Ambiguous Signaling in Evolutionary Game Theory

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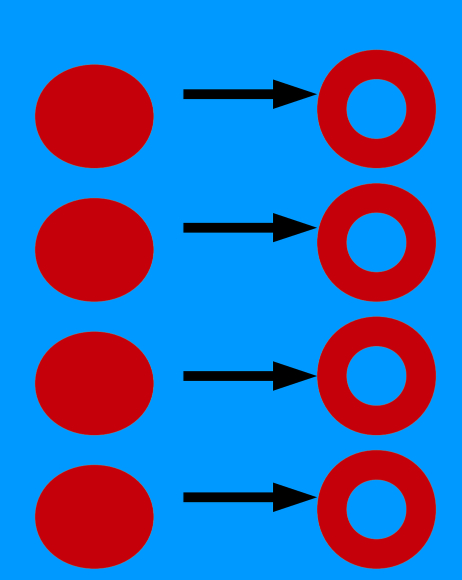
Introduction

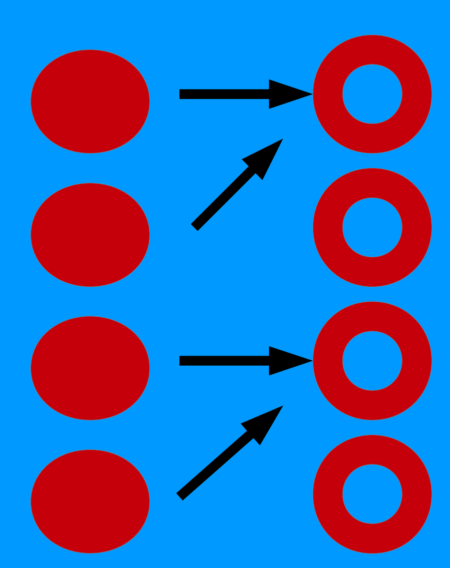
- Since Lewis (1969), ***signaling games*** have been used to model the evolution of of all sorts of biological communication systems
- Under dynamics most similar to actual evolutionary processes—dynamics including both natural selection and mutation—perfect signaling systems tend to evolve (Pawlowitsch 2008, Hutteger, Simon, and Zollman 2011).
- Real world signaling systems, however, are ambiguous. In the language of game theory, these imperfect signaling systems exhibit ***partial pooling***.
- The goal of my research is to answer the following question: ***What plausible adjustments to the signaling game model will lead to an outcome (partial pooling) more closely resembling real world signaling systems?***

Perfect Signaling



States Signals

Partial Pooling



States Signals

The Model

Traditional signaling games consist of a set of types **T** = $\{t_1 \ldots t_n\}$ a set of signals **S** = $\{s_1 \ldots s_n\}$ and a set of responses **R** = $\{r_1 \ldots r_n\}$, a sender, and a receiver. Only the sender knows the type, and on the basis of that information it sends a signal from **S**. On the basis of that signal the receiver chooses an action from **R**, and payoffs to each player are calculated by function from **T** X **R** → **F**, where **F** is the set of possible fitness values.

Improving the Model

I make two empirically-motivated additions to the model. First, I include a small cost to having a more complicated strategy. In other words, I make **signaling require effort**. Second, I add **context-sensitivity**. Mathematically, I include this by having nature send a signal that carries relatively low information about the type.

Analysis

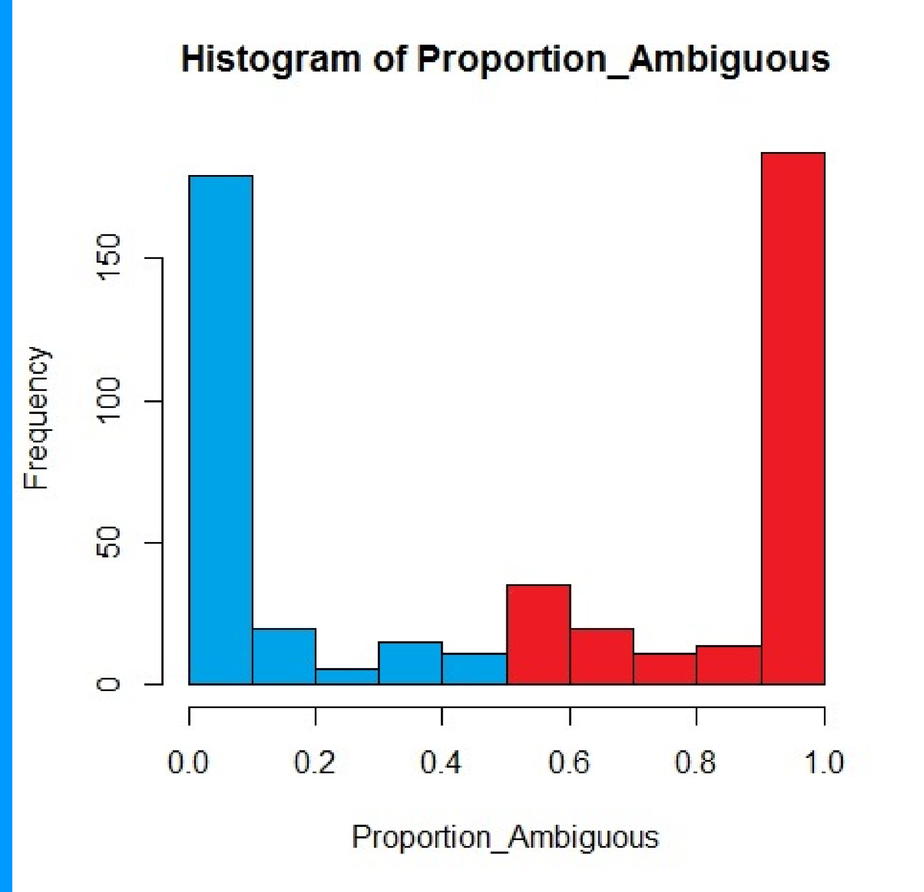
My result is partially analytical. I analyze the case where **T, S,** and **R** are all of cardinality 4, and where nature has only two signals available.

