Evolution of language driven by social dynamics

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Abstract. The survival of endangered languages in complex language competition depends on the socio-cultural status and honour endowed (by itself and by the other) among them. The restriction in the endorsement of this honour leads to the extinction of one language and rise of the other. Endorsing proper mutual honour to each other triggers the co-existence of people speaking the two languages and this can save both languages from extinction. The loss of respect to each other leads to the death of both languages. We found a minimal or critical mutual honour $u_c$ which protects the two languages from extinction. The increase in mutual honour from this minimal value allows an increase in the populations of the people who speak the two languages. The state of co-existence of competing languages abolishes the concept of minority and majority in language competition, which can be obtained by mutual honour. Further, excess of biased honour to a particular language (minority or majority) forces the language to extinct. In mean-field approximation of language competition, magnetisation parameter can be taken as an indicator of the survival of a language.

Keywords. Language competition; mutual honour; magnetisation.

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1. Introduction

Language carries the socio-cultural status of the speakers [1], and therefore triggers a competition among the languages [2], which leads to the extinction of some languages and dominance of other languages [3]. This language competition can be affected by various factors, namely decisions in social consensus [4], interaction of heterogeneous agents in the society [5] and other factors. The two-language competition modelled by Abrams and Strogatz [3] proposed the diversity of languages caused by the competition, which endangers one of the languages leading to its extinction. The model has limitations in describing the dynamics of individual speakers because it considered the behaviour of population as a whole. The model was extended to bilanguage competition, which takes into account some individual speakers of both languages in the dynamics [2]. The incorporation of bilingual speakers as a community in the two-language competition model was then proposed, which could lead to the multi-language modelling [6]. On the other hand, there are language models where the competition of two languages was studied using the predator–prey model [7].

People carry language, and language spreads out from the inhabitant region through interaction, which is proportional to the population size of those people who speak that language [8]. Competition between any two languages is greatly influenced by various factors, such as the ability of one language to influence the other language, inheriting capacity of a language to the people, social and cultural status of the language. Bilingualism model is one which incorporates bilingual speakers in the competition of two mutually intelligible or genetically similar languages allowing to maintain the endangered language [6]. It was proposed, within this model, that even though there are no endangered monolingual speakers, the existence of bilingual speakers preserved the endangered language from extinction [2]. However, if there is no linguistic advantage of the two competing languages, the disappearance of people who speak the endangered language will lead to the extinction of that language due to the conversion of bilingual speakers to the other existing language [2,6]. In these
models, the existence of bilingual speakers in language competition is an indicator of preserving endangered languages from extinction.

Language competition is greatly influenced by the social status, cultural inheritance and honour given among the speakers. These influencing factors are so strong that minority languages, which are far different from majority language, can survive if these factors are provided for them. We address these issues in this work to show the probable preventive measures to be taken up to save the endangered languages from extinction. We studied the bilingual model [2,6], which is an extended version of two-language competition due to Abrams and Strogatz [3], to understand the fundamental roles of the factors in language dynamics and evolution.

2. Bilingual model of two-language competition

The two-language competition model due to Abrams and Strogatz [3] was expanded by Minett and Wang [2] by incorporating the emergence of bilingual speakers instead of people who speak two different languages. If \( X \) and \( Y \) are two competing languages which permit the emergence of a group of people \( B \) who speak both the languages, and the competition allows these basic transitions in due course: \( X \rightarrow Y, Y \rightarrow X, X \rightarrow B, B \rightarrow X, Y \rightarrow B \) and \( B \rightarrow Y \) [2]. The first two transitions can be taken as rare transitions [2], and therefore it can be assumed that only the last four transitions are trivially observed transitions during competition [5]. If \( N \) is the population of the monolingual and bilingual speakers, then \( X + Y + B = N \), so that one can define \( x = X/N \), \( y = Y/N \) and \( b = B/N \) such that \( x + y + b = 1 \). The transition probability of a transition from state \( B \) to \( X \) is given by the power law, \( P_{BX} = \mu c_{BX} s_x x^u \), where \( c_{BX} \) is the attractiveness of the bilingual speakers towards \( X \) speakers, \( s_{X} \) is the status of the language \( X \) and \( \mu \) is the mortality rate of \( B \), i.e. replacing rate of \( B \) by \( X \). Similarly, the probability that the transition \( X \rightarrow B \) occurs is given by \( P_{XB} = (1-\mu)c_{XB} s_y y^u \), where \( s_{Y} + s_{Y} = 1 \). Then, the time evolutions of \( x \) and \( y \) are given by the net change in \( x \) and \( y \) at state \( X \) and \( Y \), respectively given by

\[
\frac{dx}{dt} = z P_{BX} - x P_{XB} = \mu c_{BX} s_{X}(1-x-y)x^u - (1-\mu)c_{XB} s_{Y} x y^u
\]

\[
\frac{dy}{dt} = z P_{BY} - y P_{YB} = \mu c_{BY} s_{Y}(1-x-y)y^u - (1-\mu)c_{YB} s_{X} y x^u.
\]  

