INDEPENDENT STUDY - ABM

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ABSTRACT

# INTRODUCTION

## ABMs

#TODO: Rewrite section with only useful information

One low-resource programming language is NetLogo, a multi-agent programming language and modeling environment for simulating complex phenomena (Wilensky 1999) whose number of open-source codes and models is reduced compared to high-resource programming languages. NetLogo is highly popular due to its user-friendly interface(Wilensky 1999), extensive documentation, and the ability to incorporate real-world data (Walker and Johnson 2019). Which combined with the ability to handle sophisticated modeling have made it widely used across various fields(Sklar 2007). Research focusing on the potential of LLMs to generate code of NetLogo could have a high impact on modelers in such fields.

Agent-Based Models (ABMs) are used to model complex systems, particularly those with autonomous, interacting agents (Macal and North 2005) in an array of domains, such as ecology, social science, economics, biology, and game theory(Allan 2010). They are particularly useful in gaining insight into the emergent behavior of complex systems(Garcia 2005). As LLMs have been adopted by a wider range of researchers, modelers have started to investigate their potential applications for ABMs. Most of these efforts are through the concept of “intelligent agents”(Junprung 2023; Park et al. 2023; Li et al. 2023), where an LLM gives the decision-making and behaviors of the agents with human-like characteristics. Other research has explored their use for interpreting the agents’ actions in an ABM(Lynch et al. 2024).

## Minority language competition vs cooperation

(Civico 2019) ABM simulates language contact and its effect on a minority language community. The model seeks to show that macro-level language contact dynamics can be explained by relatively simple micro-level behavioral patterns1. The model is validated using data from the case of Romansh speakers in the canton of Grisons, Switzerland. The model finds that:

* Exogamy is the strongest predictor of minority language decline. **Exogamy rate:** The likelihood that a female minority-language speaker will have a child with a majority-language speaker

(Castelló, Loureiro-Porto, and San Miguel 2013) The models use two primary parameters:

○ **Prestige (s):** This represents the social importance of a language. In the models, a higher prestige value means a language is more likely to be adopted.

Prestige is a parameter that represents the relative social importance or status of a language within a community. In the models presented, the probability of an agent switching from one language to another depends on the prestige of the languages involved.

Including prestige in the original Language Change model is feasible because (1) the original model simulates language change dynamics without considering prestige. Incorporating prestige aligns the model more closely with the mechanisms described in the paper, providing a more realistic simulation. (2) Prestige can be added as a parameter influencing the agents’ decision-making processes, specifically affecting the probability of adopting a new grammar. (3) integrating prestige, the model can simulate scenarios where one grammar (language) is more socially dominant, allowing exploration of language shift phenomena influenced by social factors.

Collins, Vernon-Bido, and Lane (2017) examine the effects of strategic behavior on group formation, specifically in an academic setting where researchers collaborate on publications.

The study found that concern for prestige **leads to smaller, more interconnected research groups**, as researchers prioritize collaborations with high-prestige individuals.

The level of prestige is influenced by a **smoothing factor**, which determines the rate at which prestige grows with successful collaborations.

A higher smoothing factor results in **lower average** prestige values because it limits the rate of prestige growth.

Other variables and papers considered were:

○ **Volatility (a):** This represents the propensity of speakers to shift languages. High volatility (low values of ‘a’) implies rapid language shift, while low volatility (high values of 'a') suggests resistance to change, often due to language loyalty.

Social network structure plays a significant role in language contact outcomes**.** The models show that local interactions (as in random and regular networks) tend to favor the more prestigious language, while networks with community structure can support the long-term coexistence of languages, particularly if the communities are relatively isolated

(Karjus and Ehala 2018) this study aims to model synchronic language competition using realistic, data-based agents based on a survey in Estonia.

(Castelló et al. 2007) examine the role of **bilingual speakers** and **social structure** in the dynamics of language competition between two equally prestigious languages.

The model demonstrates that bilingual individuals tend to position themselves at the boundaries between monolingual groups, facilitating communication but **not forming distinct bilingual zones**. Even when initially placed in a bilingual community, the model shows that these groups dissolve into smaller monolingual areas, with bilinguals remaining at the borders.

