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

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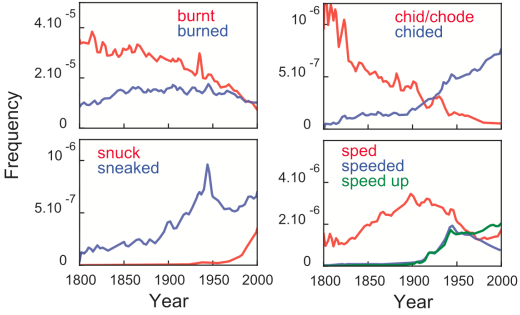
Section 1

Background literature

Collective patterns of language usage

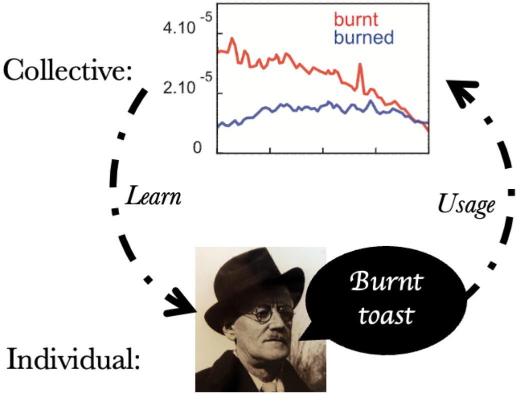
- N-gram corpus analysis of Google Books corpus[1]
- Diachronic changes in language usage and meaning[2]



[1] (Michel et al., 2011)
[2] (Bybee, 2015; Bynon et al., 1977)

Collective patterns of language

Emergence of collective-level trends from individual usage



Mechanisms of language acquisition

- Statistical learning[3]
- Propose but verify (hypothesis testing)[4]
- Structural inference[5]

[3](Smith & Yu, 2008; Yu & Smith, 2007)
[4](Trueswell et al., 2013)
[5](Kim et al., 2019)

Aging and learning

- Initially rely on associative / bottom-up learning
- Later shift to inferential / top-down learning

Section 2

Formal model

Overview

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

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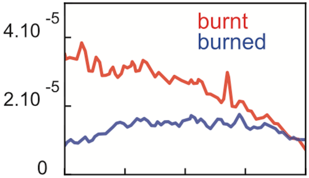
- Aim to explore how individual learning rates, aging, and group membership impact overall population-level patterns of language change

- 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[6]

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[6] (Beeksma et al., 2017)

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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

[6] (Beeksma et al., 2017)

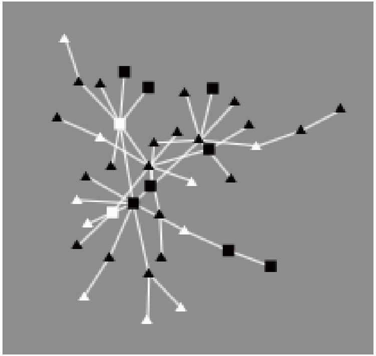
Outcome patterns[7]

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.

[7] (Troutman et al., 2008)

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

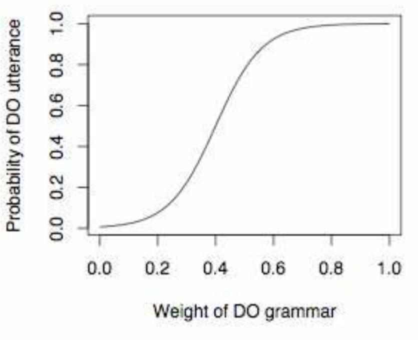
- Number of cohorts (max 2) based on specified percentage
- Cohort ages can be specified
- Option for cohort-based grammar, such that the cohorts start with different percentages of grammar 1
- Willingness to listen to out-group members

Dynamics

- Communication
  - Speaking (asynchronous)
  - 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

