Effect of Immigration on Language Distribution

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Introduction

As the 2020 presidential election rounds the corner, immigration is a hot-button issue at the forefront of cross-partisan debates. A comprehensive immigration platform will be of paramount importance in many upcoming campaigns, as it now becomes a top issue deciding how US citizens cast their votes (Reuters, 2018). Through waves of past immigration and especially in today's political climate, immigration has been and continues to be a nuanced issue with many intertwining factors at play. In particular, language and immigration are inextricably intertwined. An increase in the rate of immigration correspondingly correlates to an increase in the introduction of a foreign language into the linguistic atmosphere of a country. A foreign language can be perceived by certain native dominant-language speakers as a symbolic threat to cultural norms, leading to more restrictive immigration policies (Newman, et al, 2012). This leads to the debate of whether a foreign language is "threatening" the prevalence of the predominantly-spoken language or whether the foreign language is more likely to be dominated by a country's native language.

In exploring this problem, one interesting phenomenon to model would be the generational effect of immigrants, who speak a certain language, on a population of people who speak a different, "original" language. It would be interesting to see which language emerges as dominant over time (or the distribution of languages spoken) as the number of initial immigrants or rate of immigration changes. In addition, the role of bilingualism would also be a necessary factor to explore in trying to understand the persistence of either language. Over time, people within the population will be affected by the languages spoken around them, and parents may be able to pass on their language to their offspring, which will also affect language longevity and distribution.

Motivation for Exploration

Modeling this behavior is particularly interesting because of the political ramifications of shifts in thoughts about immigration. Both proponents and critics, across the political spectrum, can agree that immigration is highly relevant in our modern socio-political landscape. The prominence of immigration on the national political debate stage reveals its importance as an everyday issue for Americans. In a 2018 Gallup poll, 78% of registered American voters rated immigration as an issue that was very or extremely important to them (Newport, 2018).

One driving question that would be important to explore would be: "Assuming that immigrants speak a different language, what role does immigration have on the languages spoken within the country (original or immigrant), as well as bilingualism?" To break this question down, the following questions will be explored in more detail:

1. How does the initial distribution of monolingual original-language speakers and monolingual immigrant-language speakers affect the longevity of the immigrant language within the system?
2. How does the rate of immigration impact the resulting language distribution of original monolinguals, immigrant monolinguals, and bilinguals after time?

3. Does the three-generation pattern of language loss, as described by linguists, emerge within the model?

Relevancy of Agent-Based Modeling

Agent-based modeling, in particular, is a good fit for exploring the dynamics of immigration's impact on language because this exploration will involve complex interactions between different categories of people. Without agent-based modeling, it is hard to visualize what will happen as multiple groups interact, especially during a prolonged time frame such as after several generations of linguistic interaction within the population. In addition, being able to change agent-level behavior, such as the different capabilities for language acquisition between people of different ages, will allow us to explore what different emergent patterns could result from such lower-level changes.

Background

Existing Work on Phenomena

A study by Rambault and Massey titled "Immigration and Language Diversity in the United States" details the historical effect of waves of mass immigration in the United States and assesses the impacts of future immigration (Rambault and Massey, 2018). It notes that linguistic diversity within America has been driven primarily by immigration throughout history. The paper, backed by extensive historical studies of America's past, concludes that if immigration ceases, all non-English languages would "die out" within the country at a rapid rate. This is because immigrant languages are quickly replaced by monolingual English descendents within a few generations, although ethnic identities can still be preserved.

In addition, the three-generation pattern of immigrant language loss is a phenomenon where immigrant mother tongues are spoken in the first generation, preserved through bilingualism in the second generation but fade in the third generation and disappear by the fourth generation. This pattern is seen repeatedly in linguistic studies, as well as broader historical patterns, such as the language die-out patterns of the large number of European immigrants to the United States and their descendants during the mid-19th-century. In addition, other studies similarly attribute immigration language loss to generational changes (rather than from external forcings), pinpointing the third and fourth immigrant generations as key for the shift to monolingualism of the native country (Ortman and Stevens, 2008).

