THE ROLE OF CULTURAL TRANSMISSION IN INTENTION SHARING

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This paper presents a simulation study exploring the role of cultural transmission in intention sharing (the ability to establish shared intentions in communications). This ability has been argued to be human-unique, and a low level of it has deprived animals of the possibility of developing human language. Our simulation results show that the adequate level of this ability to trigger a communal language is not very high, and that cultural transmission can indirectly optimize the average level of this ability in the population. This work extends the current discussion on the human-uniqueness of some language-related abilities, and provides better understanding on the role of cultural transmission in language evolution.

1. Introduction

Language evolution is a fascinating topic in the interdisciplinary scientific community. Many empirical and theoretical studies (e.g., Oller & Griebel, 2000) have revealed a "*mosaic*" fashion of language evolution (Wang 1982) with a number of competences (e.g., social cognition, vocal tract control, imitation, etc.) all taking part in this process. There is an ongoing discussion on whether language results from abrupt changes of these abilities through macro-mutations (Pinker & Bloom, 1990), or it is caused by a quantitative evolution of "prototypes" of these abilities (Elman, 2005; Ke et al., 2006).

Among these various abilities, *intention sharing* is crucial for developing a communication system. An *intention* is a plan of action that an organism chooses and commits itself to in order to pursue a goal, and sharing intentions can be viewed as intentional (selective) comprehension during interactions (Tomasello et al., 2005). Comparative studies between chimpanzees and human infants have shown that the latter ones are good at establishing shared intentions during interactions with peers or adults, while the formers are poor at it (*ibid*). Based on these findings, Tomasello and his colleagues (*ibid*) argued that sharing intentionality must be human-unique, and the deficiency of it in animals prevents them from developing language. However, a significant difference between modern humans and chimpanzees in this ability is insufficient to indicate that this ability has been unique to humans, since it may result from a gradual evolution along with the development of the human communication system. Apart from comparative studies, we therefore need other methodologies to investigate the development of this ability in humans. Computational simulation is an efficient method in this respect, and it has been widely adopted to tackle problems concerning the evolution of language and other cognitive activities (e.g., Cangelosi et al., 2006).

This paper presents a simulation study to explore intention sharing and some possible forces that may adjust its levels. We argue first that the adequate level of this ability to trigger a communal language needs not to be very high, and that a small quantitative change of it can greatly affect the understandability of the emergent language. Second, cultural transmission can help to optimize the level of this ability in the population to "assist" language emergence. A low level of it can be increased, while a high level of it can be slightly reduced. Third, the emergence of *displacement* (human language can efficiently describe the events not occurring in the immediate environment of the conversation, Hockett, 1960) in human language could be a side effect of this optimization role of cultural transmission in intention sharing.

The rest of the paper is organized as follows: Section 2 roughly reviews the adopted language emergence model to study intention sharing; Section 3 introduces the framework used to explore the role of cultural transmission in intention sharing; Section 4 discusses the simulation results; and finally, Section 5 provides the conclusions and final remarks.

2. A brief Review of the Language Emergence Model

The model adopted in this paper was originally designed to study the coevolution of compositionality and regularity during language emergence (Gong, 2007). Its conceptual framework is shown in Fig. 1. In this model, utterances encoding simple integrated expressions such as "run<fox>" (meaning "a fox is running") or "chase<wolf, sheep>" (meaning "a wolf is chasing a sheep") are exchanged among agents during communicative acts. Through the pattern extraction ability, individuals may acquire some recurrent patterns in the exchanged utterances as lexical items (see the LEXICON rectangle in Fig. 1). By sequential learning, individuals may acquire local orders recording order relations among these lexical items in the exchanged utterances. In addition, when individuals observe that some lexical items with the same semantic role are *similarly used* in some exchanged utterances (i.e., display the same local order with respect to other lexical items), they can assign these lexical items to the same category; for simplicity, we labeled them with the syntactic roles met in simple declarative sentences in English (i.e., ‘S’, Subject; ‘V’, Verb; and ‘O’, Object). Through reiterating local orders among the categories, individuals gradually acquire emergent global order(s) to regulate the strings of lexical items from these categories and form utterances to encode integrated meanings. For example, if in an individual’s linguistic knowledge, there exist some S, V, and O categories that are locally ordered “S before V” and “S before O”, two emergent global orders (SVO and SOV) can be produced, and the integrated meaning "chase<wolf, sheep>" can be expressed as either /WOLF CHASE SHEEP/ or /WOLF SHEEP CHASE/. The initial stage of the model is a holistic signaling system in which all individuals share a small number of holistic rules to encode some integrated meanings. Through iterated communications, a compositional language having a set of lexical items and some global order(s) gradually emerges. This model gives us an appropriate level of complexity to observe the effect of intention sharing on language evolution, and the optimization role of cultural transmission in this ability.

