Teaching an old dog new tricks? Learning rates, aging, and language change

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Section 1

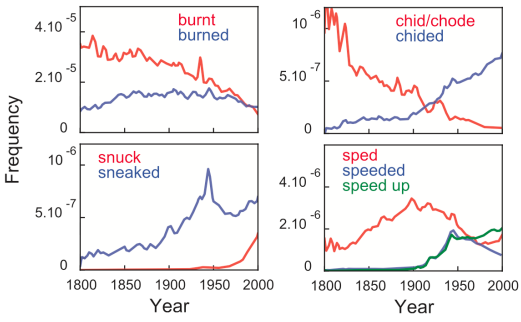
Background literature

Collective patterns of language usage change over time

- Google Books corpus (5.2 mill books) from 1800-2000[1]
- Ran a "culturenomics" study through an n-gram corpus analysis
- Quantified trends in lexical usage, grammatical patterns, and social usage

[1](Michel et al. 2011)

Collective patterns of language usage change over time



Mechanisms of language acquisition

- Statistical learning[2]
- Propose but verify (hypothesis testing)[3]
- Structural inference[4]

[2] Chen
[3] Trueswell
[4] Something?

Learning rates

- MacMurray study: parallel learning, constant learning rate
- Blachstein study? Changes over the lifetime?
- Bryersbart study?

Section 2

Formal model

Overview

- Language change as interaction between individual and collective level dynamics
- Aim to explore how individual learning rates, aging, and group membership impact overall population-level patterns of language change

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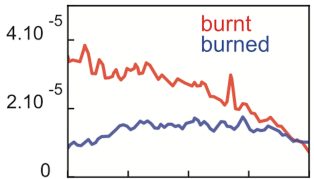
- Aim to explore how individual learning rates, aging, and group membership impact overall population-level patterns of language change

- Model of the usage and spread of a grammatical variant throughout a population
  - Past tense ending can be "-t" or "-ed", such as in "burnt" or "burned"



Model assumptions[5]

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[5] Beeksma citation

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1. Language learning is based on imitating others, though this may change over the lifespan
   - E.g., individuals may learn quickly early on, but slow down as they age
2. There are variations in preference between individuals
   - E.g., some individuals learn more quickly than others
3. Language can be influenced by external factors
   - E.g., more willing to learn from in-group members

[5] Beeksma citation

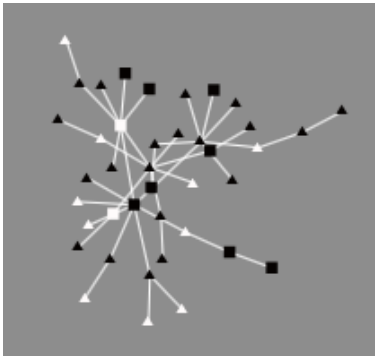
Outcome patterns[6]

1. **S-shaped curve in usage patterns**: Change happens slowly, then proceeds rapidly before slowing down again.
2. **Intra-speaker variation**: Change is gradual and there is a period of intra-speaker variation.
3. **Categorical norms**: With competition, speakers move toward categorically using just one of the competing variants.
4. **Multi-stability**: Language change can have multiple stable outcomes. *May result in dialect subgroups*
5. **Threshold problem**: Initially rare variants may manage to spread through entire speech communities.

[6] Troutman citation

Initialization: network

- Generates preferential attachment network
- Distributes grammar according to specified percentage of grammar 1
  - Two grammar variants, 0 or 1 (*burnt or burned*)



Initialization: nodes

Represent language users

- State: node's current grammar preference, initialized as 0 or 1
- Age
  - Probablistic or deterministic
- Cohort: "Age group", *either 1 or 2*
- Gamma: learning rate of a given node
  - Probablistic, deterministic, or based on age

Initialization: cohorts

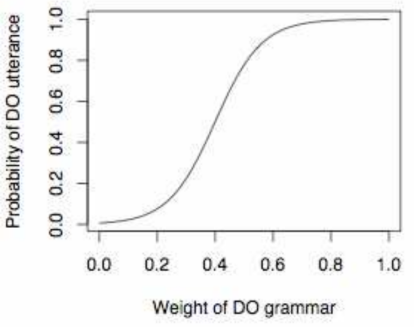
- Number of cohorts (max 2) based on specified percentage
- Cohort ages can be specified
- Option for cohort-based grammar, such that the cohorts start with different percentages of grammar 1
- Willingness to listen to out-group members