One reflection of this phenomenon in the current day is the generational language shift among Hispanic Americans in the United States. One study found that, within Hispanics in the United States, eighty percent of members of the second-generation born from immigrant parents knew the language of their parents. On the other hand, between the second and third generations, there was a statistically significant decrease in the number of third-generation Hispanics that spoke Spanish to about forty-four percent (Ortman and Stevens, 2008). This supports the idea of a three-generation model of language shift proposed by linguists, where the descendants of the descendants of immigrants will be unlikely to speak the language. In addition, studies show that this effect is even more pronounced for other immigrant groups to the United States, such as Asians, that have statistically fewer numbers as a minority group (Alba, et al, 2002). In general, research and history show that language diversity in the US is driven by immigration, but a consistent phenomenon of immigrant "language death" is possible as third and fourth generations are much less likely to speak a parent language.

Design

The model designed to explore this phenomenon was created using NetLogo, a multi-agent programmable development environment created by Uri Wilensky at Northwestern University. The main agents in the model are called "speakers," and they represent different people in the country that speak languages. In addition, the space of the entire view represents the country where immigration is taking place.

There are two different languages that exist in the country: the original language and the immigrant language. Both the original inhabitants of the country and the immigrants start off as monolingual but can later become bilingual. Speakers move around and talk to each other, as well as form matings and give birth to children, since allowing for sexual reproduction was important in being able to see the generational linguistic shifts found in existing studies. Mechanisms for language change include language learning, which occurs as speakers communicate amongst one another, and language inheritance, as mating links produce children who are affected by the parents' languages. Additionally, speakers have the capacity for bilingualism, affected by factors such as age, bilingualism threshold, and bilingualism inheritability.

If immigration flow is allowed, then additional monolingual immigrant-language speakers are introduced into the population at some rate. In addition, as the model is running, the observer can choose to add a "wave" of immigrants to the model at any time. The size of the wave of immigrants is determined by the "immigrant-wave-size" parameter. Finally, an observer can choose to watch a randomly-selected original language speaker, an immigrant language speaker, or a bilingual speaker in the model as it runs.

Rules of the Model

The following section contains a more detailed overview of the implementation of the model. The rules of the model, written in the form of NetLogo pseudocode, are outlined in the following initialization and timestep:

Initialize:

1. Create a number of original-language speakers, immigrant-language speakers, and bilingual speakers.
    a. Original-language speakers are magenta with a magenta speech bubble, and immigrant-language are teal with a teal speech bubble.
    b. Bilingual speakers have a magenta and teal speech bubble, indicating that they speak both languages.
2. All speakers will start off:
    a. With an age randomly chosen between zero and seventy-five, with a random location in the country, and being unmated.
    b. Having an "opposite-language-ability" of zero.
        i. <u>Note:</u> The "opposite-language-ability" is a property that each speaker has indicating their knowledge of the opposite language, which is relevant if they are monolingual since it also indicates how close a speaker is to

becoming bilingual. An "opposite-language-ability" of zero represents that a speaker has no knowledge of the opposite language, and as this number increases, it indicates that the speaker is gaining more knowledge of the opposite language.

At each clock tick:

- Each speaker does:
    - If my age is above seventy-five, then I will die. Otherwise, I will increase my age by one year.
    - I will face some direction randomly and move forward in that direction.
    - If I am eighteen or older, have not yet mated, and there are still other speakers, then I will consider the closest speaker to myself as a potential mate. If the potential mate is also eighteen and older and not mated, we will mate by creating a mating link between ourselves. Then, we will set our "mated?" property to true, indicating that we are now mated.
- Each monolingual original-language speaker does:
    - I will speak with the person closest to me. If the language of the closest speaker is the "immigrant language," then I will increase my opposite-language ability based on my age.
        - If I am below ten, opposite-language-ability increases by twenty-five.
        - Between ten and eighteen, opposite-language-ability increases by five.
        - If I am older than eighteen, opposite-language-ability increases by one.

