MODELLING THE ROLE OF OTHER-INITIATED REPAIR IN FACILITATING THE EMERGENCE OF COMPOSITIONALITY

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A key feature setting apart human language from other animal communication systems is compositionality (Hockett, 1960). Recent work has focused on explaining the emergence of compositional language by reference to the combined pressures of learnability and expressivity (Kirby, Tamariz, Cornish, & Smith, 2015). Learnability alone would favour a degenerate system (few signals with the most generic meanings possible), while expressivity would be served equally well by a holistic or a compositional system. Only their interaction swings the balance in favour of compositionality, which provides the simplest (most compressible) way of expressing all meanings.

Here we connect these results to two other ubiquitous features of human communication: noise and interactive repair, or the metalinguistic use of signals to address trouble in producing, perceiving and understanding (Schegloff, Jefferson, & Sacks, 1977). Interactive repair has been shown to play a crucial role in streamlining social interaction in everyday and experimental settings (Micklos, Silva, & Fay, 2018; Fay et al., 2018). Cross-linguistic work has uncovered substantial pragmatic universals in this domain, including a basic division into OPEN vs. RESTRICTED repair initiation strategies and a drive to minimize joint effort in the collaborative resolution of trouble (Dingemanse et al., 2015). We aim to bring insights from this work to computational models of cultural evolution.

We adapt the model of Kirby et al. (2015) —in which languages are transmitted over generations through iterated Bayesian learning— and extend it to incorporate noise and repair under the following design decisions, all motivated by empirical observations of interaction. Speakers produce signals that are occasionally partially obscured by noise (Bergen & Goodman, 2015). Listeners may respond directly or initiate repair using either: an OPEN request (indicating no grasp of a signal's meaning and inviting full repetition) or a RESTRICTED

request (indicating partial grasp and inviting partial repetition) (Dingemanse et al. 2015). Listeners initiate repair probabilistically depending on the level of ambiguity (uncertainty about the intended referent) and the cost associated with repair (Clark & Schaefer, 1987). This cost is higher for open than for restricted because the latter recycles part of the trouble source turn (Schegloff, 1979). We hypothesise that repair favours compositional systems under these assumptions:

1. A pressure for MINIMAL EFFORT (less costly responses are preferred)
2. A pressure to reach MUTUAL UNDERSTANDING (agents attempt to formulate interpretable signals and reach unambiguous interpretations)

We hypothesise that having only a pressure for minimal effort does not favour any particular language type, while a pressure for mutual understanding on its own will favour holistic and compositional languages equally. We hypothesise that their joint effect given the availability of repair favours compositional over holistic languages because compositional languages enable taking full advantage of the partial interpretability of signals. Learners of compositional languages should receive more reliable data in this condition, because the agents that produce the data are more likely to use repair to solve ambiguity caused by noise.

We find that the hypothesised effect of the combined pressures for mutual understanding and minimal effort appears when the probability of noise exceeds 0.5. When this is the case, the proportion of compositional languages relative to holistic languages increases when both pressures are combined, compared to when only a pressure for mutual understanding is present (Figure 1). (See supplementary materials for code and parameter space exploration.)
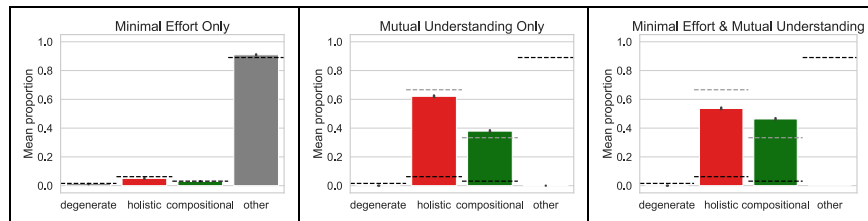

Figure 1. Mean proportions and 95% CIs of language types after convergence (generations 750-1,000 of 100 simulation runs). Dashed lines show baseline proportions of language types in hypothesis space (black for all types, grey for relative proportions of only the fully expressive language types). P(noise) = 0.6, cost ratio OPEN:RESTRICTED = 2:1, transmission bottleneck = 20 data points per learner.

In sum, we show that in addition to serving the combined pressures of learnability and expressivity, compositional languages can also be useful under the interactional dynamics of noise and repair, where they enable agents to reach mutual understanding with minimal effort.

Acknowledgements

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