Dynamics

- Communication
  - Speaking (not synchronous)
  - Neighboring agents listen
- Aging

Dynamics: Speaking

- Nodes will generate an 'utterance', which is either 0 or 1 (*burnt or burned*)
- Nodes 'prefer' a discrete grammar
- Logistic curve is used when nodes produce an utterance



Dynamics: Listening

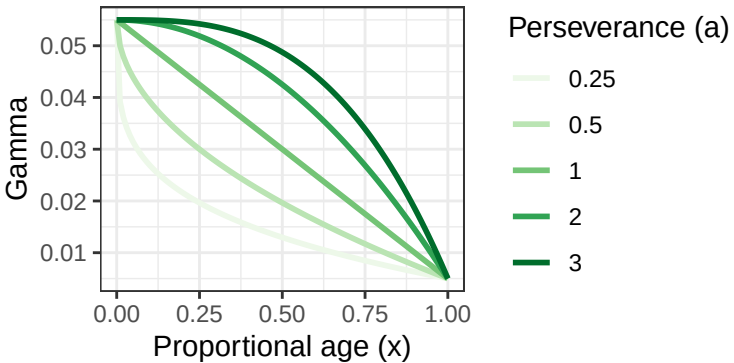
- Neighboring nodes will pick a grammar that will be used to interpret heard utterance
- If it matches the heard utterance
  - Update listener's state towards the heard state
  - Otherwise, it will update listener's state away from the heard state
  - Learning rate: *Gamma parameter modifies the step size*
- *Chance to ignore out-group*

Dynamics: Aging

- Nodes age with each tick
- Gamma changes with age: either constant or decreasing with age

Dynamics: Aging

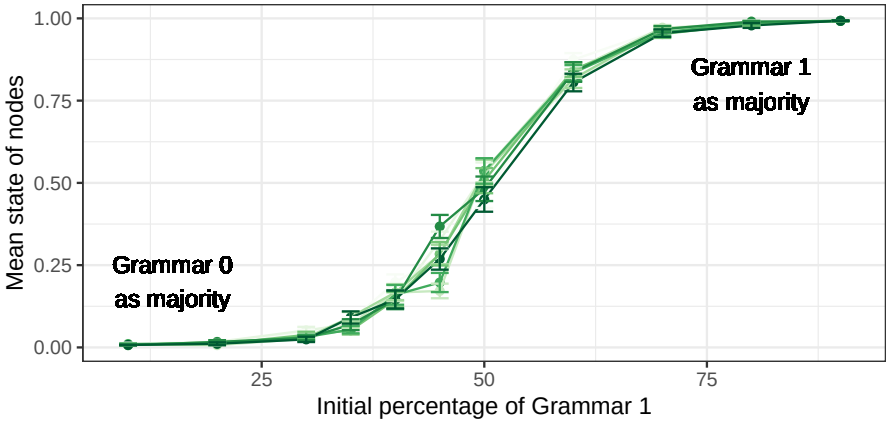
- Nodes age with each tick
- Gamma changes with age: either constant or decreasing with age
- Perseverance: how slowly gamma decays
  - Basic power law: $y = -0.05(x^a) + 0.005$