    - I will check if I have become bilingual yet. If my opposite language-ability increases the "bilingual-threshold" parameter, then I will become bilingual.
- Each monolingual immigrant-language speaker does:
    - I will speak with the person closest to me. If the language of the closest speaker is the "original language," then I will increase my opposite-language ability based on my age based on the same rules as the rules for a monolingual original-language speaker.
    - I will also check if I have become bilingual yet. If my opposite language-ability increases the "bilingual-threshold" parameter, then I will become bilingual.
- Each mating link between two mated speakers does:
    - If this mating does not yet have the maximum number of children allowed, then there is a chance that on that time tick, the mating produces a child speaker.
        - The child speaker has age zero, opposite-language-ability zero, and is located halfway between the two parents.
        - The child's language is chosen based on the language spoken by the two parents:
            - If the parents speak the same language monolingually, then the child will also speak that language monolingually (this can change as the child ages and interacts with other speakers).
            - If one parent is monolingual and the other parent is bilingual, then the child will speak the language that the parents have in common.

        - Otherwise, the child has a chance of becoming bilingual, based on the "bilingual-inheritability" parameter, or defaulting to the original language spoken in the country.
- Immigration flow occurs:
    - If immigration is allowed, then additional immigrants will enter the country at random locations at an observer-specified rate.

Model Parameters

There are a number of parameters in the NetLogo model that can be altered by the observer. The initial number of citizens, immigrants, and bilinguals in the model are determined by the *number-citizens*, *number-immigrants*, and *number-bilinguals* parameters respectively. Next, the bilingual-threshold parameter determines the threshold that a speaker's "*opposite-language-ability*" property must reach in order for that speaker to become bilingual. Then, the *bilingual-inheritability* parameter determines the likelihood of a pair of parents, who speak the two languages equally (for example, if they are both bilingual), passing on the bilingualism to their child and teaching the child both languages. In addition, *max-num-children* is the maximum number of children that each mating pair can produce. Finally, if the *allow-immigration-flow?* switch is turned on, then immigrants will enter the country at a rate determined by the *rate-of-immigration* parameter.

Justifications for Rules

In the model, monolingual turtles are able to slowly (or quickly, if they are younger) increase their knowledge of the opposite language through conversations with people who speak the opposite language instead of gaining the opposite language speaking ability all at once. This is to reflect that the language learning process doesn't happen all at once, but is the result of time and effort, especially at older ages. In addition, speaker agents have an age and grow older in order to reflect how ease of secondary language acquisition changes over a lifespan. First, agents under age ten have the easiest time learning the opposite language, based on data pinpointing ages under 10 as most critical for second language acquisition (Hartshorn, 2018). Other research points to ages 10 to 18 as also prime language-learning ages, although at a more moderate pace (Smith, 2018). As a result, agents aged 10 to 18 have the second easiest time learning the opposite language. Finally, agents above the age of 18 have a more difficult time learning the opposite language, but they are still able to learn as they speak with other agents.

One design choice in the model was the inclusion of monolingual and bilingual speakers only, excluding polyglots. This was for two reasons. First, there were only two languages involved in our system, since the system focuses on the interaction between an immigrant and native language. Second, the overwhelming population of the world is either monolingual (40%) or bilingual (upwards of 50%), so monolingual and bilingual speakers tend to be much more prevalent in the overall population (Ansaldo, 2008).

It was also important to have the languages spoken by the parents affect the languages spoken by the children to reflect the importance of the parental language in language acquisition. In addition, the model implementation contains mating links, so the children could be birthed to the same couple through time instead of all at once. This was done to reflect that, if the language of the parents changes over time (for example, if both parents become bilingual), this may affect the language of future children. In other words, children born to the same parents at different times may speak different languages.

Finally, children who are born to bilingual parents have some chance of becoming bilingual, but if they do not become bilingual, they tend towards speaking the original language in the country. This reflects that the original language is the predominant language rooted in the country. As such, learning infrastructures such as schools or parental desire for the child to assimilate linguistically may sway the default language of the child towards the original language of the country (Rumbault, 2013).

Simplifications and Assumptions

One major simplification made was that all immigrants entering the country would speak the immigrant language. In reality, immigrants to the country may speak a variety of languages, even potentially speaking the native language of the country monolingually. Next, language learning in the model is done through speakers speaking to their closest neighbor at each time tick. However, language learning is a complex phenomenon and not solely done through speech with surrounding people, although interpersonal speech is a major factor in the younger years primed for language acquisition (Hartshorn, 2018).