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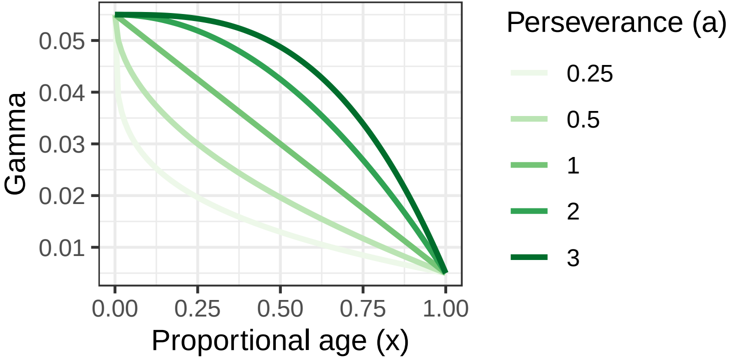
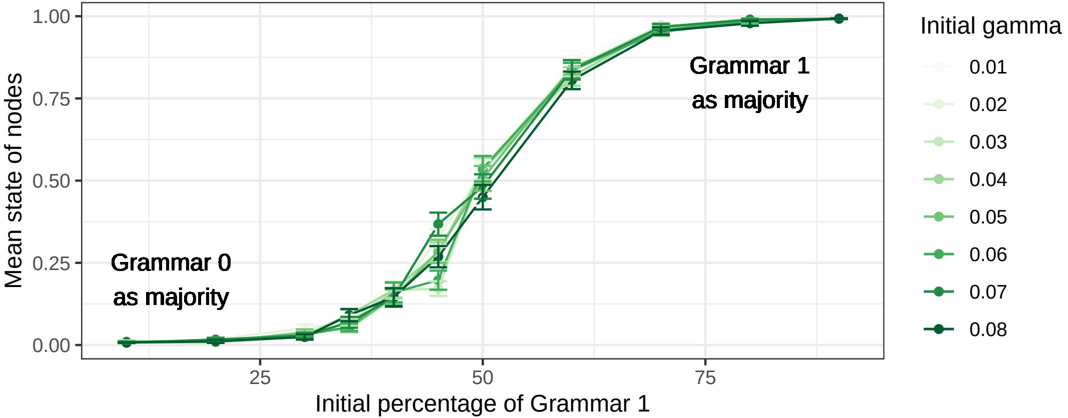
- Nodes age with each tick
- Gamma changes with age: either constant or decreasing with age
- Perseverance: how slowly gamma decays
  - Basic power law: $y = -0.05(x^a) + 0.005$