Section 3

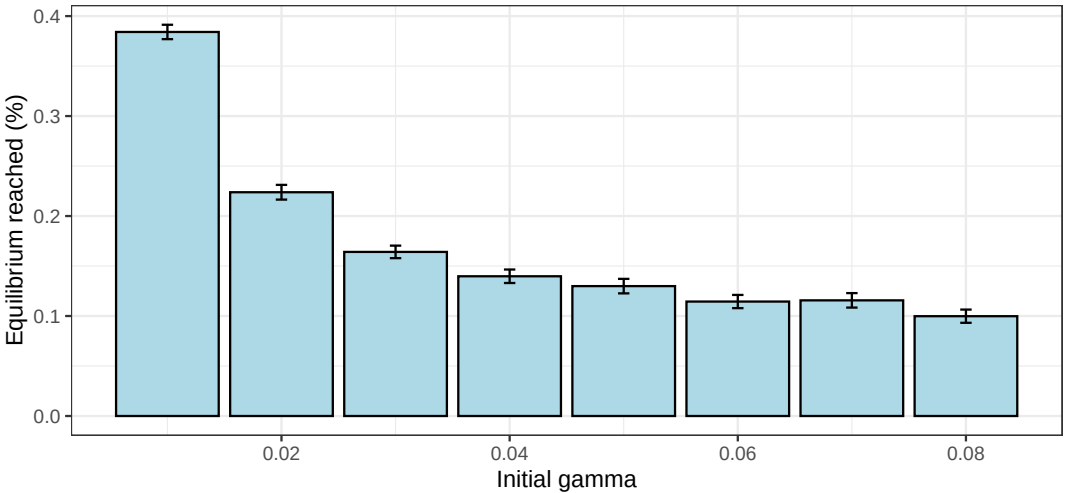
Results

Impact of learning rate



50 runs per configuration, 1000 steps total per run

Impact of learning rate



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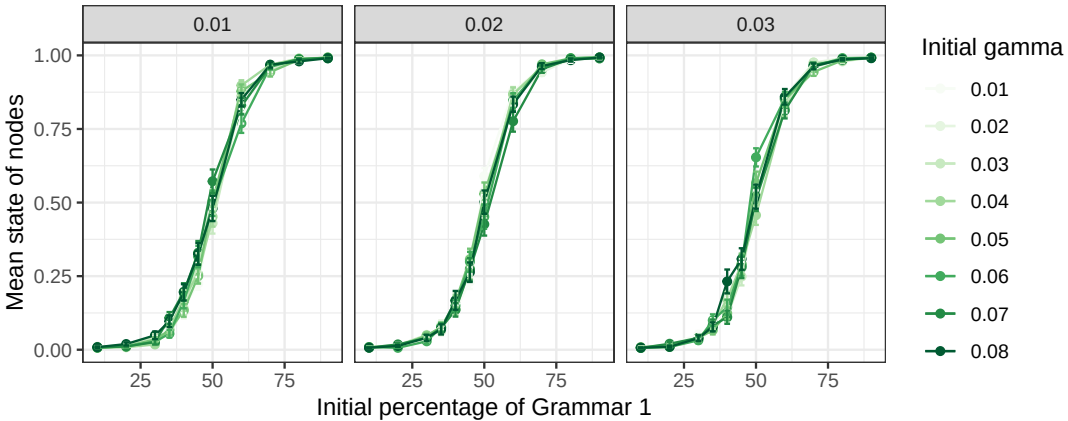
Variation of learning rate amongst individual



Faceted by Gamma SD; 50 runs per configuration, 1000 steps total per run

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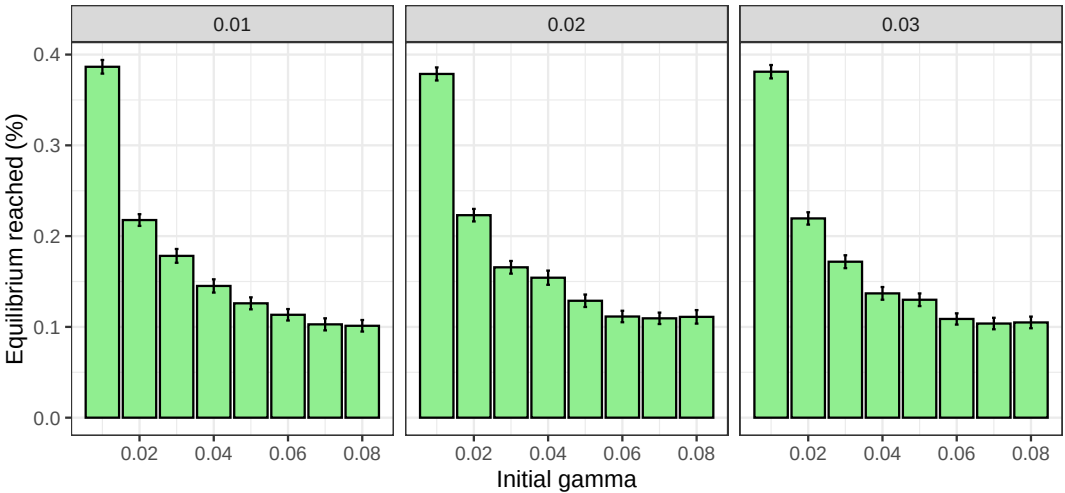
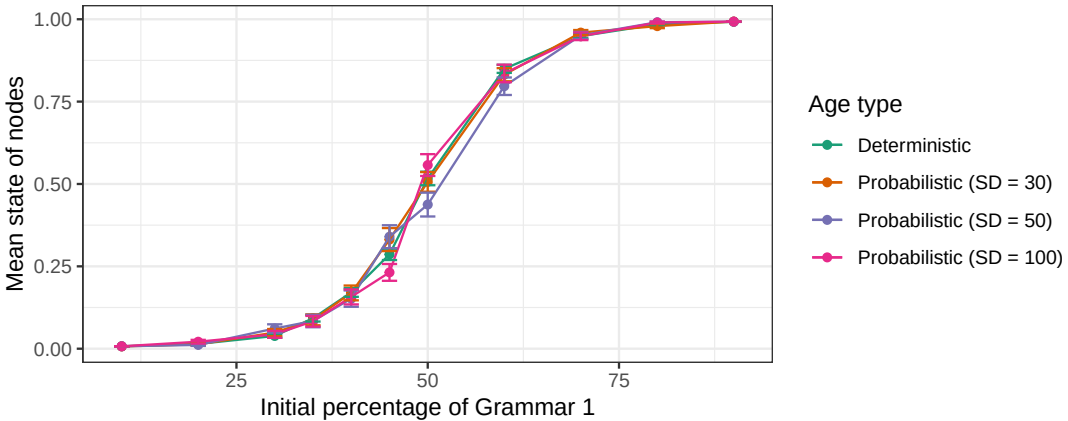