In addition, another simplification made was starting the model with all speakers having an opposite-language ability of zero, which was done to illustrate that at the beginning of the time step, the immigrant language has not yet been integrated into the country. Next, all speakers were assumed to be equally likely to mate with one another. However, people may hold implicit (or explicit) biases towards other speakers in the model or be less able to communicate with certain speakers, decreasing their likelihood of mating. Finally, we assumed that both languages were equally learnable to speakers. However, perhaps the linguistic nuances of one language might make it harder for people to learn that language.

Results, Analysis, and Discussion

Emergence of Language Death

The first topic explored was how the initial distribution of monolingual original-language speakers and monolingual immigrant-language speakers affected the longevity of the immigrant language within the system. To evaluate this, trials were run in BehaviorSpace, which is a software tool integrated into NetLogo that allows parameter sweeping and data collection as it runs the model repeatedly. For this BehaviorSpace experiment, the parameter varied was the number of initial immigrants in the population, with each possible number of immigrants undergoing ten trial runs for a total of 310 runs. The resulting data measured was the number of years in the model until both the number of immigrant speakers and bilingual speakers reached zero. In other words, this will be the time until the immigrant language fully dies out, not even preserved in the form of bilingualism. This time will be capped at 10, 000 time steps, which would represent 10, 000 years.

The result of the experiment was that in each of the 310 runs, language death emerged, and the immigrant language was replaced by a shift towards monolingualism of the native language (Figure 1). For the majority of runs, this happened under two centuries. However, there were some runs that took a much longer time for language death to emerge, such as upwards of

400 years. Despite the long time frame, in each trial, the immigrant language died out under 500 years, not even coming close to the threshold set of 10, 000 years. While the emergence of this result seems surprising, it reflects other studies on the occurrence of language death for immigrant populations. The immigrant language becomes much more extremely rarely-spoken throughout time as it becomes dominated by the native tongue through speaker assimilation and generational influence (Massey and Rambault, 2013).

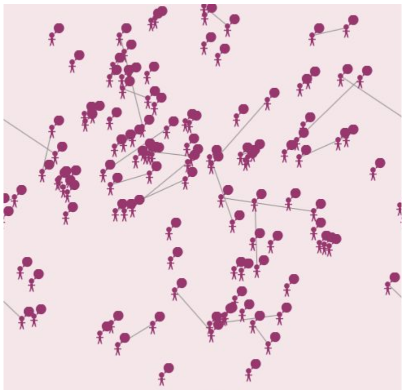

Figure 1: Emergence of language death, as seen by a homogeneously monolingual population after a number of time steps.

The following plot shows the effect of the initial immigrant-language population on the number of years until there are no more immigrant or bilingual speakers in the world (Figure 2). The linear trendline on the graph has an equation of $y = 5.6556x + 77.573$, reflecting the positive relationship between x (initial number of immigrants and y (longevity of immigrant language). Therefore, a larger initial immigrant population correlates with greater longevity of the immigrant language and a smaller number of initial immigrants in the population corresponds to a shorter lifespan of the immigrant language. This makes sense as if the trend is that immigrants are increasingly assimilating or losing their mother tongue, and there are fewer immigrant speakers in a population, the immigrant population would reach zero faster than a greater initial immigrant speaker would reach zero.

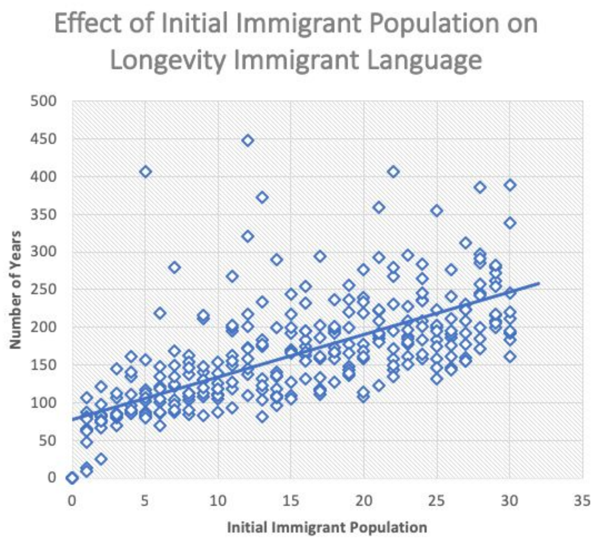

Figure 2: Plot showing relationship between immigrant population and language longevity.

