INFLUENCE OF SOCIAL NETWORKS ON GROUP DECISION-MAKING AND GROUP COHESION IN CHACMA BABOONS: A MODELING APPROACH COUPLED TO A FIELD STUDY

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Introduction

Every day, millions of humans make decisions about an issue of interest for the group or the community they represent. The general public elects a president, workers decide about which is the best project for their firm, family members choose which film they will watch on TV, and friends decide where they will go for dinner. The decision made by an individual varies according the relationships he/she has with the surrounding people (hierarchy, family, friendship). For instance, the head of a firm or the parents of a family may have a big influence in the decision-making. Equivalent processes have been well described by several authors for animal societies (for review, *cf.* Conradt and Roper, 2005).

Many animal species also live in groups and have to take collective decisions. In many species, the different activities could not be carried out in the same area. Individuals have to decide when, and where, they will move collectively. In this context, collective movements appear as a good candidate to study collective decision-making in animals.

In Primates, authors reported specific organization of individuals during collective movements (Hockings et al., 2006, Rhine and Westlung, 1981; Rhine and Tilson, 1987; Waser, 1985). For instance, dominant individuals may have a specific position in the group in movement in order to have a prior access to food or to decrease the predation risk (Boinski et al., 2000; Hall and Fedigan, 1997; Janson, 1990; Waser, 1985; Whitten, 1983). An explanation was that intentional mechanisms underlie this specific organization and take into account the high cognitive abilities of primates (Hemelrijk, 2002; Tomasello and Call, 1997). Boinski and Campbell (1995) suggested that white-faced capuchins (*Cebus capucinus*) exhibited some coercive behaviour in order to manipulate intentionally the decisions of other group members, looking like a “Machiavellian intelligence” (Whiten and Byrne, 1997). However, other complex systems exist in which the mechanisms underlying their emergence are not necessarily complex (Camazine et al., 2001). For example, the complexity of nests in social insects does not run by a central authority requiring sophisticated cognitive abilities but emerges from simple and local rules between insects (Bonabeau et al., 1997; Camazine et al. 2001). Thanks to these rules, authors explained how fishes in shoals or birds in flocks coordinated their movements (Biro et al., 2006; Camazine et al., 2001; Couzin & Krause, 2003), fireflies synchronised their flashings (Strotgartz & Stewart, 1993; Ramirez Avila et al., 2003) and locusts coordinated their marching (Buhl et al., 2006). Self-organization seems to be a parsimonious way to understand complexity of animal societies (Deneubourg and Goss, 1989; Camazine et al., 2001; Detrain and Deneubourg, 2006).

Recent studies have demonstrated that self-organized processes can exist in small groups with highly structured relationships as in white-faced (*Cebus capucinus*; Meunier et al., 2006). In the same way, authors have applied this theory to explain behavior in human crowds (Dyer et al., 2007; Helbing et al., 2000). This explanation suggests that the same general principles underlie these collective decisions and self-organization seems to be a parsimonious way to understand this complexity in animal societies (Detrain and Deneubourg, 2006; Sumpter, 2006).

Sueur and Petit (2008a) proved that macaques (*Macaca mulatta, M. tonkeana*) used voting behavior and recruitment signals to propose direction and ‘time to move’. However, processes of joining a movement and organization of group members at departure depend on mimetism, where individuals decide to follow only highly-affiliated conspecifics (Sueur et Petit, 2008b; Sueur et al., in prep). Primates seem to be good candidates to study self-organized processes in species with highly cognitive abilities. Affiliation relationships seem to be a key characteristic for the cohesion and the stability of groups (Wey et al., 2007). This selective mimetism based on affiliation is probably a self-organized process (Deneubourg & Goss, 1989; Bonabeau et al., 1997; Detrain and Deneubourg, 2006). Macaques seem to display complex behaviors, as well (Sueur and Petit, 2008a) as use self-organized rules, during collective decision-making for moving (Sueur et al. in prep).

Social networks as affiliative relationships constrain many social phenomena such as information or disease transmission, coalitions and group fission (Chepko-Sade et al., 1989; Dow et de Waal, 1989; Silk et al., 2004; Van Horn et al., 2007; Voelkl and Noë, 2008; Whitmeyer and Yeingst, 2006).The influence of social networks have been neglected in the study of decision-making processes in animals' groups. In this project, I aim to study the influence of social networks on individual decision making, and, subsequently, on collective decision-making and group cohesion.