50 runs per configuration, 1000 steps total per run

Checkpoint

- Increased gamma decrease time to equilibrium, but not (systematically) affect the final outcome

Decrease in learning rate with age



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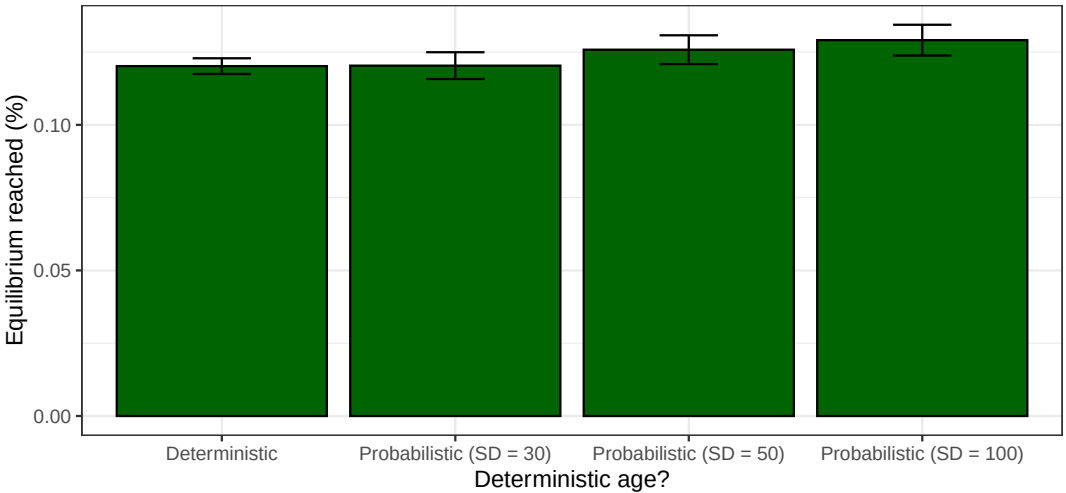

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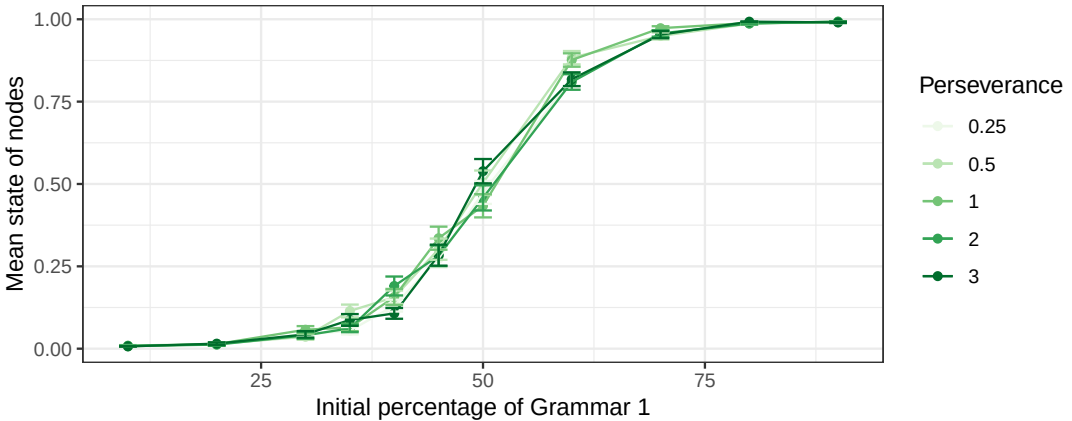
Variation of speed of decrease (perseverance)



