Production and comprehension pressures jointly shape lexicon structure

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Cross-linguistically, lexicons tend to be more phonetically clustered than required by their phonotactics; that is, words are more similar to each other than they need to be (Dautriche et al. 2017; Mahowald et al. 2018). From the perspective of communication, this is somewhat puzzling: a vast body of work has demonstrated that comprehension is easier when words are more distinct (e.g. Chan & Vitevitch 2009; Luce & Pisoni 1998). However, competing functional pressures may help explain why lexicons exhibit this structure. For example, lexicons built from a smaller inventory of sound sequences are more *compressible* (Ferrer-i-Cancho et al. 2013), which may be beneficial for learning (Kirby et al. 2015). Furthermore, words with more neighbours and higher phonotactic probability (i.e. words that are more similar to other words) are pronounced more quickly and accurately (e.g. Stemberger 2004; Vitevitch & Luce 2005; Vitevitch & Sommers 2003), suggesting that clustering may also be beneficial for language production.

Here, we use an exemplar-based computational model to test what kinds of production mechanisms might give rise to increased clustering on an evolutionary timescale. In this model, pairs of agents learn a miniature artificial language and use it to communicate with each other over multiple rounds. Initial languages consist of 20 strings of 8 randomly-selected phonemes; each string is assigned to an atomic meaning, with meanings represented by integers. In each communication round, agents take turns as producer and receiver for all meanings. We implement two biases in the production process: first, errors tend to replace lower frequency sounds with higher frequency ones (Dell 1986; Levitt & Healy 1985; Motley & Baars 1975), and second, words with higher phonotactic probability are retrieved more easily (Chen & Mirman 2012; Vitevitch 2002). These biases – which, by themselves, give rise to highly clustered lexicons – are held in check by a comprehension mechanism, whereby more distinctive signals are recognised more easily. Signals that result in successful communication are strengthened in the agents' memory, while less successful signals tend to be lost over time due to a limit on memory size. As the effects of these opposing forces accumulate over generations, initially random lexicons become somewhat more clustered, but ultimately stabilise (Figure 1).

Overall, this work sheds light on how organisational properties of the lexicon may arise from a trade-off between production and comprehension pressures. Behavioural experiments are underway to test how the strength of these competing pressures is affected by factors such as word frequency and word length.

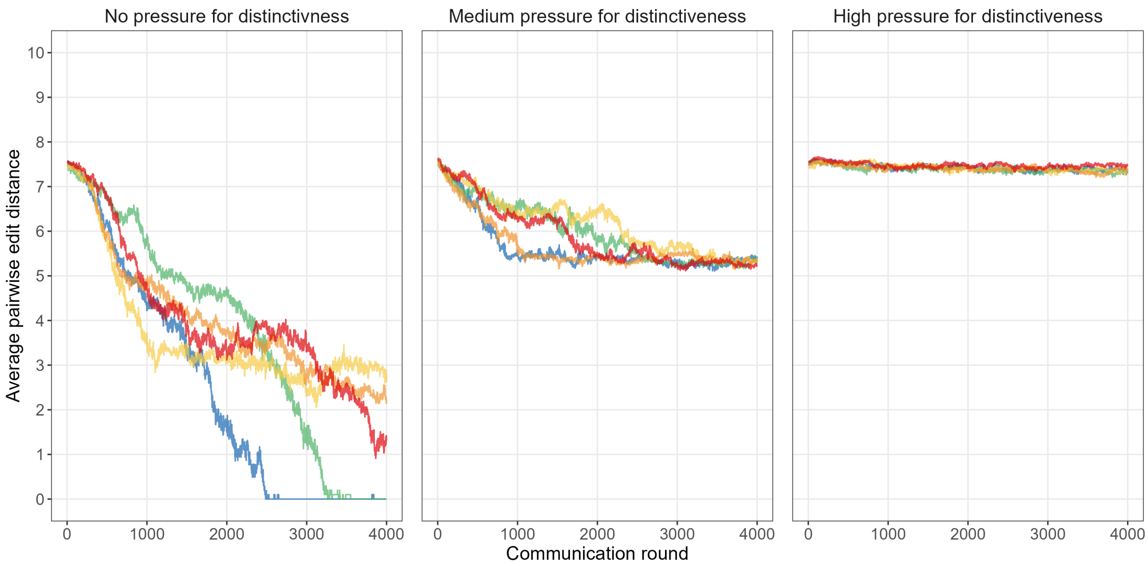

Figure 1: Average pairwise edit distance between words in the lexicon over 4,000 rounds of simulated communication. Each line represents a different chain, initiated with a unique random lexicon (shown at Generation 0). As edit distance decreases, words are becoming more similar to each other i.e. the lexicon is becoming more clustered. When there is no pressure for distinctiveness (the receiver is always told the correct meaning and does not have to interpret the signal themselves), edit distance decreases rapidly – sometimes to the point of collapse (one word for every meaning). When the receiver has to infer the meaning of received signals, the extent to which the lexicon becomes more clustered depends on how sensitive they are to small differences between signals; in the most extreme case where the receiver struggles to tell the difference between words that share any phonemes in the same position, edit distance does not decrease at all.

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