The critical points of the above coupled differential equations (1) and (2) are given by the conditions, \( \frac{dx}{dt} = 0, \frac{dy}{dt} = 0 \). The critical points \( (x^*, y^*) \) are calculated from these conditions, and \( (0,0) \) is found to be one critical point, and the other can be obtained from the equations and by the following expression:

\[
x^* = \Lambda y^*; \quad \Lambda = \left( \frac{c_{XB} c_{BY} s_{X}^2 \mu}{c_{BX} c_{YB} s_{X}} \right)^{1/2m-1}.
\]  

This expression and the two equations \( \frac{dx}{dt} = 0, \frac{dy}{dt} = 0 \), lead to the expressions for \( x^* \) and \( y^* \) as

\[
x^* = \frac{\Lambda}{1 + \Lambda + \Gamma} \left( 1 - \frac{1}{\mu} \right) \frac{c_{XB} s_{Y}}{\mu c_{BX} s_{X}} \]

\[
y^* = \frac{1}{1 + \Lambda + \Gamma} \left( 1 - \frac{1}{\mu} \right) \frac{c_{XB} s_{Y}}{\mu c_{BX} s_{X}} \]  

The critical points given by (4) and (5) depend on the language bias, social status and honour provided.

3. Mean-field approximation of language competition

The infinite population limit allows the society to be fully connected due to the interaction of people speaking various languages [9]. In this limit, one can define \( m = x - y \), which is closely similar to the magnetisation parameter. If \( v \) is a bias parameter, defined as \( v = s_{X} - s_{Y} \), then by putting \( s_{X} = s \), we get \( v = 2s - 1 \). Then, the time evolutions of magnetisation parameter \( m \) can be obtained from eqs (1) and (2). Similarly, from \( x + y + b = 1 \) we have, \( \frac{dm}{dt} = -\frac{d}{dt}(x + y) \). The time evolutions of \( m \) and \( b \) are given by

\[
\frac{dm}{dt} = \frac{\mu}{2u} \left[ c_{BX} s_{X}(1-b+m)^u - c_{BY}(s-v)(1-b-m)^u \right]
\]

\[
+ \frac{1-\mu}{2u+1} \left[ (1-b)^2 - m^2 \right] \times \left[ c_{XB}(s-v)(1-b-m)^{u-1} 
\right]
\]

\[
- c_{YB} s_{Y}(1-b+m)^{u-1} \]  

\[
\frac{db}{dt} = \frac{\mu}{2u} \left[ c_{BX} s_{X}(1-b+m)^u + c_{BY}(s-v)(1-b-m)^u \right]
\]

\[
+ \frac{\mu-1}{2u+1} \left[ (1-b)^2 - m^2 \right] \times \left[ c_{XB}(s-v)(1-b-m)^{u-1} 
\right]
\]

\[
+ c_{YB} s_{Y}(1-b+m)^{u-1} \right] .
\]
The critical points \((m^*, b^*)\) of the above differential equations (6) and (7) can be obtained using the conditions \(\frac{dn}{dt} = 0, \frac{db}{dt} = 0\). The two equations obtained from these two conditions give two critical points \((0,1)\) and the other critical points are given by

\[
m^* = \frac{\mu}{\mu - 1} \left[ \frac{c_{BY}(s - v)}{c_{YB}} - \frac{c_{BXs}}{c_{XB}(s - v)} \right] \quad (8)
\]

\[
b^* = 1 - \frac{\mu}{1 - \mu} \left[ \frac{c_{BXs}}{c_{XB}(s - v)} + \frac{c_{BY}(s - v)}{c_{YB}} \right]. \quad (9)
\]

The above critical points are greatly affected by various parameters, such as the status, bias and mortality rate of the languages. The population difference between people who speak two different languages remains constant, and this means that there is no competition between the two languages and they exist in harmony.

## 4. Results and discussions

The language dynamics driven by various parameters are presented here by solving the coupled differential equations (1), (2), (8) and (9) using standard fourth-order Runge–Kutta method of numerical integration [10]. The complicated language dynamics, affected by various social and cultural factors is studied and some possible criteria are provided to save endangered languages from extinction.

### 4.1 Language dynamics driven by social status

The social status of the two competing languages, indicated by \(s_X\) and \(s_Y\), greatly influences the attractiveness of each language, leading to the conversion of speakers of one language to the other, and vice versa. If \(X\) and \(Y\) are minority and majority languages, respectively, and the social status endorsed to both the languages has large difference \((s_X = 4, s_Y = 8)\), then the speakers of minority language will decrease monotonically with time (figure 1, left panel) and will be extinct after a particular time. The speakers of majority language will be increased for certain range of time due to the conversion of minority to majority language speakers, and then remain stationary (figure 1, left panel). The extinction time of the minority language is slow if the social status difference, \(\Delta s = (s_Y - s_X)\rightarrow 0\) with large \(s_X, s_Y\), and minority language comes into existence if \(\Delta s = 0\).