In addition, the following box-and-whiskers plot (Figure 3) demonstrates the resulting spread of immigrant language longevity following the experiment. The interquartile range of the plot shows that half of the data falls between one to two hundred years for immigrant language die-out in the simulation for the parameters that were specified. In addition, it shows that language lifespans that fell closer to four centuries were outliers coming from less than two percent of trials. This means that within just a few generations, both the immigrant language and bilingualism cease to exist within the model and are no longer spoken by the speaker agents.

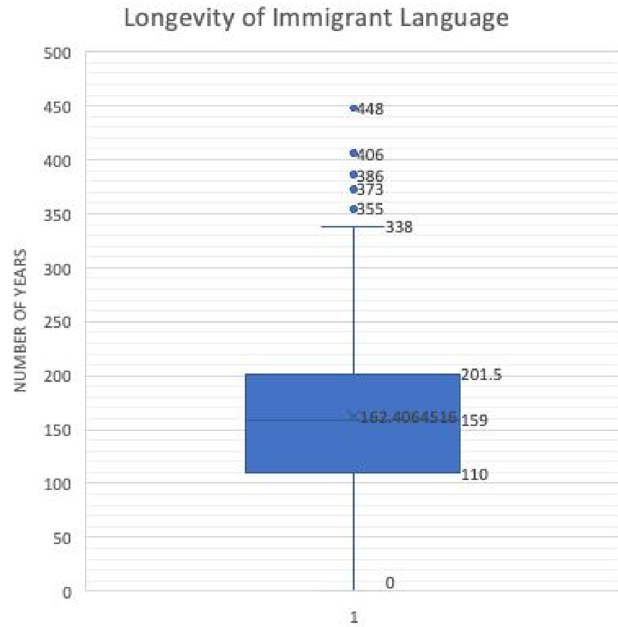

Figure 3: Box-and-whiskers plot of number of years until the number of immigrant and bilingual speakers reaches zero. Minimum: 0 years, Maximum (excluding outliers): 338 years, Median: 159 years, Mean: 162.406 years, 1st Quartile: 110 years, 3rd Quartile: 201.5 years.

Overall, the results of this experiment reflect the emergence of language loss when there is no immigration flow into a country, despite an initial population of immigrants existing in the country. Not only did language death emerge in this model, but it also emerged even when the number of immigrants increased substantially, becoming increasingly large proportions of the overall population. This reflects findings that show that even if there is a substantially larger proportion of immigrants in the population, the end trajectory towards linguistic death still remains the same when there is no influx of first-generation immigrant speakers into the country (Massey and Rambault, 2013).

Impact of Rate of Immigration on Long-Term Language Distribution

Now that the system behavior has been analyzed without an inflow of immigrants, it is also interesting to see what emerges when immigrants are introduced into the model at a positive rate. To study this, a similar BehaviorSpace experiment will be run three times, varying the rate of immigration into the model and studying the resulting percentage of the population that is monolingually original-language speaking, monolingually immigrant-language speaking, and bilingual.

During the experiment, 75% of the population will be original-language speakers, and 25% of the population will be immigrant-language speakers. These proportions of the initial population will be held constant, along with other parameters (bilingual-threshold 60, bilingual-inheritability 50, max-num-children 2). With each different trial, the rate of immigration will increment by one from 0 to 10, and each value will be run ten times for each of the three different times that the experiment is run (in order to cleanly collect different data), for a total of 300 runs. After the model runs for 400 time steps, corresponding to 400 years, data is collected for either the amount of monolingual immigrant-language speakers, monolingual original-language speakers, or bilinguals. The baseline of 400 years was chosen because in the previous experiment, without immigration, the maximum immigrant language longevity, excluding significant outliers, was 338 years. So, without any rate of immigration, the immigrant language is likely to have died out by 400 years. Therefore, it will be interesting to compare the differences in the resulting distribution of languages as a rate of immigration is introduced after this timespan.

