



# Naming game with biased assimilation over adaptive networks

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## HIGHLIGHTS

- A modified two-word naming game with biased assimilation is proposed.
- The proposed model can reach global consensus as long as the interacting network is connected.
- The behavior of adaptively reconnecting links can greatly accelerate the convergence speed.

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## ABSTRACT

The dynamics of two-word naming game incorporating the influence of biased assimilation over adaptive network is investigated in this paper. Firstly an extended naming game with biased assimilation (NGBA) is proposed. The hearer in NGBA accepts the received information in a biased manner, where he may refuse to accept the conveyed word from the speaker with a predefined probability, if the conveyed word is different from his current memory. Secondly, the adaptive network is formulated by rewiring the links. Theoretical analysis is developed to show that the population in NGBA will eventually reach global consensus on either A or B. Numerical simulation results show that the larger strength of biased assimilation on both words, the slower convergence speed, while larger strength of biased assimilation on only one word can slightly accelerate the convergence; larger population size can make the rate of convergence slower to a large extent when it increases from a relatively small size, while such effect becomes minor when the population size is large; the behavior of adaptively reconnecting the existing links can greatly accelerate the rate of convergence especially on the sparse connected network.

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## 1. Introduction

Collective behavior can be found widely in the real world, such as bird flocks, fish swarms and herding effect [1]. In the past decade lots of attentions have been paid to the research on collective behavior from different perspectives, for example opinion formation on social network [2–4], consensus of hybrid opinion with mobile individual [5], consensus problem in multi-agent system [6]. In this paper, we concern the collective behavior based on naming game (NG), which is originally proposed in [7,8]. In NG, a population of individuals plays pairwise interaction over complete network, which can lead to emergence of a shared lexicon.

Studies on NG have received lots of interest since its presence. These studies mainly focus on the influence of individuals' dynamics. Ref. [9] assumed the individuals during successful interactions update their memory with probability  $\beta$  and

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**Table 1**  
Possible interactions and outcomes of Two-Word Hearer-Only Naming Game.

Before interaction		Transmitted name	After interaction	
Speaker	Hearer		Speaker	Hearer
A	A	A	A	A
A	B	A	A	AB
A	AB	A	A	A
B	A	B	B	AB
B	B	B	B	B
B	AB	B	B	B
AB	A	A	AB	A
AB	A	B	AB	AB
AB	B	A	AB	AB
AB	B	B	AB	B
AB	AB	A	AB	A
AB	AB	B	AB	B

proposed a generalized two-word NG model, where non-equilibrium phase transition can be observed. Lu et al. in [10] gave a broadcasting version of NG model. Baronchelli in [11] further investigated the dynamics of broadcasting two-word NG model by considering only speaker or hearer updating his memory after a successful interaction. Ref. [12] considered the influence of the committed agent with different stance and investigated the dynamics of opinion formation based on two-word NG over different networks. Li et al. in [13] proposed a modified naming game where the speaker can speak to multiple hearers at one time. It is showed that the proposed model can reach convergence much faster than the minimal NG model, but reduce the individual's ability to learn new words. Ref. [14] studies the dynamics of NG with individual's preference. Ref. [15] considered the influence of propensity and stickiness on the dynamics of the two-word NG model. Ref. [16] proposed an extended NG model, which consider the scenario that individuals communicate with each other in subgroups and each speaker can convey multiple words at one time. This extended NG model can speed up convergence compared to the model presented in [13]. Another modified NG model was proposed in [17], where the hearer may receive wrong word with an error rate. Recently NG with memory loss is considered in [18].

There are some other studies mainly concerning the role of network topology. Ref. [19] investigated the influence of high-degree agent. Ref. [20] considered the influence of small world geographical network on NG. The effect of time-varying network topology is analyzed in [21]. Ref. [22] assumes the individual picks up his hearer from his neighborhood with a probability depending on their communication success rate.

The previous studies on NG assume that all of the people treat the information in the same way. However, people in the real world usually deal with the received information in a biased manner [23]. To the best of our knowledge, there are few works which analyze the scenario that people in NG assimilate the information in a biased manner. It is thus necessary to further study NG from this aspect. To this end, this paper will analyze of the dynamics of NG with biased assimilation on dynamical network topology.

The rest of this paper is organized as follows. Naming game with biased assimilation (NGBA) is formulated in Section 2, where the dynamics of NGBA from the perspective of both theoretical analysis and numerical simulations is also presented. Section 3 gives the formulation of NGBA over adaptive network, while Section 4 is devoted to analyzing the dynamics of NGBA on different adaptive networks. Finally comes some discussions and conclusions in Section 5.

## 2. Model formulation and analysis

### 2.1. Naming game with bias assimilation

Original NG considers a population of identical individuals, which observe the same object and try to communicate its name with each other. Each individual starts with empty memory. Each time one pair of connected individuals is randomly chosen. One is acted as “speaker”, while the other as “hearer”. If the speaker has no name on the object (empty memory), he will invent one name and convey it to the hearer. Otherwise, he will pick up one name at random from his memory and convey it to the hearer. If the hearer has the same name in his memory, such interaction is a success and both speaker and hearer will discard all the names but the conveyed one. Otherwise, such interaction is a failure, and the hearer will add the conveyed name to his memory. In this paper, the two-word Hearer-Only NG is concerned, where the possible names for each individual are  $\{A, B, AB\}$ , and only hearer will update his memory after interaction, while speaker keeps his memory unchanged. The speaker and hearer update their memories according to the rule shown in Table 1.

In this paper, inspired by the fact that in the real world people are apt to accept the confirming evidence at face value while critically examine the disconfirming evidence [24], we propose a modified NG by taking into account the effect of biased assimilation. Differing from the rules shown in Table 1, in the naming game with biased assimilation (NGBA) the hearer will not simply change his memory when the information he received from the speaker is different from his own. Instead, the

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