An Agent-Based Model of Spoken Language as a Complex Adaptive System

Computational agent-based modeling has been successfully used in various research areas, including epidemiology [1] and climate studies [2], e.g. to gain insights into the COVID19 pandemic and the effects of climate change. Recently, agent-based models (ABMs) have become more popular in the speech sciences [e.g. 3, 4, 5], but their full potential is far from being realized. Here I introduce soundChangeR, an ABM of sound change, and the first of its kind that was implemented as a publicly available R package and comes with a full documentation of the code (link will be provided after review) [6]. ABMs like soundChangeR offer an artificial world and controlled environment in which the role of cognitive, social, and linguistic factors in sound change can be explored. The input to soundChangeR is a dataset of real speech consisting of acoustic parameters (e.g. formants, duration, energy values) that adequately characterize the sound(s) under investigation within a word, extracted from the speech of actual speakers. Each speaker is then represented by a computational agent that can produce and perceive traces of speech based on principles from episodic models of speech [7] and exemplar theory [8]. The memorization of a perceived exemplar causes an update to the agent's exemplar clouds and phonological categorization which in turn affects the agent's speech production. This feedback loop can lead to phonetic shifts when a phonetic bias in the input data is reinforced through the interactions [9, 10]. Phonological classes in soundChangeR are derived separately for each agent by means of machine learning algorithms and can be updated over time, allowing for phonological changes like splits and mergers to happen [11]. I will argue that ABMs offer a unique way of testing hypotheses computationally that could not be tested experimentally. The main advantage of ABMs like soundChangeR is that they can model spoken language as a complex adaptive system [12], i.e. a system in which microscopic actions and decisions on the level of the individual lead to population-wide patterns [13]. Thus, by taking into account idiosyncratic phonetic variation [14], individual social and cognitive factors [15, 16], as well as the stochasticity of interactions between speaker-listeners [17], agent-based simulations can advance our understanding of the complex interplay between intra- and extralinguistic factors that are involved in sound changes.

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