Section 3

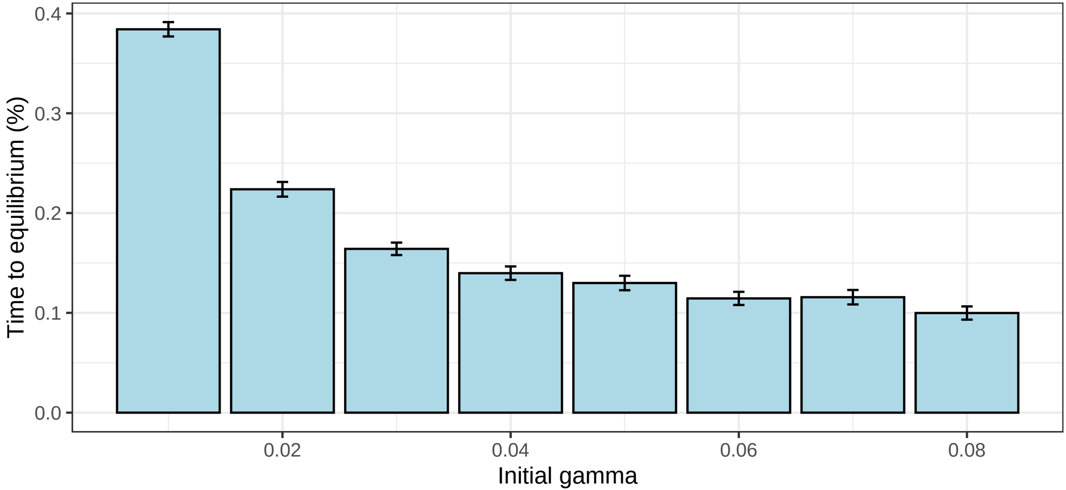
Results

Impact of learning rate



50 runs per configuration, 1000 steps total per run

Impact of learning rate



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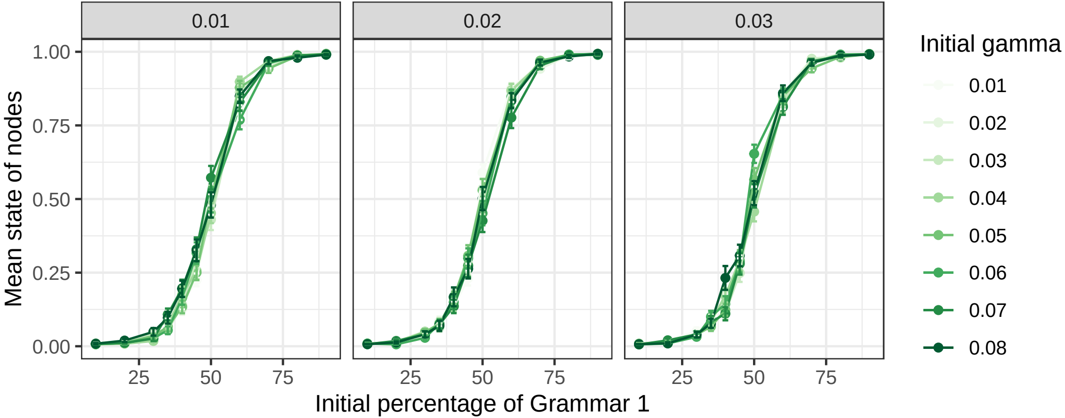
Variation of learning rate amongst individual



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

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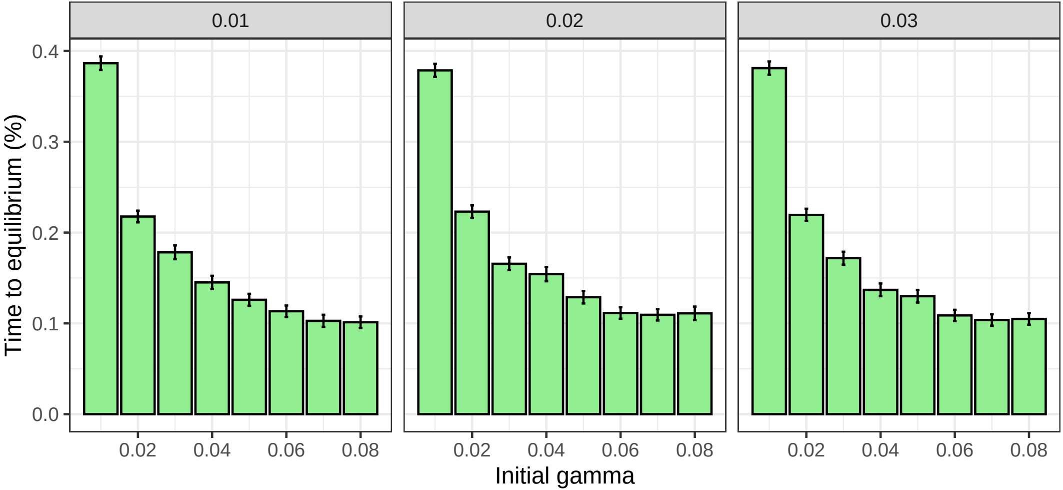
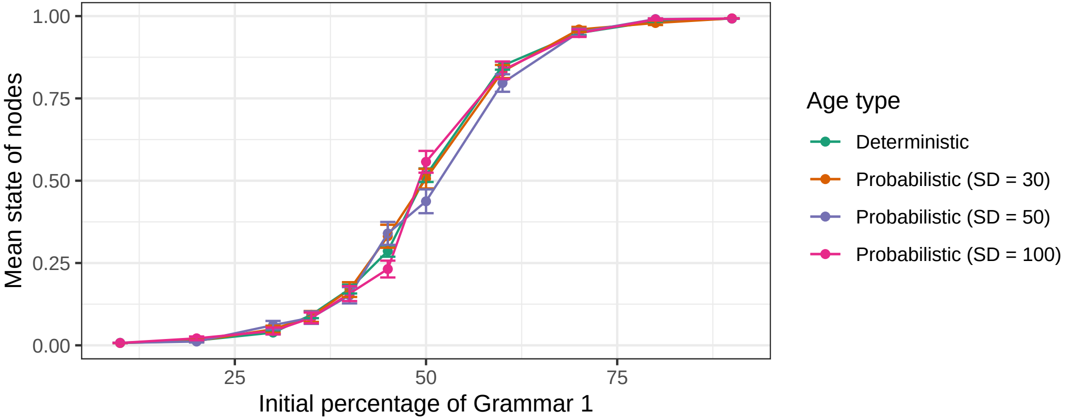


