# MODELLING CULTURAL EVOLUTION OF PRAGMATIC COMMUNICATION WHEN LANGUAGE CO-DEVELOPS WITH PERSPECTIVE-TAKING

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Language use relies on the pragmatic ability to take into account an interlocutor's perspective when producing and interpreting utterances (Levinson, 1983). In natural language, semantic meaning can be underspecified (i.e. a given utterance can be compatible with multiple literal interpretations), and a specific interpretation is arrived at by means of pragmatic inference. Brochhagen et al. (2018) used a computational model of iterated learning to show that this division of labour can evolve when two different pressures are combined: a pressure for learnability and a pressure for communicative success. The pressure for learnability favours lexicons with simpler representations, and therefore makes lexicons with underspecified meanings more likely to evolve. The selection pressure for communicative success causes pragmatic communicators to be favoured, because these can compensate for the ambiguity of the signals in an underspecified lexicon by means of their pragmatic ability. In this model, both lexicons and communication types (i.e. literal or pragmatic) were culturally transmitted (through joint inference), and under the combination of the two pressures described above, they could co-evolve to produce the division of labour we see in natural language.

In a similar model, Woensdregt (2019) explored how lexicons and pragmatic ability evolve when accurate lexicon-learning depends on a co-developing ability to infer the speaker's perspective. In this model, learners were jointly inferring the lexicon and perspective of their cultural parent. Lexicons in this model were therefore culturally transmitted (as in Brochhagen et al., 2018), but pragmatic ability was transmitted genetically. Woensdregt showed that in this case, a similar division of labour to the one described above can arise both under a selection

pressure for communicative success alone, and under a selection pressure for accurate perspective-inference alone.

Here, we demonstrate that language, pragmatic communication, and perspective inference can all simultaneously culturally evolve by combining features of both Brochhagen et al. (2018) and Woensdregt (2019). We are specifically interested in how lexicons and communication types evolve (through iterated learning) in the absence of any selection pressures. Following Woensdregt, our model treats communicative behaviour as the outcome of an interplay between the context in which communication occurs, the agent's individual perspective on the world, and the agent's lexicon. The combination of a given context and the speaker's perspective determines a probability distribution over potential referential intentions for the speaker. Each agent's perspective and lexicon are private mental representations, not directly observable by other agents. Language learners are therefore confronted with the task of jointly inferring both the lexicon and perspective of their cultural parent. Importantly, the learner always considers all referents as potentially being intended by the speaker, and can therefore not rely on cross-situational learning (Siskind, 1996) in order to infer the lexicon. Hence, the learner must rely on perspective-learning to learn the lexicon. Following both Brochhagen et al. and Woensdregt, we base our model of pragmatic communication on the Rational Speech Act model (Goodman & Frank, 2016), in which a speaker chooses their utterance by maximising the probability that the listener will interpret it as their intended referent. The addition of perspectives and contexts (following Woensdregt) means that pragmatic speakers choose their utterance not just based on the combination of their intended referent and their lexicon, but also on the context.

Two outcomes are plausible, which represent different divisions of labour between the culturally transmitted language and pragmatic inference by individuals in the population. We could have a lexicon of unambiguous one-to-one mappings being used by literal agents; or we could have a less-specified language being used by pragmatic agents. We show that, even in the absence of any selection pressures, the latter division of labour is a more likely outcome of cultural evolution. In other words, a language that relies on pragmatics evolves. Why is this? We argue that there are several possible lexicons that when combined with a literal speaker can lead to a learner inferring that the speaker is pragmatic and using a different lexicon. Importantly, the converse situation is less likely. More generally, this is because pragmatic communicators use their utterances more flexibly, depending not just on their intended referent and lexicon, but also on the context. Thus, once a pragmatic communication type has been adopted, it is unlikely to be confused with a literal communication type, because literal communicators use their utterances more strictly dependent on whether they are associated with the intended referent or not. Pragmatic communication is therefore an "attractor" in the space of culturally evolving systems (Sperber, 1996). Once it has evolved, populations may find it hard to retreat from it.

## References


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