I will observe different groups of chacma baboons (*Papio hamadryas ursinus)*. Studying different groups of baboons will allow us to understand the influence of social networks and of group size on decision-making processes during collective movements.

To summarize, we aim to understand how social networks influence the decision-making process in terms of:
1) degree of self-organization of the decision (from combined to consensus decision),
2) sharing of the decision (from unshared to equally shared decisions),
3) group cohesion.

The Baboons

Chacma baboons live in multimale-mutlifemale groups. They form matrilineal clans, females staying in the group while males emigrate at puberty (Silk et al., 2004, 2006a, 2006b). The social structure of this species has been well studied (Altmann and Altmann, 1974; Altmann and Alberts, 2003; Silk et al., 2004a, 2004b) and knowledge about social interactions and relationships of group members is crucial in order to study collective decision-making. Scientists followed some groups of chacma baboons for many years: individual characteristics (age, sex) and social relationships (affiliation, kinships, and dominance) are known (Altmann and Altmann, 1974; Altmann and Alberts, 2003; Silk et al., 2004a, 2004b).

Chacma baboons can live in groups from 10 to 200 individuals and in different environmental conditions (Altmann and Altmann, 1974; Hill and Dunbar, 2002). These characteristics are rare in the primate order (Lehmann et al., 2007) and will allow us to study collective decisions in small but also large groups of individuals with complex cognitive abilities. It will also allow us to study the influence of ecological pressure on the decision-making process.

Studying collective movements requires the observation of all group members during a significant period of time and a certain stability of environmental conditions (Meunier et al., 2006; Gautrais et al., 2007; Sueur et al., in prep). Savannah conditions can fulfill these requirements: relief and vegetation allow a good visibility and observation of animals (Noser and Byrne, 2007).

Hypotheses

Different groups of chacma baboons with different group sizes will be studied. Studying different groups will help us to understand how social networks influence individual and collective decisions. The different patterns of groups, in terms of group size, number of matrilines, sex-ratio and social relationships will allow us to verify the role of certain individuals and their relationships in the decision-making process (Lusseau, 2007, Sueur and Petit, 2008b). In the same way, we will assess if individual decisions are influenced by the behavior of all group members and that the process would be more a global negotiation or if an individual decides to move according to its local and preferred partners, suggesting a self-organized processes (Bonabeau et al., 1997; Conradt and Roper, 2005).

According to the importance of nepotism and of hierarchy in this species (Alberts and Altmann, 2003), we expect that the consensus would be partially shared (Conradt and Roper, 2005), old and dominant individuals having a more important role in the decision-making process than others. As the network of a group is mostly matrilineal, we guess that females would have more influence in the decision-making than males. Nevertheless, the consensus could not be unshared given the extreme and costly decisions it leads to (Conradt and Roper, 2003). Then we will try to measure costs and benefices of such kinds of consensus. Moreover, voting behaviors about which direction to choose have been found in macaques (Sueur and Petit, 2008a; Sueur and Petit, in prep) and in Hamadryas baboons (Kummer, 1968), suggesting a sharing of the decision. We assume, therefore, to find similar behavior in chacma baboons and would aim to test the influence of social relationships on this negotiation process and the possibility of subsequent group fission.

Materials and Methods

Subjects and environment

We will study two semi-habituated groups at the Wildcliff reserve in South Africa Cape. One presently consists of 15 members, with only one (alpha) male. The other has approx 75 members, with many infants and juveniles. There is some flow between the two troops.

Social relationships

Dominance relationships will be recorded using all occurrence sampling (Altmann, 1974). Using instantaneous sampling every five minutes (Altmann, 1974), affiliative relationships will be quantified by the number of scans, where individuals will be observed in proximity, out of moving context, at a distance equal or inferior to one meter. The affiliative relationships include the preference for certain group members (kin related and non-kin related ones).

Observation procedure of collective movements

Two or three observers will observe each group during a three month period, from dawn to dusk, to record at least 100 collective movements per group.

A preliminary period of about one month for each group will allow the observers to identify group members and determine criterion in order to define a collective movement.

Spatial position of the group will be collected thanks to a GPS at departure and at end of each collective movement (Noser and Byrne, 2007; Sueur and Petit, 2008a). Similarly, topography and type of vegetation will be recorded.

Toughbook (Panasonic) with Tablet PC will be used to directly record the behavior of each individual. Nevertheless, 2 camcorders will continuously film group members in order to record all behavior and to analyze *a posteriori* positions and activity of each individual at the departure of a collective movement.

