The Importance of Rapid Cultural Convergence in the Evolution of Learned Symbolic Communication

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Abstract. Oliphant [5, 6] contends that language is the only naturally-occurring, learned symbolic communication system, because only humans can accurately observe meaning during the cultural transmission of communication. This paper outlines several objections to Oliphant's argument. In particular, it is argued that the learning biases necessary to support learned symbolic communication may not be common and that the speed of cultural convergence during cultural evolution of communication may be a key factor in the evolution of such learning biases.

1 Introduction

Language is unique among the communication systems of the natural world - it is culturally transmitted, the relationship between basic lexical tokens and their meanings is arbitrary and those basic lexical tokens are combined to form structured forms which are used to communicate complex structured meanings. How did language come to be as it is and why is it unique?

Much recent work in the field has focused on the evolution of syntactic communication. Explanations of the human capacity for syntax have placed emphasis on two contrasting adaptive processes:

Genetic adaptation of the genetically-encoded human language acquisition device to support syntactic communication due to fitness advantages offered by syntactic communication (e.g. [4, 7]). Explanations of this kind appeal to a unique set of selection pressures favouring the evolution of syntax in humans to explain the uniqueness of language.

Cultural adaptation of language in favour of compositionality, due to cultural selection resulting from language learner biases during cultural transmission of communication (e.g. [1, 3]). Such models are not primarily concerned with the origin of the language learner's biases but appeal to a uniquely human preexisting mental capacity to explain the uniqueness of language.

Recent work by Oliphant [5, 6], building on pioneering work by Hurford [2], focuses on the more basic issue of the emergence of arbitrary and conventionalised word meaning. Oliphant works within the cultural adaptation framework and makes two claims.

Firstly, human language is the only learned symbolic communication system. Secondly, language is unique in this respect due to the human capacity to read the communicative intentions of other language users. Once this capacity is established optimal, learned symbolic communication reliably follows through cultural evolution of communication systems under a commonly-occurring learning bias.

This paper is primarily concerned with integrating the genetic and cultural adaptation styles of explanation and applying this integrated approach to an investigation of Oliphant's second claim. The integrated model suggests that the type of learning bias identified by Oliphant may not in fact be commonly occurring and the speed of cultural convergence may be a critical factor in the evolution of such a learning bias.

2 The Model

The model is an extension of the model outlined in [6] and is described in full in [9]. Briefly, a population of communicative agents is simulated over time. Agents in the population breed according to communicative accuracy to produce new agents who inherit the genetically-encoded learning rule of their parents.[1] The new agents then make N observations of the communication systems[2] of members of the population and acquire their own communication system based on these observations and their genetically-encoded learning rule. There are therefore two interacting selection pressures at work in the model - natural selection in favour of genes encoding learning rules which result in acquisition of communication systems which allow successful communication, and cultural selection in favour of communication systems which conform to the biases of the learning rules present in the population.

3 Objections to Oliphant's Conclusions

This model suggests three objections to Oliphant's conclusion that the capacity to accurately observe meaning, unique to humans, combined with a commonly-occurring learning rule (a variant of Hebbian learning) results in the evolution of optimal learned symbolic communication.

Firstly, as discussed in [8], the types of learning rule which result in cultural selection for optimal communication systems (which will be termed *constructor* rules) have some very specific biases regarding allowable relationships between meaning-signal pairs and may not be widespread in the natural world. Secondly, as discussed in Section 4, constructor rules may be unlikely to evolve in a population even under apparently ideal circumstances. Finally, work in progress suggests that the combination of constructor rules and a diminished capacity to observe meaning may still result in the

[1] Agents are bidirectional associative networks mapping from unit vector meanings to unit vector signals. The learning rules for these agents specify the conditions under which connection strengths are increased, decreased, or left alone depending on the two inputs to that connection. This leads to 81 possible learning rules.

[2] Agents observe meaning-signal pairs - the ability to observe meaning accurately is assumed, as in [6].

emergence of near-optimal communication, and may in fact create selection pressures to improve the capacity to observe meaning - communication may precede and lead to the capacity to observe meaning accurately.

4 N and Speed of Cultural Convergence

If, as suggested in [8], constructor rules are not commonly occurring, a slightly modified version of Oliphant's argument seems appealing - given a preexisting capacity to observe meaning such learning rules will emerge reliably under natural selection for communicative success due to the fitness payoff they confer. Results generated by the model outlined in Section 2 suggests that this hypothesis is incorrect.

Table 1 indicates the proportion of simulated populations converging on optimal or near-optimal communication systems after a fixed number of generations for various values of N. It is clear that optimal communication systems do not reliably emerge under these conditions, although they are more likely to emerge given more learning by immature agents (larger N).

Table 1. The number of successful runs (out of 100) for various values of N

N	1	3	5	10	15	20	25	30
Successes	0	4	15	39	38	41	56	57

The unreliable emergence of optimal communication is due to the delay between the emergence of genotypes encoding constructor rules and any fitness advantage to agents with such genotypes. Agents using constructor rules need time to converge on an optimal communication system - cultural selection over repeated cultural transmission gradually moves the communication systems of agents using constructor rules into increasingly optimal overlapping areas of communication system space until all such agents have converged on an optimal system.

In the early stages of this construction process individuals using constructor rules have little fitness advantage over other individuals. As a consequence the genetic transmission process will be essentially random - the population will undergo genetic drift. In successful runs genetic drift preserves constructors, by chance, in sufficient numbers for sufficient time to allow the construction process to get well under way. Constructors then show increased communicative accuracy which leads to steady selection for constructor genes, constructor numbers in the population increase and the population converges on an optimal communication system. In unsuccessful runs genetic drift never provides constructor rules in sufficient numbers for the construction process to take off.

Increasing N increases the speed at which cultural convergence occurs between constructor agents, reducing the dependence on benevolent genetic drift and increasing the likelihood of populations arriving at optimal communication systems. While allowing runs to continue for longer or changing the mutation rate used in the model might make optimal communication more likely to emerge for lower N, such tinkering would obscure the essentially contingent nature of the emergence of constructor rules and the importance of rapid cultural convergence in evolving such learning biases.

5 Conclusions

Oliphant [6] argues that optimal, learned symbolic communication will trivially emerge given a capacity to observe meaning during cultural transmission and a commonly-occurring learning bias. This paper raises three objections to Oliphant's proposal. Firstly, the learning bias necessary to construct an optimal, learned communication system may not in fact be commonly-occurring. Secondly, even if other species were capable of observing meaning, the correct learning bias might be unlikely to evolve due to a delay between the emergence of the bias and a fitness payoff to individuals possessing it. The rapid cultural convergence resulting from large N is shown to reduce this delay and increase the likelihood of appropriate learning biases evolving in the population. Thirdly, near-optimal communication systems may emerge and be maintained in populations of agents incapable of accurately observing meaning.

These results emphasise the importance of interactions between genetic and cultural adaptation in models which do not discount one adaptive process as a starting assumption. Specifically, even if a particular learning bias results in the emergence of optimal communication systems through processes of cultural selection we cannot assume that natural selection will reliably find that bias or that the process of natural selection will be unaffected by the process of cultural selection.

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