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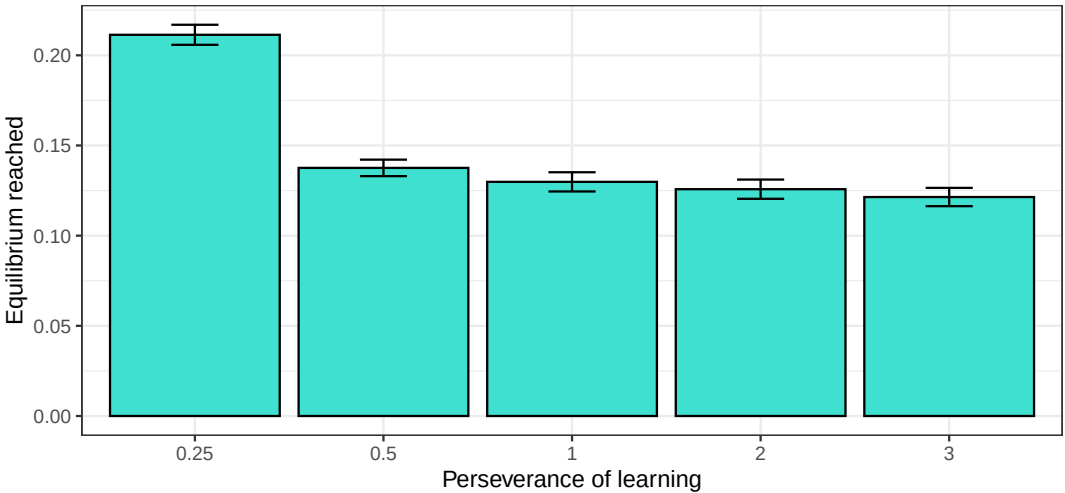

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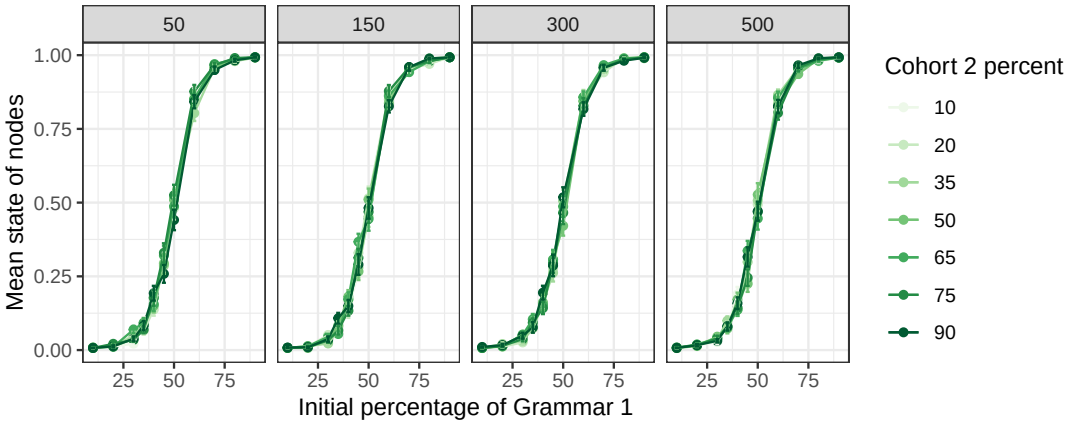
Checkpoint

- Gamma impacts time to equilibrium (TTE)
- No difference in TTE when perseverance is > 0.5

