986), Macwhinney & Leinbach (1991), Plunkett & Marchman (1991, 1992), Hare & Elman (1995), Plunkett & Juola (1999)

vs.

Formal linguists: explicit rules + memory of exceptions

Pinker & Prince (1988), Ling & Marinov (1993), Marcus et al. (1995), Taatgen & Anderson (2002), Yang (2002)

WHAT KIND OF SIMULATION DO WE WANT?

- Language use as the main driving force behind language change:

Agent-based simulations

WHAT KIND OF SIMULATION DO WE WANT?

- General applicability is only useful when **producing** language, not when learning it

⇨ Agent-based simulation

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, e.g. how do you exactly measure it? What to do with verbs that show variation? Does one occurrence of ‘vraagde’ count for as much as 1000 occurrences of ‘vroeg’?

WHY DO THE FREQUENCIES OF THE GRAMMATICAL CONSTRUCTIONS ONLY PLAY A ROLE IF THE AGENT HAS NEVER HEARD THE VERB BEFORE?

Alternative: formula that takes into account both the frequencies of the lexical and grammatical constructions.

- More realistic, but also more complex: necessitates the inclusion of two more parameters
- Current approach makes the agents highly conservative. If anything, this impedes the rise of the weak inflection

IS IT NOT REDUNDANT FOR THE AGENTS TO KEEP BOTH THE GRAMMATICAL AND LEXICAL CONSTRUCTIONS IN MEMORY?

Yes it is, but is is also very minimal in its assumptions. It only assumes that any pattern that is recognized by humans will become more entrenched in their memory if they encounter it more often.

The alternative is a rule-list approach, which assumes that regular and irregular forms are handled fundamentally different by agent memory. That is a quite expensive assumption.

WHAT IF: NO RULES, ONLY ANALOGY?

Model does not need to change: the frequency of the grammatical constructions is exactly equal to the sum of the frequencies of its verb forms.

WHY DO WE USE ONLY ONE DENTAL SUFFIX IF THERE ARE GERMANIC LANGUAGES WITH MULTIPLE WEAK CLASSES, E.G. ICELANDIC?

One ‘dental suffix’ means that, each time an agent hears any past form with a dental suffix, this dental suffix becomes **more entrenched** in its memory. It is this dental suffix that is available for all verbs to form their past tense.

Conversely, if an agent hears a past form conjugated according to the first strong class (Dutch *ij* → ee), then **only this class** becomes more entrenched in the agent’s memory, and not the second class (Dutch *ie* → oo). This is the simulation’s core assumption of **general applicability**.

If you disagree with this assumption, you are wellcome to build another simulation. If you can show the same effects, using less assumptions, you have **disproven the current simulation**.

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 ARE SOME OF THE QUESTIONS THE PRESENT SIMULATION CANNOT ANSWER?

- 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)