Exploring the impact of contextual input on the evolution of word-meaning

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1 Introduction

It is widely acknowledged in the field of language evolution that language users learn word-meanings, for which the following question is relevant: what kind of input is required to learn word-meanings? The most obvious form of input is speech, but in this paper we are concerned with the pragmatic of contextual cues that indicate the meaning of spoken words. Such cues may, for instance, be provided by establishing joint attention or by evaluating corrective feedback, but there is some evidence that children do not need such directed cues to learn the meaning of their first words (Lieven, 1994).

Recent computational studies on the evolution of language show how agents can learn word-meanings successfully. In most of these studies it is assumed that either joint attention was established or that agents receive corrective feedback. Both conditions have also been studied successfully with mobile robots (Vogt, 2000). Only few studies have investigated whether cues such as joint attention and corrective feedback are really necessary (Smith, 2001, Vogt, 2000). Although Smith's simulations indicate that neither type of input is required, this is not confirmed by Vogt's robotic experiments. Both studies used a minimal experimental setup - only 2 agents and, in Vogt's case, a very limited number of objects to communicate about. It is therefore interesting to study the impact of the three conditions on lexicon formation in a scaled experiment, which is the focus of this paper. In addition, we look how the lexicon evolves under the three conditions and a population dynamics as modeled by the iterated learning model (Kirby and Hurford, 2002).

2 Three language games

In the simulations of this paper, populations of agents play adaptive language games to bootstrap a shared lexicon (Steels and Kaplan, 1999). In a language game two agents - a speaker and a hearer - are selected from a population and observe a context that contains a number of predefined meanings. The speaker selects a topic from the context and produces an utterance by searching in its lexicon for a matching word-meaning association, which the hearer tries to interpret. Selection of an association depends both on its applicability in the context and the strength of its association given by a score. At the end of the game both agents adapt their lexicons: new associations may be constructed and existing ones may be strengthened or weakened. By playing a large number of language game, a lexicon emerges.

The simulations of this paper involve three variants of a language game: the observational game, the guessing game and the selfish game, which all differ in their use or disuse of joint attention and corrective feedback. The *observational game* (OG) is based on (Oliphant, 1997) and uses joint attention to indicate the topic of a game and it uses Hebbian learning to regulate the strength of associations. The *guessing game* (GG) is based on (Steels and Kaplan, 1999) and uses corrective feedback to allow reinforcement learning. In the *selfish game* (SG), based on (Smith, 2001, Vogt, 2000), neither source of input is used and the agents learn the associations with Bayesian learning techniques.

The iterated learning model (ILM) of (Kirby and Hurford, 2002) applies to all types of language games and models a population dynamics. In the ILM a population consists of a group of adults speakers and an, in our case, equal sized group of learners who only act as hearers and start with empty lexicons like the adult speakers of the first iteration. After a fixed number of language games the adults are replaced by the learners and new learners enter the population. This process is iterated over and over again.

3 The results

With the three models, a number of simulations were done in which the world consisted of 100 meanings and the context size in each game was fixed at 5. Figure 1 shows the results of these experiments.

The upper left figure shows the communicative success of simulations with the three types of language games using a population size of 2 without iterated learning. As shown both the OG and the GG converge to 1 within 1,000 games and are indistinguishable from each other,

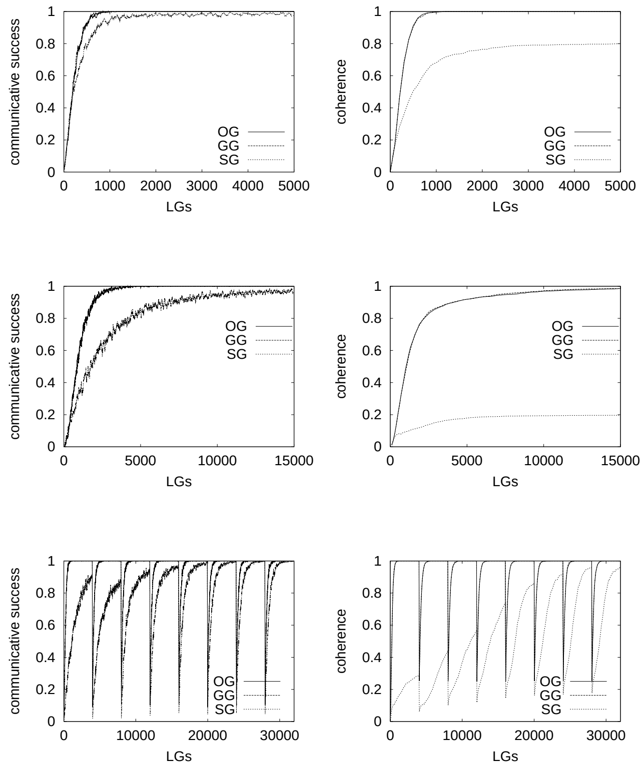

Figure 1: The results of the simulations with population sizes of 2 (top row), 5 (second row) and 8 (bottom row) where the latter also applies the ILM. The figures show the evolution of the communicative success (left column) and the coherence of the lexicon (right column).

which holds for all following experiments. The SG approaches 1, but does not reach this after 5,000 games. The upper left figure shows the evolution of the coherence in the same simulations. The coherence measures to what extent the agents use the same vocabulary as a speaker and converges to 1 almost equally fast as the communicative success for the OG and the GG, but it does not exceed 0.8 for the SG. This means that the lexicons for the OG and GG show no ambiguities, while the lexicon of the SG is still ambiguous.These results confirm previous results as reported by, e.g., (Steels and Kaplan, 1999, Oliphant, 1997, Smith, 2001).

The graphs in the middle row show the results of simulating the language games with a population size of 5 and no iterated learning. Although the communicative success shows a similar but slower evolution for all games, the coherence of the SG does no exceed 0.2, which is a drastic decrease. We have done simulations with population sizes up to 20 agents, and the results get worse with increasing population sizes, although no clear dependency between the results and population size has been observed.

The bottom figures show the communicative success and coherence of applying the ILM to the language games for a population size of 8. The simulation was done over 8 iterations of 4,000 games each. Clearly the communicative success and coherence of the OG and GG converge to 1 pretty fast in each iteration. The results of the SG reveal that the communicative success converges to 1 from the sixth iteration and the coherence reaches an increasingly higher end-value in each iteration.

4 Conclusion

The selfish game shows that agents can learn word-meanings without using directed information concerning a word's meaning, but this only works for larger populations when agents can learn the lexicon from adult speakers This is probably because learners in the ILM receive more consistent speech that they can pass on to a next generation of learners even more consistently. So although the selfish game may explain some phenomena of lexicon acquisition, it is not a likely scenario for explaining the origins of language as it appears too difficult to bootstrap a coherent lexicon to be advantageous for a population. The observational or guessing games provide more likely strategies.

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