Two age cohorts



Faceted by Cohort 2 age; 50 runs per configuration, 1000 steps total per run

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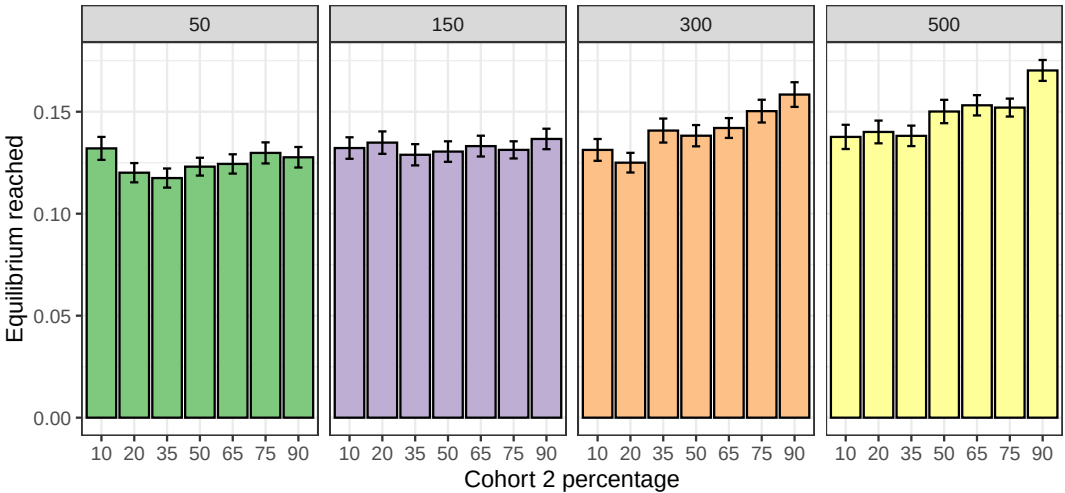

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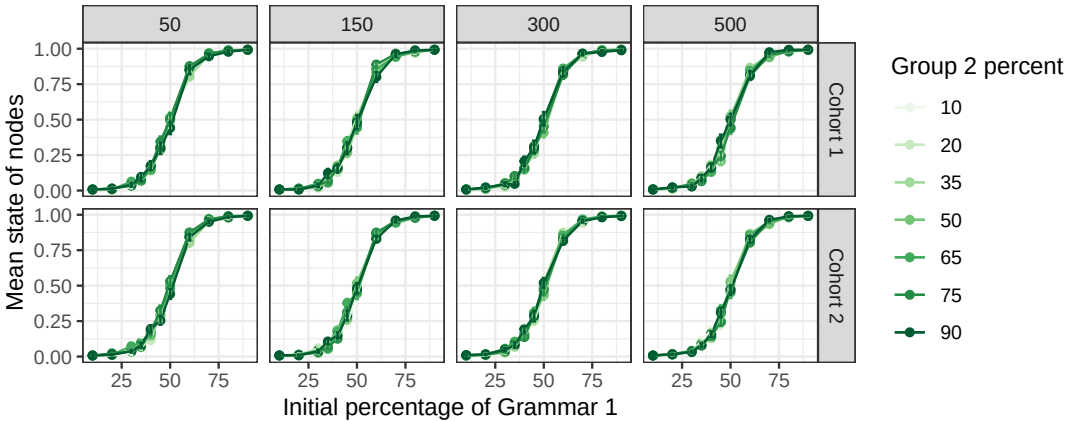
Two age cohorts: group equilibria