I prove that in this case, and under a dynamic with selection and mutation, populations will always evolve to partial pooling in the limit. The proof is too long to include here, but it hinges on the ability of ambiguous signalers to invade populations of perfect signalers by 'eavesdropping.' Perfect signalers, however, cannot invade populations of ambiguous signalers.

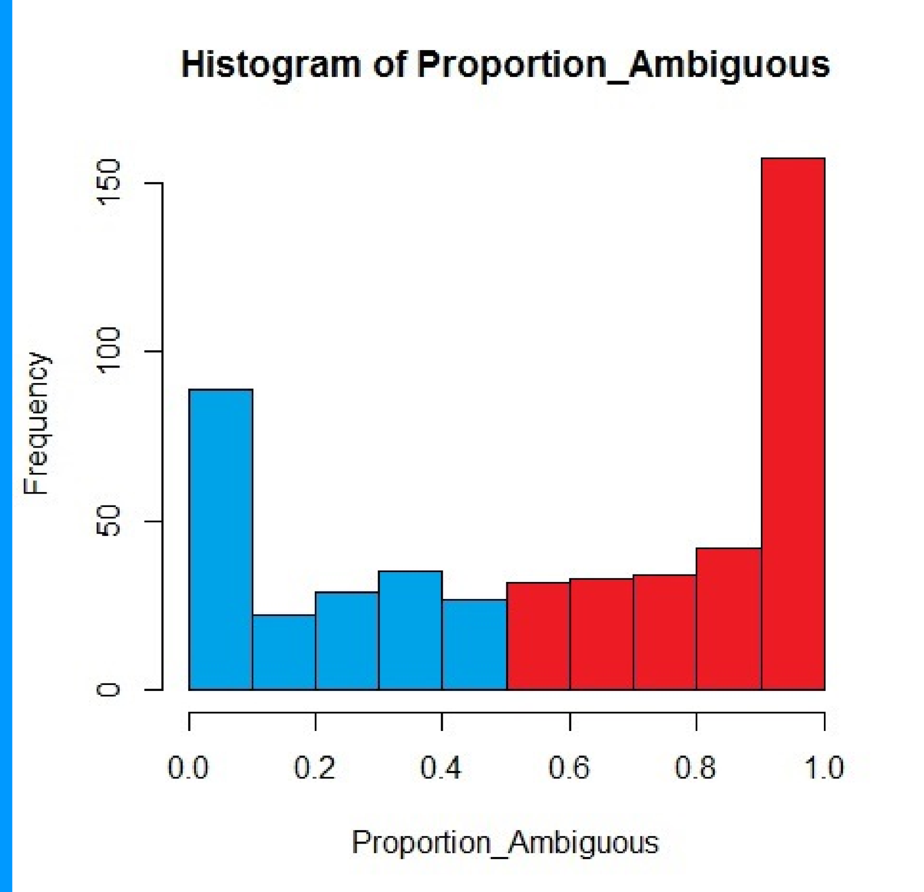
Simulations

- My analytical proof says nothing about timescale. I coded individual-based simulations in Java to explore whether partial pooling signaling emerges in realistic timescales
- **Simulation 1: Invasion**
  Using a birth-death process I model a single ambiguous signaler invading a population of 1000 perfect signalers with the complexity cost set to 3%.
  Result: In 4994/5000 simulations, partial pooling completely invades within 750 generations.
- **Simulation 2: Tower of Babel**
  Using a discrete replicator dynamic (Taylor and Jonker 1978) and randomized initial populations of size 300, I compare what occurs after 100 generations with and without mutation.
- **Results:** 500 trials of each case show that partial pooling is favored only with mutation.

Case 1: No mutation
- X-axis: proportion of the population using partial pooling strategies after 100 generations
- Y-axis: number of simulations reaching that proportion
- Red: population predominantly ambiguous
- Blue: population predominantly perfect signalers



Case 2: Mutation
- The balanced distribution in Case 1 suggests that populations move to the nearest attractor, whether it is ambiguous or not.
- But the results of Case 2 show that the perfect signaling attractors are weak, and prone to disturbance by mutation and invasion:
- Even in <100 generations about half of the perfect signaling populations are successfully invaded.



Conclusion

The results of my analysis and simulations demonstrate how signal cost and context sensitivity can lead to the use of less-informative signals.
I have shown how to accommodate these factors within the signaling games framework.

References

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