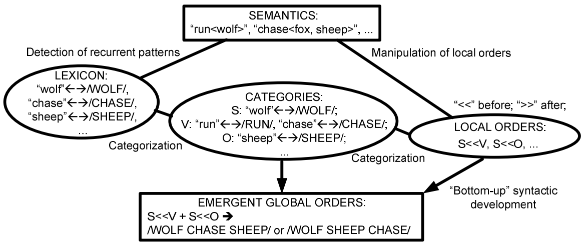


Figure 1. The conceptual framework of the language emergence model: the SEMANTICS rectangle stands for the predefined semantic space; the ovals represent the three aspects of linguistic knowledge acquired by agents based on different domain-general abilities: pattern extraction, sequential learning, and categorization; the EMERGENT GLOBAL ORDERS rectangle encompasses the emergent syntactic patterns triggered by this linguistic knowledge.

Intention sharing in this model is simulated as an individual’s parameter, *Reliability of Cue* (*RC*), which indicates the probability (from 0.0 to 1.0) for the listener in a communication to accurately acquire the speaker’s intended integrated meaning in the heard utterance from an *environmental cue* (an ongoing event in their environment). In a communication without shared intention, a wrong cue containing an event different from the speaker’s intended meaning is given to the listener. From the speaker's perspective, *RC* indicates the probability of choosing an ongoing event in the immediate environment as the topic of the communicative act. From the listener's perspective, it indicates the probability of referring to the ongoing event to assist comprehension. If *RC* is 1.0, shared intentions are established in all communications; if it equals to 0.0, the listener only gets the wrong cues, and no shared intentions are established in communications. In this paper, the relations among *RC*, language emergence and cultural transmission are discussed.

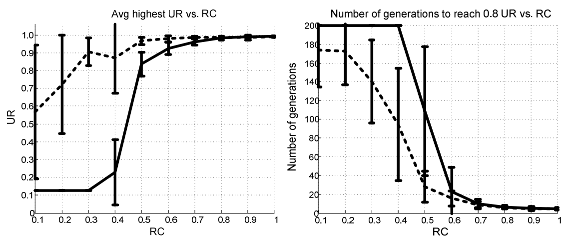
3. The Cultural Transmission Framework

Cultural transmission is defined here as the communications among individuals from the same (intra-generational) or different (inter-generational) generations. As the medium of language exchanges, it plays important roles in language evolution. In this paper, we assume that there is an ongoing optimization process based on linguistic understandability during cultural transmission; individuals who can better understand others in communications may obtain more resources and produce more offspring, and these offspring may maintain some of their parents' language-related abilities. Under this assumption, a cultural transmission framework is simulated to test whether this optimization process plays some role in adjusting *RC*. In this framework, after a number of intra-generational transmissions, some individuals who have higher linguistic understandabilities will become "parents" and produce "offspring". The offspring replicate their parents' *RC* values with some occasional, small changes. Here, GA-like mechanisms such as crossover (an exchange of two parents' *RC* values) and mutation (a tiny increase/decrease in a *RC* value) are applied during the reproduction. After "birth", the offspring start to learn from their parents through inter-generational transmissions, and then replace them and other individuals from the previous generation. After that, a new cycle begins. For the sake of comparison, we implement another type of simulations without optimization, in which agents are randomly chosen to be parents and produce offspring regardless of their communicative success in each generation. During the reproduction process, crossover and mutation are also applied.