The results of the first experiment (Figure 4), which looked at the monolingual immigrant-language speaking population, showed a positive relationship between the rate of immigration and monolingual immigration. This result makes sense, as if there are more first-generation immigrants being introduced into the system, there would be a more sustained immigrant-language speaking population. As the rate of immigration increases, the monolingual immigrant-language speaking population increases at an increasing rate.

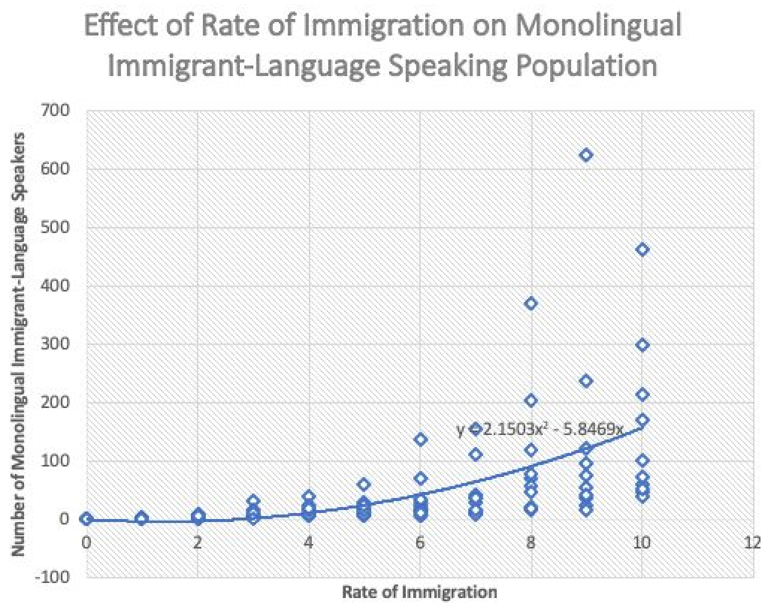

Figure 4: Plot showing rate of immigration vs. immigrant-language population. Trendline is polynomial with order two: $y = 2.1503x^2 - 5.8469x$.

During the second experiment, which considered the impact of the rate of immigration on the monolingual original-language population, there was again a positive, increasing relationship between the rate of immigration and monolingual original-language population (Figure 5). This makes sense as reproduction rates are maintaining the current population, and then population growth is being largely created by an influx of people into the country. However, in contrast with the immigrant-language speaking population, the population growth is happening at a decreasing rate, showing it may be possible for the immigrant language to overtake the original language based on their current rates of growth. However, within the experiment, the original language population is still experiencing growth overall and retains dominance.

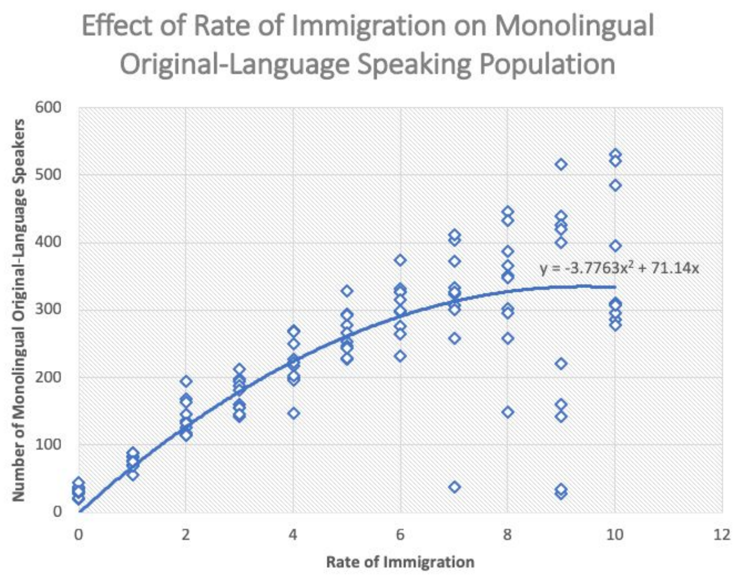

Figure 5: Plot showing rate of immigration vs. original-language population. Trendline is polynomial with order two: $y = -3.7763x^2 + 71.14x$.