50 runs per configuration, 1000 steps total per run

Checkpoint

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

Decrease in learning rate with age



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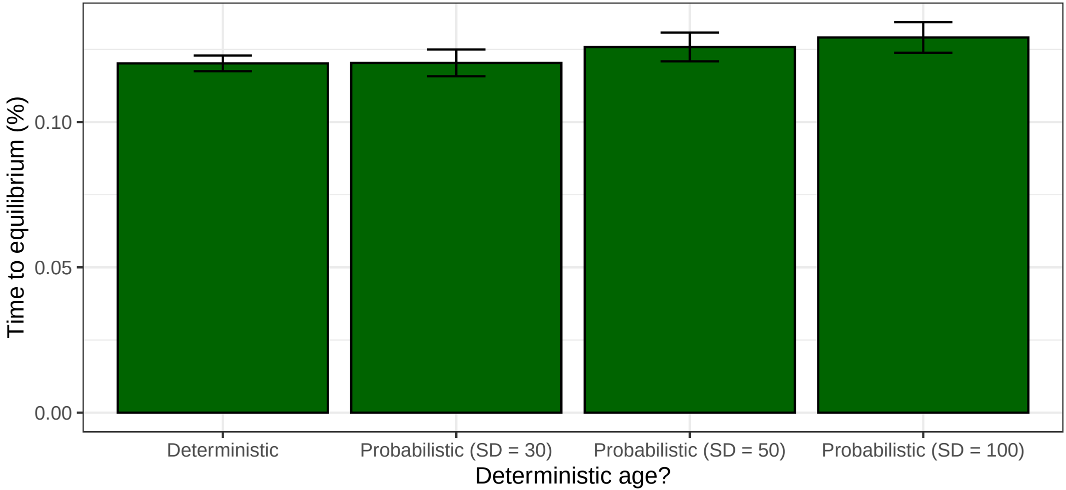

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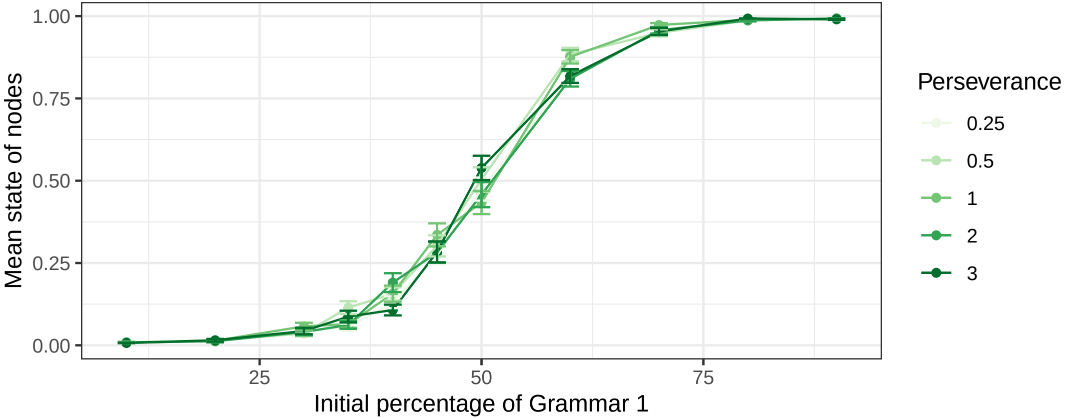
Variation of speed of decrease (perseverance)