In all simulations of this paper, the population is made of 10 agents. In the first generation, all individuals' *RC* values are randomly chosen from a Gaussian distribution of *RC* whose standard deviations are 0.01 and their means range from 0.0 to 1.0. In each generation, there are 200 rounds of random pairwise intra-generational transmissions and 200 rounds of inter-generational transmissions from parents to offspring. A round of transmissions includes 10 communications among different pairs of agents. The number of generations is 200. In each generation, after intra-generational transmissions, 5 agents are chosen as parents, each of which produces 2 offspring. During the reproduction process, the crossover rate is 0.05 and a small (0.1) increase/decrease of the *RC* values occurs with a probability of 0.02 (the mutation rate). In the simulations with optimization, parents are chosen according to their linguistic understandabilities, i.e., the average percentage of integrated meanings that they can accurately understand when other agents speak to them. In the simulations without optimization, parents are randomly chosen. In each condition of the simulations, the results of 20 runs are collected for statistical analysis, and they are discussed in the following section.

4. The Simulation Results

Fig. 2 (a) records the average and standard deviation values of the highest *UR* throughout the simulations in the 20 runs with different initial *RC* values. *UR* here records the average linguistic understandability of the whole population. Fig. 2 (b) illustrates the average numbers of generations to reach a relatively high *UR* (0.8) under different initial *RC* values.



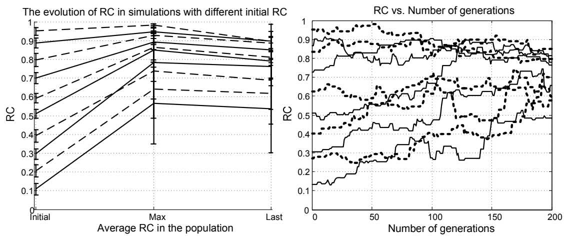
(a) (b)

Figure 2. The simulation results with and without optimization: (a) Average highest *UR* vs. *RC*; (b) Number of generations to reach 0.8 of *UR* vs. *RC*. The dashed lines trace the results with optimization in cultural transmission, and the solid ones trace the results without optimization.

In the simulations without optimization, when *RC* is low (below 0.3), *UR* is rather low (around 0.125, that is the *UR* of the initially shared holistic rules), and a communal language with a high *UR* does not emerge in the population; when *RC* lies in the interval [0.4 0.7], a communal language emerges, and the increase in *RC* can accelerate language emergence, which is indicated by the decrease in the number of generations to reach a high *UR*; when *RC* is rather high (over 0.8), an increase in *RC* does not further accelerate language emergence. These results show that without optimization, a relatively low *RC* (around 0.5) is sufficient to trigger a communal language with a high *UR* (around 0.8), and a small increase in *RC* from 0.4 to 0.5 causes a qualitative change from no language to a communal one. In other words, a small phenotypic change could result in a communication means of a totally different nature (Elman, 2005).

In the simulations with optimization, the adequate level of *RC* to trigger a communal language is further reduced; a much smaller initial *RC* (0.2) can trigger a communal language with a relatively high *UR* (over 0.6). In addition, language emergence in these simulations is more efficient than that in the simulations without optimization. However, if the initial *RC* is high (over 0.7), language emergence doesn't differ much in these two types of simulations.

Finally, we examine the *RC* values in the simulations with optimization. Fig. 3 (a) traces the average and standard deviation values of initial, maximum and last *RC* throughout the 200 generations in the simulations with optimization, while Fig. 3(b) traces the *RC* values in some particular runs in these simulations.



(a) (b)

Figure 3. The evolution of *RC* in the simulations with optimization: (a) statistical results regarding *RC*, each line summarizes the initial, maximum and last *RC* values in the simulations with a particular range of initial *RC* (from 0.1 to 1.0 with a step of 0.1); (b) specific *RC* values in different runs, each line records the *RC* values at different generations in one simulation.

Two roles of cultural transmission with respect to *RC* are shown in these figures. The optimization process in cultural transmission is based on individual linguistic understandability. Since a high *RC* contributes to the acquisition of correct linguistic rules that help an individual to accurately understand others' idiolects, it can be indirectly selected by cultural transmission, and gradually spread in the population. Then, the average level of *RC* in the population increases gradually in respond. This increasing effect is well illustrated in Fig. 3, especially when the initial *RC* is low (below 0.8). However, if the initial *RC* is already high (around 0.7), cultural transmission does not greatly change it, but maintain it throughout the simulations. In addition, for a rather high *RC* in [0.9 1.0] interval, cultural transmission may lead to a slight reduction of it; its last value becomes slightly smaller than its initial one, as shown in Fig. 3 (a).