The social status given to the majority language is smaller than that to the minority language, \(s_X > s_Y\), then the majority language will become extinct and minority language will survive (figure 1, upper right panel). Further, if \(s_X, s_Y\rightarrow\) small, then even if \(\Delta s = 0\), both minority and majority languages will become extinct

### 4.2 Language driven by mutual honour

The mutual honour (indicated by the parameter \(u\)) endorsed to each other in language competition plays an important role, which can save both minority and majority languages from extinction (figure 2). Low social status \((s_X = 0.4, s_Y = 0.4)\) with low mutual honour (large value of \(u = 1\)) given to each other, drives both languages to extinct at different times (figures 1 and 2). Keeping this social status fixed and decreasing the value of \(u\) allows the increase in the number of the language speakers. The maximum critical value of \(u, u_c\), is found to be \(u = 0.9635\) which can save both the languages from extinction (non-zero population). The populations of the people who speak two languages first decreases up to minimum non-zero populations, and then the two populations become equal and constant as a function of time. After this time of co-existence, there is no distinction between majority and minority languages because the populations of the two languages are the same. This indicates the co-existence of people who speaks two languages at this social status. Minimum honour between
the two languages can be used to increase the attractiveness of each individual language, and to save the languages from extinction (figure 2).

Now, if $u$ decreases, the co-existence of the two languages occurs much early, and the numbers of the language speakers increase. This increase in the populations speaking two languages at co-existence is because proper honour is given to each other.

### 4.3 Social status can save minority language

The populations of people speaking majority and minority languages are calculated as a function of $s_X$ for a fixed value of $s_Y$ (figure 3). The populations of the people who speak the two languages fluctuate as a function of social status of the minority language ($s_X$), but the population of people who speak minority language increases as $s_X$ increases. At the same time, the population of the majority language decreases as a function of $s_X$ with large fluctuations due to social fluctuations with time.

The co-existence of the two languages happens only at a few points, and then they are parted away from the co-existence. These co-existing points are the points at which both the languages can be saved from extinction. Beyond this point, one of the languages will be extinct.

### 4.4 Magnetisation as an indicator of language extinction

The magnetisation $m$ is calculated as a function of time for different values of $u$ for fixed values of other parameters (figure 4). Magnetisation for large values of $u$ ($u > 1$) shows slow variation with time and the behaviour becomes steady state. The dynamics of $m$ for small values of $u$ ($u < 0.0382$) become monotonically
increased as \( u \) decreases. Since \( m = x - y \), the monotonic increase in \( m \) with time indicates the dominance of one language over the other, leading to the extinction of one language.

The increase in \( m \) is due to language competition, and reaching a steady state indicates the co-existence of the two languages where conversion of one language speaker to the other and vice versa does not take place. The decrease in \( m \) for \( u = 2 \) as a function of time indicates either extinction of both the languages or co-existence of the two languages (same populations of the language speakers).

5. Conclusion

Language dynamics is a complicated process, which involves competition, change, evolution and struggle for survival. The dynamics of competing languages is affected by various factors, namely mutual honour, prestige, social status and carrying culture which can drive the languages at different states, i.e. extinction or survival. When two languages compete, the language which has relatively low social status will quickly extinct and the language having relatively higher social status will be able to survive in the long run. However, if the social status of both the languages is smaller than a critical value, both the competing languages will be extinct.

The survival of bilingual speakers in two-language competition can be a signature of maintaining minority language to survive along with majority language. It could be due to the fact that the minority language is preserved by the people who speak this language along with the other language. However, if the status of the minority language is very low compared to the other, then the bilingual speakers will be attracted quickly towards the higher status language, and the other language will be extinct. The competition between the two languages is done via transition by the bilingual speakers.

The co-existence between two languages is a peculiar state of competing language dynamics which allows the survival of both the languages with same population. This is possible only when the mutual honour between each other is increased above a critical value. Hence, the survival of both the languages can be possible if the two competing languages endorse mutual honour and respect.

Magnetisation in mean-field approximation can be used as an indicator of language survival in language competition. The monotonic increase in magnetisation shows the survival of one language and the extinction of the other language. The steady state of the dynamics of magnetisation can be a state of co-existence of the two languages. The decrease in the value of this parameter may indicate the extinction of both languages or co-existence state. However, the language competition is a complicated process, and there are lots of issues in understanding this process so that one can save endangered languages. The breakdown of a language into a number of dialects, which may become independent languages, and understanding their complicated dynamics need to be investigated to highlight the importance of language competition.

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