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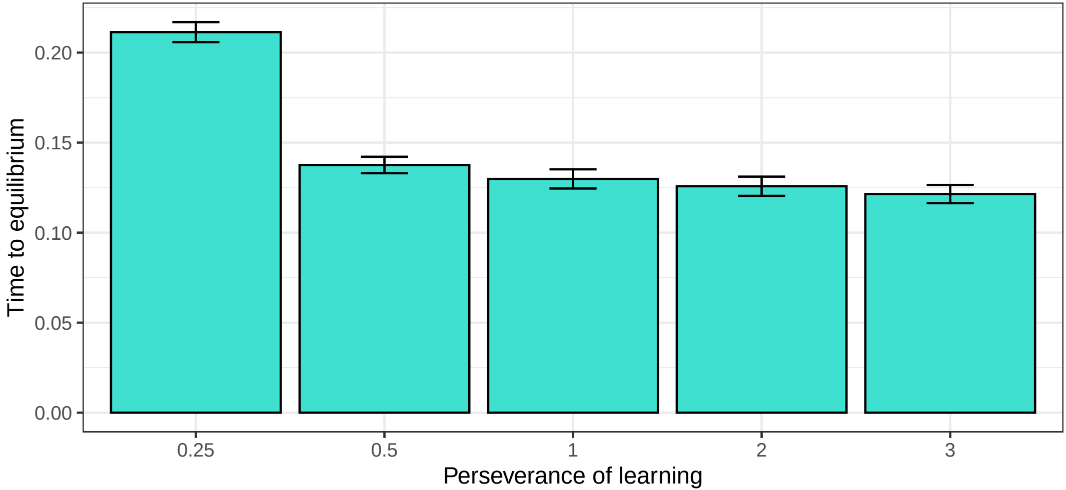
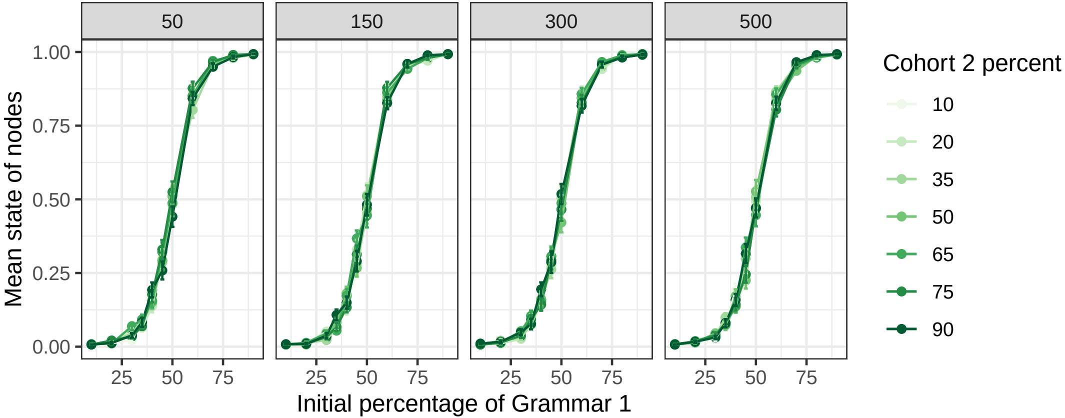