Slightly reducing a rather high *RC* is a side effect of optimization. Since these initial *RC* values are high enough to trigger a communal language, an individual who has a *RC* slightly lower than them may still have a high understandability, and be chosen as the parent to produce offspring and spread this *RC* to the population. Then, the average level of *RC* in the population may slightly drop, without greatly affecting the understandability of the emergent language. In this situation, there are a number of communications with no shared intentions during cultural transmission, which provides the opportunity for agents to develop more robust linguistic knowledge that needs no assistance of environmental cues or even resists distractions of wrong ones. This reliable language can efficiently describe the events not occurring in the immediate environment. It can gradually liberate itself from the restrictions of nonlinguistic information, and get efficiently used in communications with no environmental cues or other nonlinguistic assistance. Compared with the increasing effect on *RC*, this reducing effect is not much explicit in the short run, but it is crucial for the evolution of language in the long run.

5. Conclusions

The simulations in this paper demonstrate the roles of cultural transmission in intention sharing. Cultural transmission can adjust the level of this ability to trigger a communal language. Meanwhile, it can also prevent this ability from going rather high so that displacement can be gradually developed in the emergent language. Apart from shaping some linguistic features such as compositionality (Kirby, 1999) and regularity (Gong, 2007), our study shows that cultural transmission can help to optimize some language-related abilities, leading them to optima that are not necessarily the highest possible values.

The framework in this paper can be adopted to study the role of cultural transmission in other language-related abilities, such as the ability to detect recurrent patterns or manipulate local orders. Such an approach will provide a clear picture on the “mosaic” fashion of language evolution, and help to verify the claim of Connectionism (Elman, 2005) that language sits at the crossroads of a number of small phenotypic changes in our species that interact uniquely to yield language as the outcome.

In the end, a remark has to be made. Our work mainly discusses the role of cultural transmission in optimizing the level of intention sharing in a population of individuals during language emergence. The adoption of GA-like mechanisms does not imply that this ability has to be updated necessarily through genetic transmission. Instead, we suggest that the level of this ability can be modified during inter-generational transmissions. For instance, when talking to their offspring, through a careful control of the environmental cues, parents can clearly direct their attention and intentionally help them build up a certain level of intention sharing. This remark distinguishes us from Innatism.

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References

Cangelosi, A., Smith, A. D. M., & Smith, K. eds. (2006). *The evolution of language: Proceedings of the 6th international conference*. London: Word Scientific Publishing Co.

Elman, J.L. (2005). Connectionist models of cognitive development: Where next? *Trends in Cognitive Science*, *9*, 111-117.

Gong, T. (2007). *Language evolution from a simulation perspective: On the coevolution of compositionality and regularity*. Doctoral dissertation. Hong Kong: The Chinese University of Hong Kong.

Hockett, C. F. (1960). The origin of speech. *Scientific American*, *203*, 88-96.

Ke, J-Y., Coupé, C., & Gong, T. (2006). A little bit more, a lot better: Language emergence from quantitative to qualitative change. In A. Cangelosi, A. D. M., and K. Smith, (Eds.), *The evolution of language: Proceedings of the 6th international conference* (pp. 419-420). London: Word Scientific Publishing Co.

Kirby, S. (1999). *Function, selection and innateness: The emergence of language universals*. New York: Oxford University Press.

Oller, K. & Griebel, U. eds. (2000). *Evolution of communication systems: A comparative approach*. Cambridge, MA: MIT Press.

Pinker, S. & Bloom, P. (1990). Natural language and natural selection. *Behavioral and Brain Sciences*, *13*, 707-784.

Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, *28*, 675-691.

Wang, W. S-Y. (1982). Explorations in language evolution. Osmania Papers in *Linguistics*, 8. Reprinted in W. S-Y. Wang, (Ed.), *Explorations in language*, Taipei (pp. 105-131). Taiwan; Seattle, WA: Pyramid Press.