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Simulating vowel chain shift in Xumi☆

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Abstract

This paper presents a simulation study of a vowel chain shift in Xumi (Tibeto-Burman). It adapts de Boer's (2000, 2001) model of vowel systems in a population of artificial agents. The goals are: (1) to test one specific hypothesis of the relevance of a loan phoneme to the observed changes in the chain shift, and (2) to address on the basis of our Xumi data some general questions of interpretation related to synchronic vowel chain shifts. Our simulation results shed light on a complex scenario of change in Xumi that involves both system-internal factors and a system-external factor (the addition of a loan phoneme). Our simulation results also suggest that the particular combination of mechanisms and constraints in the model's settings—random acoustic noise, self-organization, and contrast maintenance—is a viable hypothesis for vowel chain shifting. Our study demonstrates that computational simulations are helpful in evaluating different approaches to a specific instance of sound change.

Keywords: Agent-based model; Vowel chain shift; Self-organization; Contrast maintenance; Xumi; Tibeto-Burman

1. Introduction

This paper applies computer modeling to a study of one concrete scenario of change in Xumi (旭米), an unwritten Tibeto-Burman language, spoken in one mountain valley in Sichuan Province in the People's Republic of China.[2] Despite its small area of distribution, the language is spoken in two dialects with limited mutual intelligibility. Many consistent phonetic changes between the two dialects can be observed, but investigation of the origin and course of individual changes is difficult to pursue because all available evidence is synchronic. In this study we aim to tackle this difficulty through computer modeling. Naturally, computer modeling cannot replace missing historical data, but it can supplement traditional methods of linguistic analysis by providing a possibility of testing alternative hypotheses related to a specific instance of sound change. In addition to specific hypothesis testing, application of computer modeling to a concrete scenario of change, be it even in a little-known language, such as Xumi, may be useful in furthering our understanding of the type of change being modeled and of the key parameters that may underlie related processes in other real-world languages.

☆ Each author contributed equally to this paper, by bringing in their respective expertise. Chirkova, trained as a linguist, has taken primary responsibility for data collection, and for the description and analysis of the chain shift in Xumi. She was also the primary writer and editor. Gong, trained as a computer scientist, has taken primary responsibility for conducting simulations and presenting simulation results.

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[2] This language is also known as Shixing (史兴), see Chirkova (2009) for a detailed introduction and a grammatical sketch.

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Our study focuses on a vowel chain shift in Xumi. Previous analyses (Chirkova and Chen, 2013; Chirkova et al., 2013) identify a common system of eight vowels in its two dialects. One dialect is described as having an additional (i.e. ninth) vowel phoneme, which it arguably borrowed from a contact variety of Tibetan (Kami). The previous analyses also suggest that the addition of the ninth loan vowel phoneme led to a series of related changes in the phonetic realization of the eight native vowel phonemes in that dialect. In other words, it led to a vowel chain shift: a series of related sound changes that are causally connected (Labov, 1994:118–121).

In order to evaluate this hypothesis, we used the agent-based model of vowel systems developed by Bart de Boer (2000, 2001) (see de Boer, 2000:445–453; de Boer, 2001:38–54 for detailed descriptions of the original model and the underlying settings).[3] Agent-based models are designed to explore how iterated interactions among independent autonomous entities (agents) gradually lead to collective behaviors at the population level (for overviews see de Boer, 2006; Bonabeau, 2002; Gilbert, 2008; Gong and Shuai, 2013; Gong et al., 2014; Railsback and Grimm, 2012; Wagner et al., 2003). Each agent is equipped with predefined or evolved mechanisms that enable interaction with other agents. By manipulating these mechanisms and ways of communication between agents, it is possible to simulate various phenomena in the human socio-cultural environment. One advantage of agent-based models is that existing models can be easily expanded and adapted to new research goals (Belew et al., 1996; de Boer, 2006), as we did in the present study.