50 runs per configuration, 1000 steps total per run

Checkpoint

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

Two age cohorts



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

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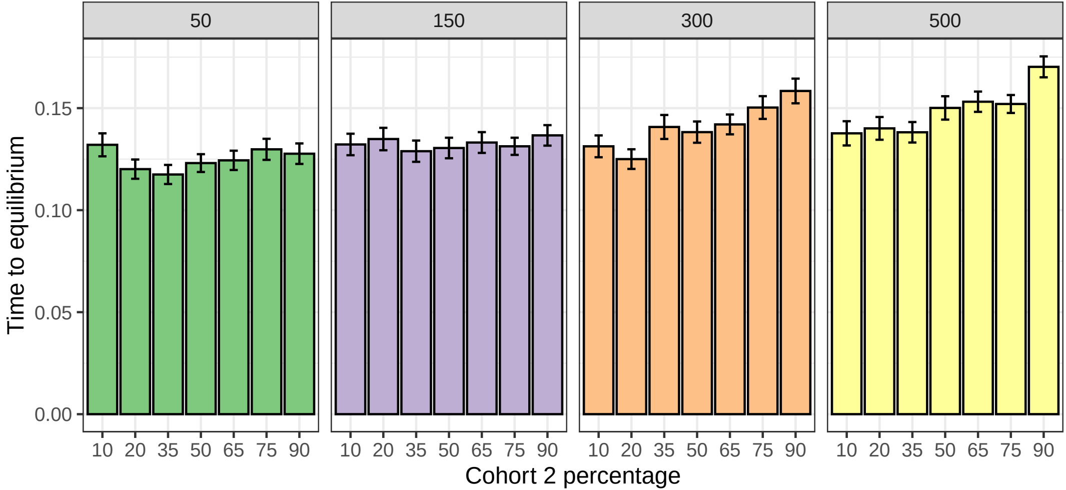

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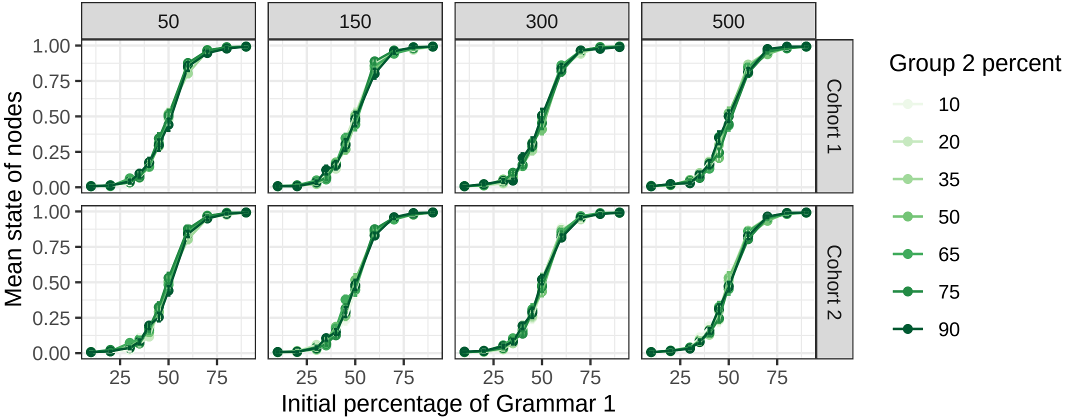
Two age cohorts: group equilibria