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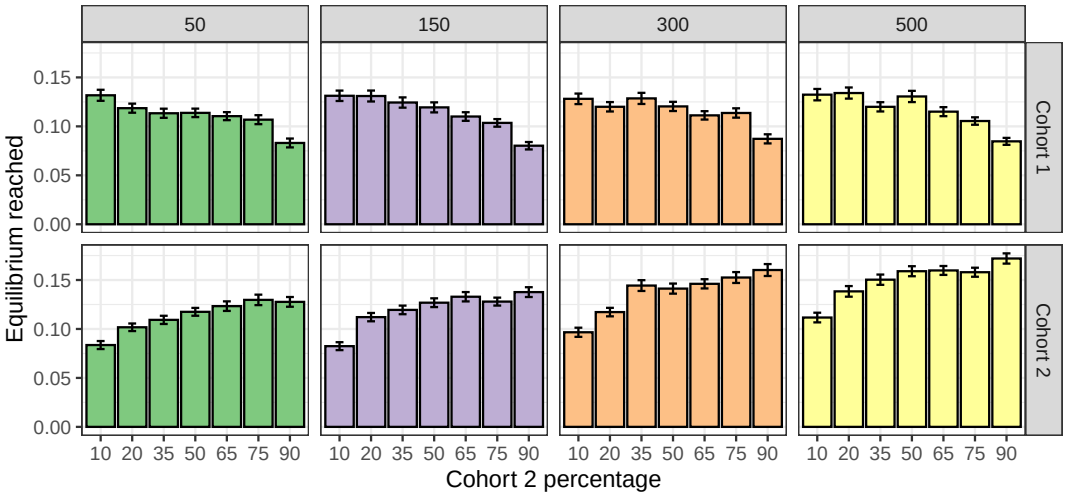
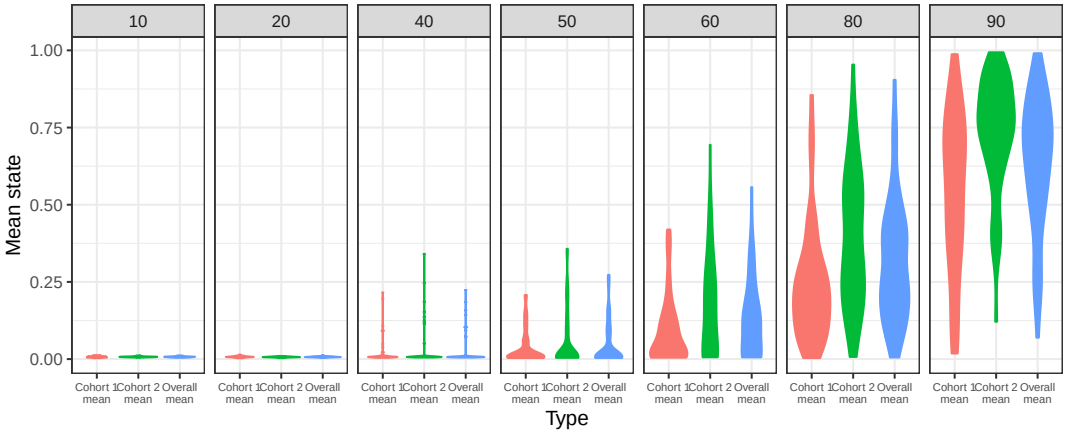


Faceted by cohort 2 age; 50 runs per configuration, 1000 steps total per run

Checkpoint

- Gamma impacts time to equilibrium (TTE)
- No difference in TTE when perseverance is > 0.5
- As the difference between age groups increases, the impact of population composition on when the overall equilibrium is reached increases (takes longer)
- Little difference between group equilibrium; older cohort slows down the equilibrium

Cohort-based grammar: Only Cohort 2 has grammar 1



Gamma decreases at constant rate; Cohort 1 does not have grammar 1; 50% Cohort 2; 50 runs per configuration, 1000 steps total per run

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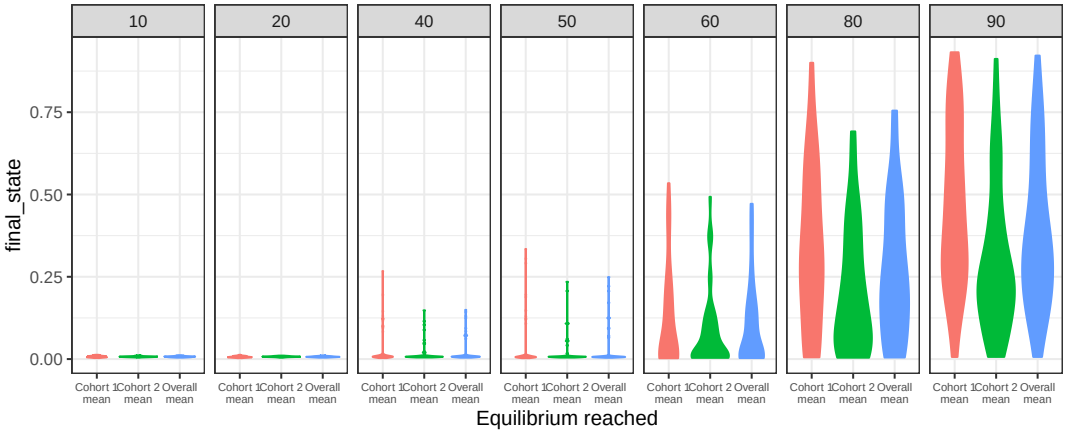

