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The influence of social structure on the propagation of social information in artificial primate groups: A graph-based simulation approach

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Abstract

Observations of primate groups have shown that social learning can lead to the development of temporal stable traditions or even proto-culture. The social structure of primate groups is highly diverse and it has been proposed that differences in the group structure shall influence the patterns of social information transmission. While empirical studies have mainly focused on the psychological mechanisms of social learning in individuals, the phenomenon of information propagation within the group has received relatively little attention. This might be due to the fact that formal theories that allow actual testing have not been formulated, or were kept too simple, ignoring the social dynamics of multi-agent societies. We want to propose a network approach to social information transmission that (1) preserves the complexity of the social structure of primate groups and (2) allows direct application to empirical data. Results from simulation experiments with artificial group structures confirm that association patterns of group-members influence the expected speed of information transmission during the propagation process. Introducing a forgetting rate shows that under certain conditions the proportion of informed individuals will reach a stable rate in some systems while it will drop to zero in others. This suggests that the likelihood to observe temporal stable traditions shall differ between social systems with different structure.

Keywords: Information transmission; Social system; Weighted graph; Social network

1. Introduction

In the early 1950s, the Japanese primatologist Kinji Imanishi used an imaginary dialogue between an evolutionist, a layman, a monkey and a wasp to demonstrate that culture—defined as the non-genetic transmission of habits—was entirely possible, and even likely, for animals other than humans (de Waal, 1999). This proposition was of course vigorously opposed by those who wanted the term culture to be reserved for humans alone. Whether or not some animal species have a ‘‘full blown’’ culture was, and still is, a matter of fierce debate. However, plenty of evidence has been collected that animals are capable of transmitting information socially and that such information transmission can lead to temporally stable traditions. The most famous examples for such traditions in animals include birdsong dialects (Kroodsma and Baylis, 1982), milk bottle opening in British tits (Hinde and Fisher, 1951), potato washing in Japanese macaques (Kawai, 1965), termite fishing (Goodall, 1968; Lohnsdorf, 2006), nut cracking (Biro et al., 2003; Sugiyama and Koman, 1979) and the use of medical plants (Huffmam and Seifu, 1989; Huffman and Hirata, 2004) in chimpanzees. Experimental studies with guppies demonstrated that fish are able to learn new routes and foraging tasks socially both in the laboratory and in the wild (Laland and vanBergen, 2003; Reader et al., 2003).

So far the majority of experimental studies on social information transmission have focused on the psychological mechanisms responsible for social learning (see Heyes

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and Galef, 1996; Zentall and Galef, 1988; and chapters therein) and neglected social processes as potential influences on both the likelihood of transmission and the type of information that can be acquired socially (Coussi-Korbel and Fragaszy, 1995). The traditional experimental approach to social learning where individuals are tested in isolation after they have observed a physically separated demonstrator was repeatedly criticised for two reasons. First, it was argued that the understanding of social learning from ecological and comparative perspectives would be aided by experiments on social learning in groups rather than in individuals (Lepoivre and Pallaud, 1985). Second, it was criticised that this type of experiments says little about the diffusion processes of socially learned behaviour through populations (Laland et al., 1996) and about the influence of the social dynamics on the transmission process (Coussi-Korbel and Fragaszy, 1995).

Studies of diffusion processes in pigeons have demonstrated that information transmission can be inhibited by the individuals' propensity to adopt certain roles as either producers or scroungers (Giraldeau and Lefebvre, 1986, 1987; Laland and Plotkin, 1990). In the laboratory transmission, chain studies (Curio et al., 1978; Horner et al., 2006; Laland and Plotkin, 1990) have tried to simulate passage of information transmission along a line of several individuals, by iterating the classical social learning paradigm and using the observer of one test as a demonstrator for the next test. This paradigm was taken a step further by Galef and Allen (1995) who adopted a method by Jacobs and Campbell (1961) for the study of the stability of arbitrary traditions in humans. In their experiment founder colonies of rats were taught an arbitrary food preference. Individual members of the founder colony were then slowly replaced with naïve subjects and even several generations after the last founder had been removed, the arbitrary food preference was still evident. The same effect could be demonstrated in guppies where preferences for routes to a food source were transmitted over several generations (Laland and Williams, 1997). While these studies have convincingly demonstrated that information can actually spread in a population by means of social learning, they have still not addressed the question how information spreads within natural populations. The lack of studies in this direction might be primarily due to missing predictions how information shall spread in such populations, or that existing theories are kept too general to allow actual testing (Laland and vanBergen, 2003; Reader, 2004).

Field observations—mainly of primate groups—revealed a long list of seemingly socially transmitted habits. However, due to the observational character of these studies it is usually not possible to exclude asocial learning processes as candidate explanations for these behaviours. To support the claim that these behaviours were in fact socially transmitted, it was suggested that the spreading pattern of the behaviour itself can reveal something about the learning process involved (Galef, 1991). Lefebvre (1995) re-analysed the data of 21 cases of presumably culturally transmitted feeding innovations in primate groups. Social learning processes are argued to result in accelerating diffusion curves, such as the logistic, the exponential, or the hyperbolic sine (Boyd and Richerson, 1985; Cavalli-Sforza and Feldman, 1981; Laland et al., 1996) as the number of demonstrators of the behaviour increases over time. In contrast, asocial learning should result in a linear diffusion curve. According to Lefebvre, the primate data supported the assumption that the innovations were transmitted socially. However, recently (Laland and vanBergen, 2003) demonstrated that even asocial learning processes can result in accelerating diffusion curves if one incorporates variation in the individuals' learning rates—a truly justified assumption—into the model. Reader (2004) summarises over 20 datasets where diffusion curves have been used to distinguish social from asocial learning. He reported that the shapes of the curves were quite variable and often did not fit the predictions sufficiently. As a likely reason for this discrepancy he suggested that the models were so far too simple, neglecting the effects of the population's social structure. Recently, Kendal et al. (2007) have investigated social learning processes in small groups of callitrichid monkeys. They simulated the effects of three learning processes—stimulus enhancement, observational learning and asocial learning—and selected the model-parameters that provided the best fit to the data. Logarithmic and inverse functions provided the best fit for most diffusion curves. They found no evidence for observational learning; however that might be due to the nature of the foraging task. Socio-spatial parameters might play only a marginal role in such egalitarian species studied under spatially confined conditions and were not included in the model.

To investigate effects of the social structure on the propagation dynamics, we developed a stochastic model that allows us to make predictions about the expected patterns of information transmission in closed social units. This model shall include varying transmission rates for different individuals according to the social structure of the system and it should be formulated in a general way that does not restrict its applicability to only a small class of social systems.

2. Method

2.1. Graph-representation of social systems

Social systems can be described in many different ways. For the study of social dynamics it is, however, crucial that the complexity of the system is not lessened by an overly reductionist descriptor. A method to avoid this is to represent the group structure by a socio-matrix (Moreno, 1946). For the study of information transmission, the critical variable is the likelihood with which