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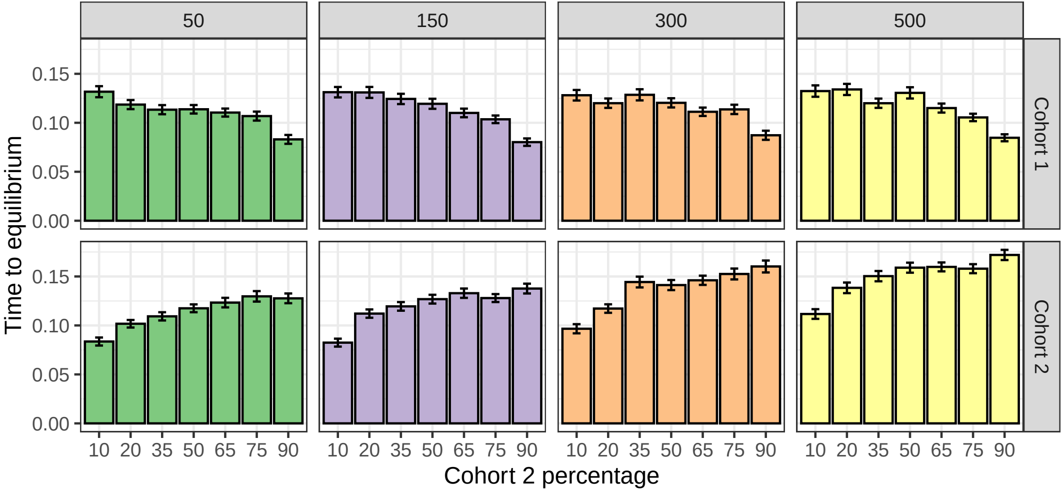
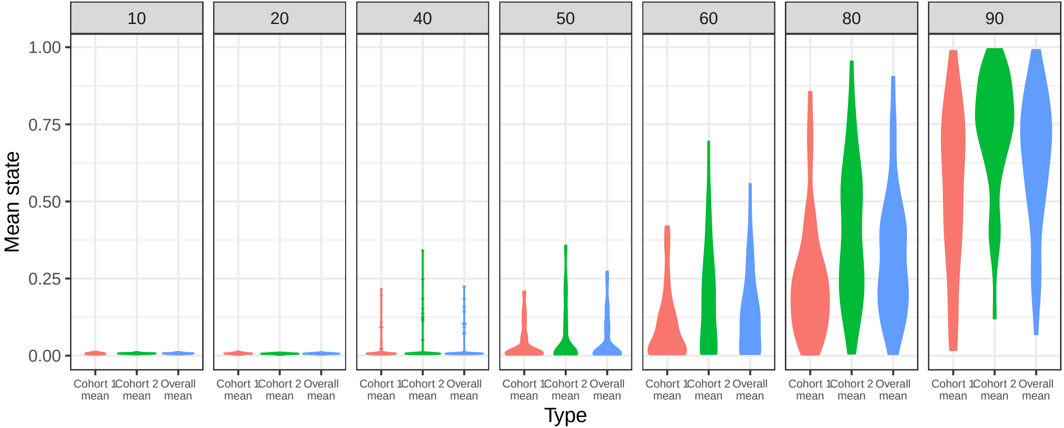


Faceted by cohort 2 age; 50 runs per configuration, 1000 steps total per run

Checkpoint

- Gamma impacts time to equilibrium (TTE)
- No difference in TTE when perseverance is > 0.5
- Older cohort slows down TTE
- As the age gap increases, the impact on TTE increases as well

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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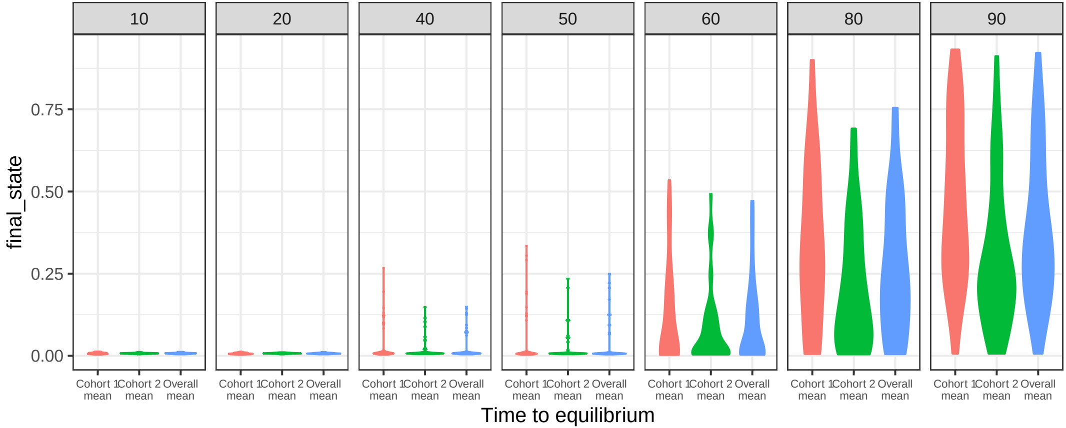
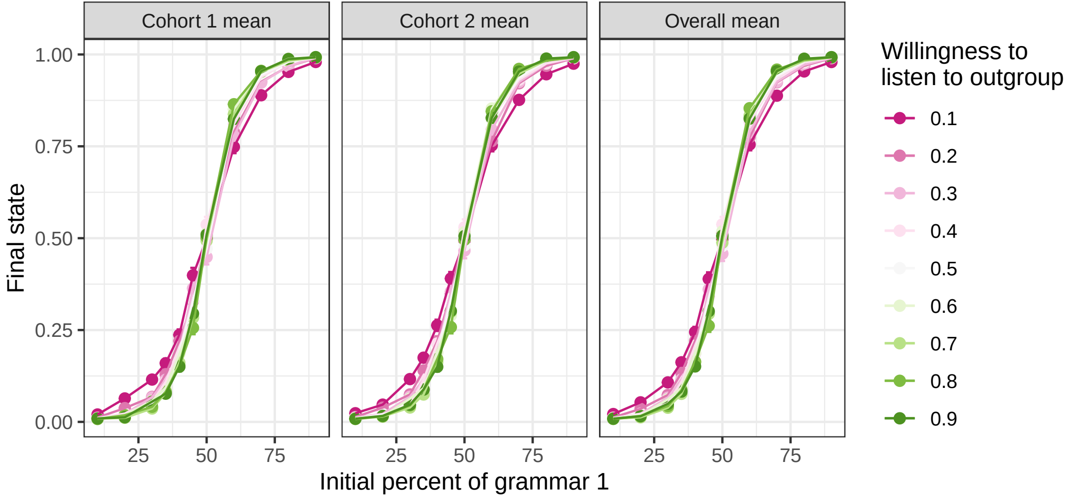