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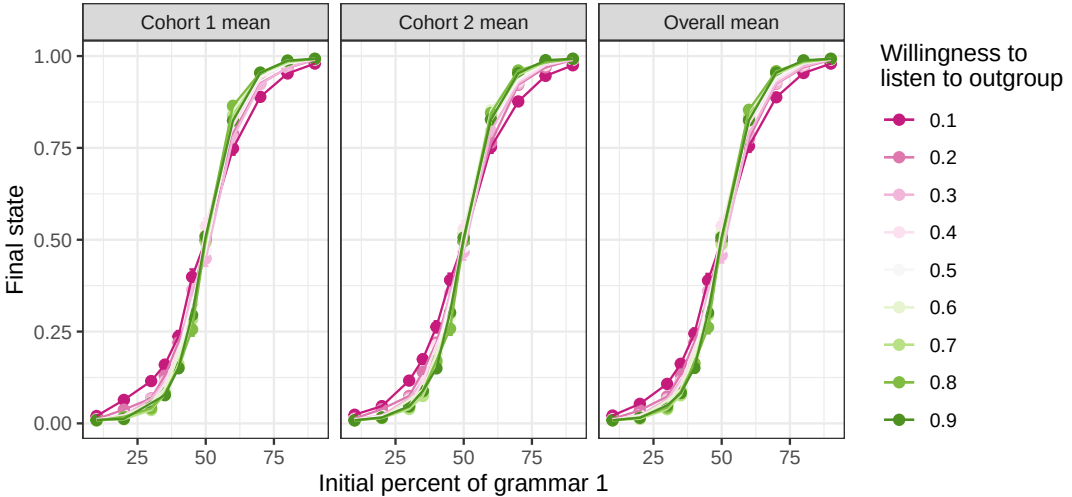
Checkpoint

- Increased gamma speeds up when equilibrium is reached, but not the final outcome; modulated by perseverance
- Older cohort delays equilibrium
- When cohort 1 does not use grammar 1, as cohort 2's starting percentage of having grammar 1 varies, they will drive the population towards using grammar 1
- However, when cohort 2 does not use grammar 1, cohort 1 starts with increasingly higher percentages of using grammar 1, they themselves may end up with using grammar 1 more, but it does not drive the overall group usage.

Cohort preference



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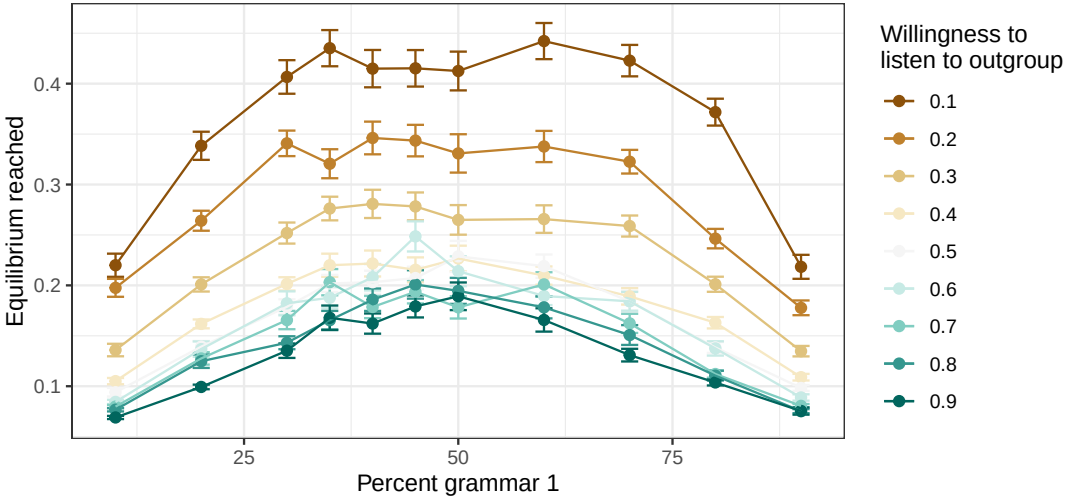

Checkpoint

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- Older cohort delays equilibrium
- “Innovator” and “Reservoir” groups
- Group preference will delay the equilibrium, and slightly impact equilibrium value

Section 4

Discussion

Conclusions

Thank you.

References

Michel, Jean-Baptiste, Yuan Kui Shen, Aviva Presser Aiden, Adrian Veres, Matthew K. Gray, The Google Books Team, Joseph P. Pickett, et al. 2011. "Quantitative Analysis of Culture Using Millions of Digitized Books." *Science* 331 (6014): 176–82. https://doi.org/10.1126/science.1199644.