The third experiment considered the rate of immigration and the resulting bilingual population after time. Like the immigrant-language population, the bilingual population increases at an increasing rate, albeit with a much more gradual increasing rate. Therefore, a rise in the rate of immigration increases the population of all languages speakers but alters the language distribution of the country to increasingly favor immigrants and then bilinguals by proportion. However, even at the high rates at immigration within in the experiment, the immigrant language does not yet overtake the original language, as during this process, immigrants and bilinguals are becoming increasingly assimilated into the original language (as seen in the previous section titled “Emergence of Language Death”). As immigrants are entering the country and adding to the immigrant population, the descendants of immigrants are assimilating and contributing to the bilingual/monolingual populations, thus spreading population growth among all three categories.

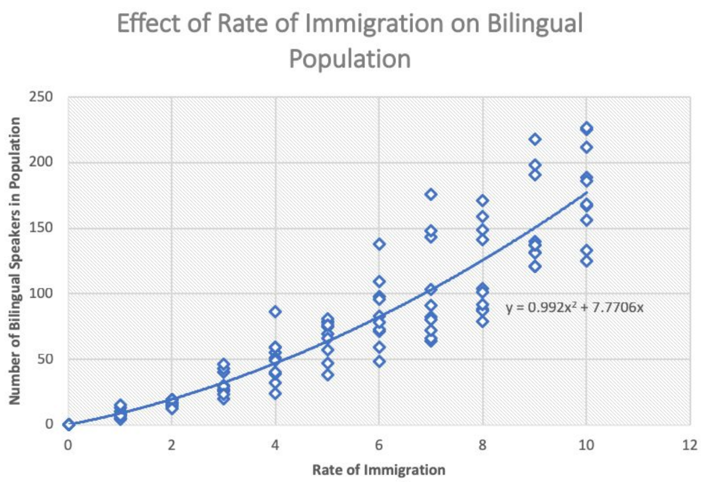

Figure 6: Plot showing rate of immigration vs. bilingual population.
Trendline is polynomial with order two: $y = 0.992x^2 + 7.77706x$

Overall, this experiment shows that it is possible to maintain the lifespan of the immigrant language through a consistent rate of immigration and that the rate of immigration has an exponential effect on the number of immigrant-language speakers. This also reflects studies which show that if not enough first-generation immigrant-language speakers are introduced to "offset the rising tide" of the linguistic deaths seen after the second generation, the persistence of the immigrant-language will be impacted (Massey and Rambault, 2013). This also indicates that there may be an ideal, positive rate of immigration that can maintain the immigrant-speaking population without significantly decreasing the monolingual-speaking population.

Three-Generation Pattern of Bilingualism

Finally, the three-generation pattern of language loss can also be seen as an emergent behavior within this model. The following charts show the percentages of original-language monolinguals, immigrant-language monolinguals, and bilinguals respectively through a run of the model with no rate of immigration (Figure 7). During this run, the initial population had 30 original-language speakers and 10 immigrant-language speakers, as well as the same parameters seen in earlier experiments. As the years passed within the country, the percentage of immigrant-language monolinguals decreased, while the percentage of original-language monolinguals increased. However, the number of bilinguals increases and then decreases throughout the generations.

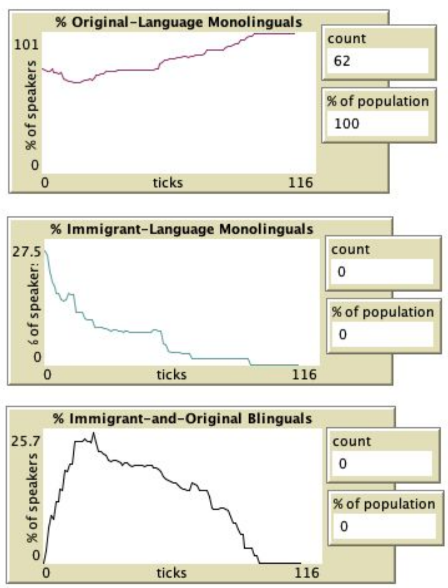

Figure 7: Charts showing the changes in language distribution as time passes in the country.