Gamma decreases at constant rate; Cohort 2 does not have grammar 1; 50% Cohort 2; 50 runs per configuration, 1000 steps total per run

Checkpoint

- Gamma impacts time to equilibrium (TTE)
- No difference in TTE when perseverance is > 0.5
- Older cohort slows down TTE, exacerbated by increased age gap
- Reservoir? When grammar varies only in the older cohort, their initial starting percentage will draw the younger cohort
- Innovator: when grammar varies only in the younger cohort, 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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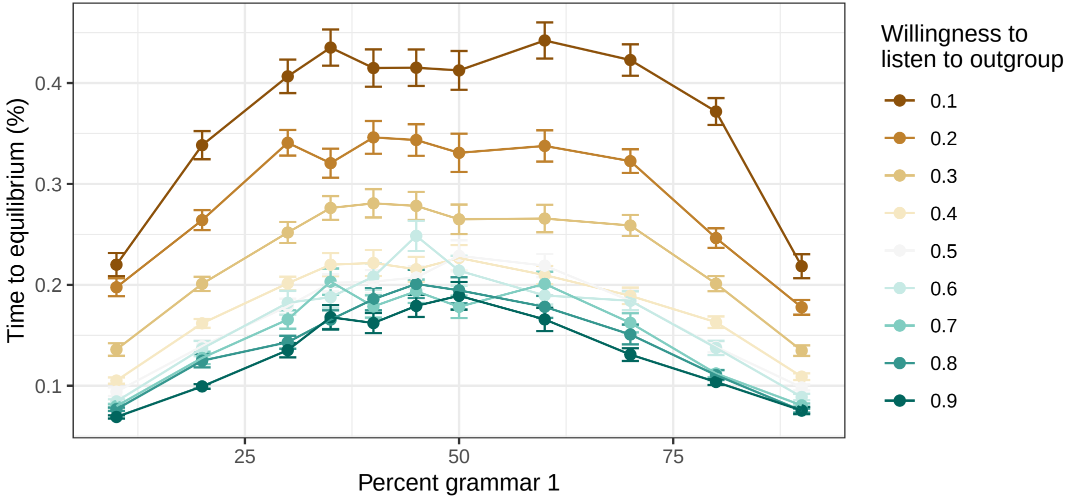

50 runs per configuration, 1000 steps total per run

Checkpoint

- Increased gamma speeds up when equilibrium is reached, but not the final outcome; modulated by perseverance
- Older cohort delays equilibrium
- "Innovator" and "Reservoir" groups
- Group preference will delay the equilibrium, and slightly impact equilibrium value

References

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