de Boer's (2000, 2001) model was originally developed to study the formation of vowel systems. It provides support for the thesis that self-organization plays an important role in determining the structure of vowel systems. Self-organization is defined as a process in which patterns at the global level are properties that spontaneously emerge from the numerous local interactions among the individual components (cf. Camazine et al., 2001:8; de Boer, 2001:24). An advantage of de Boer's model for our investigation is that it is based on a realistic representation of vowels in the articulatory and acoustic spaces, hence allowing for a realistic replication of the vowel systems of the two dialects of Xumi.

de Boer's model already includes in its original architecture a number of mechanisms that have been argued to underlie vowel chain shifts in real-world languages, more specifically: (i) emergence of patterns through self-organizational pathways (e.g. Liljencrants and Lindblom, 1972), and (ii) phonetic variation due to random noise in production and perception, which steadily introduces new phonetic variants (Bybee, 2001; Pierrehumbert, 2001, 2002; Wedel, 2006).[4] We adapted de Boer's model to the chain shift scenario in Xumi by building in the constraint of contrast maintenance, one of the defining criteria of vowel chain shifts (as explained by Labov, 1994:115–291; Martinet, 1952, 1955; and others). We generally followed the original model for all remaining settings. We manipulated some key parameters (such as acoustic noise ratio) and evaluated the results in relation to our empirical data (see section 5). Overall, we accept the known limitations and assumptions of de Boer's model, which may not correspond directly to actual features of real-world languages (as acknowledged by de Boer; see de Boer, 2000:463; de Boer, 2001:40–41 for discussion).[5]

We used the adapted system to run two sets of simulations: (i) an eight-vowel system, initialized on the observed vowel parameters of the eight-vowel dialect of Xumi (hereafter referred to as ''eight-vowel simulations''); and (ii) a nine-vowel system, where a ninth vowel is added to the eight-vowel system (hereafter ''nine-vowel simulations''). The goal of the eight-vowel simulations was to analyze any potential change due to system-internal factors and mechanisms (random noise, self-organization, and contrast maintenance). The goal of the nine-vowel simulations was to test the specific hypothesis of the relevance of the ninth loan vowel phoneme to the set of changes in the nine-vowel dialect. In addition to that specific hypothesis, the two sets of simulations also allowed us to address on the basis of our Xumi data some general issues of interpretation raised by synchronic vowel chain shifts. These include (summarized on the basis of Gordon, 2001:194–219; Gordon, 2002): (i) how can an ongoing chain shift be identified and studied? (ii) how to establish whether changes are interrelated? (iii) how to establish the chronology of changes? (iv) how to determine whether contrast preservation plays a role in a given change? and (v) should one expect all links in a chain to reflect the influence of contrast preservation?

The simulation results were evaluated on the basis of the acoustic distances between the evolved vowels in the two sets of simulations, respectively, and the empirically observed vowels in the nine-vowel dialect of Xumi. Contrary to the previous analysis of the vowel chain shift in Xumi as resulting from the addition of a loan phoneme to the eight-vowel system (Chirkova et al., 2013), our simulation results suggest that the vowel chain shift in Xumi should rather be understood as a combined effect of system-internal factors and a system-external factor (the addition of a loan phoneme). The simulation results also suggest that all changes in the phonetic realization of the vowel phonemes in the nine-vowel

[3] The original program has been kindly provided to us by Bart de Boer.

[4] These mechanisms have been explored in exemplar-based models of language (e.g. Blevins, 2004; Pierrehumbert, 2001, 2002; for an overview and discussion, see Wedel, 2006 and references therein) and tested in an agent-based model of vowel chain shift by Ettlinger (2007). Ettlinger (2007) argues that the changes in a chain shift result from the self-organizing behavior of exemplar-based categories. The self-organizing behavior is such that when one vowel moves, another fills the gap. In contrast to the present study, vowels in Ettlinger's model are defined in a one-dimensional space, and the chain shift scenario only involves two vowel phonemes.

[5] These limitations and assumptions include direct feedback on imitative success and lack of phonological context.