**The model predicts eventual language extinction, even with equal prestige.** The study concludes that neither bilingualism nor social structure, in isolation, can ensure long-term language coexistence in a finite population. One language eventually dominates, leading to the extinction of the other, along with the disappearance of bilingual speakers.617

(Charalambous, Sanchez, and Toral 2023) **Rewiring Promotes Coexistence:** Simulations show that rewiring significantly increases the likelihood of both languages coexisting in the long term, even for large network sizes where previous models predicted the dominance of one language.

**Rewiring**, in the context of this paper, is a mechanism introduced into the agent-based model to simulate the **adaptation of social networks based on language preferences**. It allows agents (representing speakers) to change their interaction partners to better align with their preferred language. The dissatisfied agent breaks the existing link and forms a new link with a different agent.

# BACKGROUND

# methodology

## Incorporation of prestige into Simulation model

To incorporate prestige, the following updates were made:

* **Added a Prestige (of grammar 1) Parameter**: Introduce a global variable prestige that represents the relative prestige of *grammar 1* compared to grammar 0. This variable can range between 0 and 1.
* **Updated Agent Decision Logic**: The procedures where agents decide to adopt a new grammar now include the prestige factor. The probability of switching should now depend on both the proportion of neighbors using a particular grammar and the prestige of that grammar.
* **Adjusted Communication Procedures**:
  + In the *listen-threshold* and *listen-individual* procedures, included the prestige parameter when determining if an agent should adopt a new grammar.
  + For probabilistic learning (*listen* procedure), adjusted the probability calculations to factor in prestige.
* **Updated Interface Elements**:
  + **Added a Slider**: Created a slider named prestige allowing users to set the prestige value between 0 and 1.

## Experimental design

We want to investigate how varying the prestige and threshold-val parameters affect the adoption of Grammar 1 overtime in the networked population.

**Input Parameters**:

* **prestige**:
  + *Meaning*: The relative prestige or social influence of grammar 1.
  + *Values*: 0.0 to 1.0 (lower values mean lower prestige of grammar 1).
* **threshold-val**:
  + *Meaning*: The threshold proportion of neighbors using Grammar 1 is required for an agent to adopt Grammar 1.
  + *Values*: 0.0 to 2.0 (higher values make it harder to adopt grammar 1).

**Output Parameters**:

* **final-grammar1-proportion**:
  + *Meaning*: The proportion of agents using grammar 1 at the end of the simulation.
  + *Calculation*: (count nodes with [state = 1]) / count nodes
* **ticks**:
  + *Meaning*: The number of time steps the simulation ran before stopping.

Parameters to Vary:

1. **Prestige (prestige)**:
   * *Definition*: Represents the relative prestige of grammar 1 compared to grammar 0.
   * *Range*: 0.0 to 1.0 (inclusive)
   * *Increments*: 0.2
   * *Values*: [0.0, 0.2, 0.4, 0.6, 0.8, 1.0]
2. **Threshold Value (threshold-val)**:
   * *Definition*: Determines the proportion of neighbors with grammar 1 required for an agent to adopt grammar 1.
   * *Range*: 0.0 to 2.0 (inclusive)
   * *Increments*: 0.5
   * *Values*: [0.0, 0.5, 1.0, 1.5, 2.0]

Fixed Parameters:

* Number of Nodes (num-nodes): 100
* Percentage of Grammar 1 (percent-grammar-1): 50%
* Alpha (alpha): 0.025
* Update Algorithm (update-algorithm): "threshold"
* Sink State 1? (sink-state-1?): False
* Logistic? (logistic?): False

Total Combinations:

* Number of prestige values: 6
* Number of threshold-val values: 5
* Total parameter combinations: 6 \* 5 = 30

Repetitions:

* For each parameter combination, perform 30 independent simulation runs to account for stochastic variability.
* Total simulation runs: 30 parameter combinations \* 30 runs = **900 runs**

For each simulation run, we recorded the following output parameters:

* Final Proportion of Grammar 1 Users:
  + Calculation: (count nodes with [state = 1]) / (count nodes)
* Number of Ticks:
  + Total time steps are taken in the simulation.

Results of the experimental design:

A diagram of a heatmap

Description automatically generated

Analyzing the simulation results, we observed negative correlations between prestige and output (-0.58) and between threshold and output (-0.62). These negative correlations indicate an inverse relationship between the variables: as the prestige of Grammar 1 or the threshold value increases, the final proportion of agents adopting Grammar 1 decreases. This outcome is somewhat counterintuitive, as one might expect that higher prestige would lead to higher adoption rates of the prestigious grammar.

# results and discussion

# CONCLUSION and future work

# Acknowledgments

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