The changing distribution of bilingualism reflects the emergence of bilingualism in the second generation, partially caused by the descendants of immigrants becoming bilingual. However, as time passes, future generations are less likely to preserve this bilingualism. In the end, bilingualism between the immigrant and original language follows the path of the immigrant language and becomes lost. Only monolingual speakers remain in the model after approximately 100 years (Figure 8); however, during the run of the model, bilingual speakers emerge and then disappear (Figure 9).

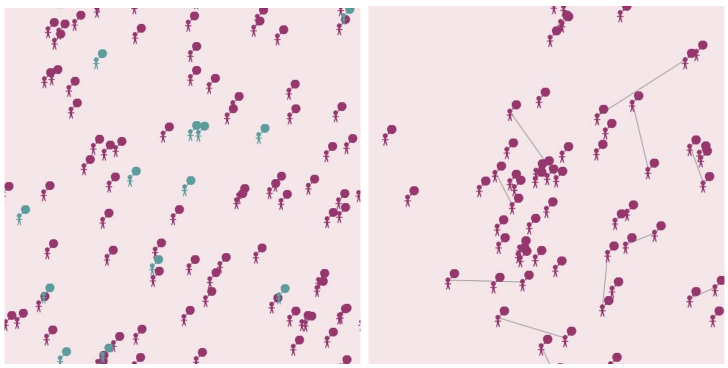

Figure 8: Before (left) and after (right) language death emerged in the model. Immigrant-language speakers are teal and original-language speakers are magenta.

The following screenshot shows one of the possible ways that the immigrant language is lost (Figure 9). A bilingual speaker is mated with a monolingual original-language speaker, so they teach their child the original language as it is the language that they communicate with and the language that the child is predominantly exposed to in the language acquisition years. Therefore, within this family, there is a loss of bilingualism as the bilingual and original-language parent are generationally replaced by two original-language children. The accumulation of these agent-level behaviors results in the overall emergent trend of a shift towards original-language monolingualism.

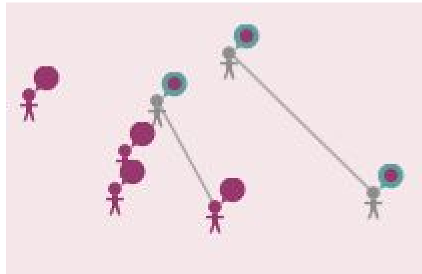

Figure 9: The mating link (grey line) on the right between a bilingual speaker (magenta-and-teal bubble) and an original-language speaker (magenta) produces two original-language speaking children (magenta) to their left.

The emergence of this pattern reflects the same trends seen in studies demonstrating the “three-generation pattern” of linguistic assimilation, where the second generation preserves the immigrant language through bilingualism, but the language becomes lost in the third and fourth generations (Ortman and Stevens, 2008).

Conclusion

Potential Future Work

Currently, the model displays an original language and an immigrant language, as well as the resulting bilingualism between them. One potential extension to this model is introducing additional languages to the model, that is, adding immigrants who speak different languages into the system. Additional parameters could include the number of speakers of each additional language, the number of bilinguals for each permutation of two languages, and rates of immigration for different languages. The model could also be extended to include trilingualism or other polyglotisms.

Another possible extension is having younger speakers go to “school," where they are more likely to be exposed to the original language, potentially increasing the dominance of the immigrant language through assimilation. In addition, the model could be extended to introduce "communities" for the immigrant language similar to ethnic hubs such as the Chinatowns seen in San Francisco and other major cities. Groups of immigrants who speak the same language, which could be implemented through a network structure, may be more likely to move towards the same geographical region and connect, thus potentially sustaining the usage of the immigrant language.

In conclusion, within an agent-based system, it is possible to model the emergence of language death as a result of the three-generation language pattern of language loss. This shows that, contrary to those arguing that the existence of immigrants and immigrant languages are a threat to a native language, it is actually more difficult to maintain stable bilingualism throughout the generations or persistence of the immigrant language without a positive rate of immigration. In fact, a foreign language is more likely to be dominated by the primarily-spoken native language of the country. This is important as public perceptions towards immigration and multiculturalism will not only shape decisions about the future demographics of many countries but also trickle down into the lives of citizens in countless, complex ways.

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