When the collective movement will begin, identity, behavior and departure latency of the first departed individual will be recorded using the focal-animal sampling method (Altmann, 1974; Leca et al., 2003; Sueur and Petit, 2008a). After, the identity, the behavior and the departure latency of each follower will be recorded using the same method. We will determine the departure latency of an individual by scoring the time elapsed between the departure of this individual and the end of the previous collective movement. This latency corresponds to the time during which this individual is stationary, i.e., carrying out an activity other than moving. Thanks to these latencies, we can calculate and model the departure probability of each individual (Meunier et al., 2006; Sueur et al., in prep).
Progression order and associations of group members will be noted at the departure, middle and end of each movement.

Statistical analysis

We will distinguish socio-demographical, behavioral and spatio-temporal variables in the analyses, as well as the different phases of a collective movement (before departure, at departure and after departure of a movement; Sueur and Petit, 2008a). The dependent variables will be the departure latencies and the number of followers (if all group members do not follow the first individual, i.e. in case of fission). Each individual will be characterized by its age, sex and hierarchical rank. We will use Spearman rank correlations to test for the effect of age and hierarchical rank of individuals on the dependent variable, Mann–Whitney tests for that of sex. Influence of kinship, dominance and affiliation will be studied using social network analysis. We will use a General Linear Model to test influence of behavioral variables (activity, number of pauses, number of back glances, speed, etc.) and spatio-temporal ones (dispersion of the group, positions of individuals, departure latencies) on the decision-making process of a group. These tests will be carried out for each group.
On the other hand, the influence of group variables such as group size, environmental conditions and demographical structures (age and sex ratio) will be analyzed using a GLM.

Social network analysis

The social relationships in and between groups will be studied using a social network analysis approach (Chepko-Sade et al., 1989; Krause et al., 2007; Wey et al., 2007; Whitehead, 2008). In the same way, we will use this methodology to understand the organization of individuals during collective movements (Sueur and Petit, 2008b)
We will analyze these social networks using software such as SocProg2.3 (Sueur and Petit, 2008b; Whitehead, 1997, 2007) or Ucinet6.0 (Borgatti et al., 2002; Sueur and Petit, 2008b). These programs calculate some indices that allow us to determine:

- if a population or a group is divided into subgroups and which factors might influence this division,
- if strengths of association differ between individuals,
- if some of the individuals occupy a more central role in the life of the group and in the decision-making process. In the context of collective movements, these individuals with a central role could be qualified as 'leaders' (Byrne, 2000; Conradt and Roper, 2003, 2005; Holekamp et al., 2000; Lusseau, 2007; Sueur and Petit, 2008b).

Modeling

We will first implement the social networks of each group (the one of kinship and the one of affiliation) in a model developed in Netlogo3.14 (Sueur et al., in prep). Secondly, the departure latencies of each observed individual, for each group, will allow us to determine individual departure likelihoods which we will implement in the model (Sueur et al., in prep). Thus, we will collect data about decision-making processes obtained from the observation of real groups, about simulated decision-making processes obtained from social networks of the same real groups, and about simulated decision-making processes obtained from theoretical social networks. Comparisons between the data of decision-making processes of each condition (observed, simulated with observed social networks, simulated with theoretical social networks) will be carried out to assess if general principles as density dependence, mimetism, etc. could underlie collective decision-making processes (Buhl et al., 2006; Sueur et al., in prep), i.e. if primates can take complex collective decisions thanks to simple rules as find in insects and fishes.

Perspectives

Results from social networks analyses would be used in other domains than collective decision-making. This kind of study has already been carried out in order to understand the process of information or disease transfer. However, further studies are necessary in order to understand mechanisms underlying collective phenomena such as social learning or collective movements.

The model in which different directions are proposed will be compared with results observed in different species, even human people in the case of vote in elections or in referendums. On the other hand, our results could also be used for conservation purposes. Sometimes, in zoo parks or reserves, animals become too numerous and one must to split the group in order to avoid food depletion and increased aggression. In such cases, our model will be a useful handling tool in determining which subgroups are the most stable.

A lot of scientists working on artificial intelligence or robotics use results on collective decision-making process in animals to enhance communication between agents or robots (Halloy et al., 2007; Wang and Chen, 2003). Our results could be used in these domains to improve synchronization and communication of individuals in an artificial group.