

## Interdisciplinary PhD in Cognitive and Network science at Aix-Marseille University

### Title: Emergence of shared conventions in non-human social networks

Supervisors: Alain Barrat (CPT, Marseille, France) and Nicolas Claidière (LPC, Marseille, France)

We are looking for a PhD candidate with a strong background in mathematical or physical sciences and an interest in cognitive science and animal behaviour to work on a project called “**Emergence of shared conventions in non-human social networks**” at Aix-Marseille University (France). The project is built on a collaboration between two researchers with complementary expertise, a specialist in evolutionary theory and adaptation (Nicolas Claidière) and a specialist in the theory, analysis and data-driven modelling of complex systems and networks (Alain Barrat).

Conventions form an essential part of human social and cultural behaviour and may also be important to other animal societies. How does a group of individuals reach a shared convention in a self-organised way, without external input such as institutions? How can a stable shared convention change, sometimes overturned by a minority of individuals committed to a new convention? An increasing number of studies, both empirical and theoretical, has brought indications of a complex role of the social network structure on such issues.

The PhD project aims at improving our understanding of the complex interaction between social organisation and emergence and dynamics of shared conventions in a non-human animal group. To this aim, we will study a group of ~20 baboons located in the Station de Primatologie near Marseilles. A nonhuman primate model offers the best animal model of complex societies and has the advantage of facilitating the study of the long-term evolution of cognitive performances and social network characteristics.

The PhD student will gather data, perform experiments, study and implement theoretical models to study the emergence of conventions in this group of non-human primates. More specifically, the student will

- perform a review of models for the emergence of a shared convention in a social network and implement the most relevant ones numerically;
- devise experiments for studying the emergence of shared conventions in the group through binary interactions in the computerized experiments; to create “committed” minorities of animals that favor a certain convention, study how the position of the minority members in the social network impacts the dynamics and whether a globally shared convention is reached;
- compare these dynamics with the theoretical models reviewed;
- gather social network data using a proximity tracking system, analyse the resulting data using social network analysis and temporal network tools, and study the co-evolution of the social network and of the conventions;
- devise and implement procedures necessary to enhance or suppress the social relationships of the baboons through computerised testing, and to verify their impact on the social network data.

Funding is for 3 years and depends on the success of the candidate at an interview (on 13 or 14 June 2022).

Further details can be found in the attached document.

If you are interested in applying for this position, please send a one page cover letter, your CV with Bachelor and Master’s grades and the name of two referees to [alain.barrat@cpt.univ-mrs.fr](mailto:alain.barrat@cpt.univ-mrs.fr) and [nicolas.claidiere@normalesup.org](mailto:nicolas.claidiere@normalesup.org) by **April 29<sup>th</sup>, 2022**. Do not hesitate to contact us for further information.

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Relevant references :

<http://www.nicolas.claidiere.fr/wp-content/uploads/Conventions-Formaux-2021.pdf>

<http://www.nicolas.claidiere.fr/wp-content/uploads/rspb.2021.1164.pdf>

<https://www.nature.com/articles/s42005-022-00845-y>

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## **PhD project: Emergence of shared conventions in non-human social networks**

Conventions form an essential part of human social and cultural behaviour and may also be important to other animal societies. How does a group of individuals reach a shared convention in a self-organised way, without external input such as institutions? How can a stable shared convention change, sometimes overturned by a minority of individuals committed to a new convention? An increasing number of studies, both empirical and theoretical, has brought indications of a complex role of the social network structure on such issues.

From the theoretical point of view, many models of processes on networks have been put forward to describe the emergence of consensus and of shared conventions in a population where individuals interact in a pairwise fashion along their social network: for instance, in the Voter model, individuals have a binary opinion (0 or 1), and at each interaction an individual simply copies the opinion of one of their neighbours; in bounded confidence models, opinions can take continuous values, individuals can interact only if their opinions are close enough; in the naming game, interactions are asymmetric, with an individual proposing a name for an object, and a successful interaction if the other person already uses the name for the same object. These models can display a rich phenomenology, and many studies have shown the importance of the structure of the network on which individuals interact. It has also been shown that a small minority of committed individuals can overturn a convention shared by the large majority of individuals, if the minority reaches a critical size (critical mass theory).

Empirical studies are fewer, ranging from observational studies (e.g. the emergence of a shared hashtag on twitter) to controlled experiments of social coordination among humans: in such experiments, the structure of interactions can be controlled, but does not correspond to any real social network as the individuals do not know each other.

For non-human animals, very little is known on the emergence of shared conventions in a group [Couzin et al., 2011], and in particular on the possible role of the animal social network in this context. Many studies have investigated social networks of various species of non-human animals, focusing however mostly on measuring and characterizing them, and in some cases on following and understanding their temporal evolution, but not on the interplay between social network and evolution of behaviour.

This project aims at improving our understanding of the complex interaction between social organisation and emergence and dynamics of shared conventions in a non-human animal group. To this aim, we will study a group of ~20 baboons located in the Station de Primatologie near Marseilles. A nonhuman primate model offers the best animal model of complex societies and has the advantage of facilitating the study of the long-term evolution of cognitive performances and social network characteristics. Both PhD supervisors have collaborated in the past on studying and characterizing the social network in this group of baboons, using different measuring infrastructures [Gelardi et al. 2019 (Animal Behaviour), 2020 (Proc. Roy. Soc. A.), 2021 (Proc. Roy. Soc. B)].

The project will leverage (i) a sensor-based infrastructure [Barrat et al. 2014, Gelardi et al., 2020] allowing to measure the dynamics of the group's social networks at both short and long term, and (ii) a new infrastructure to allow collaboration between animals during cognitive tests (with a benefit for animals when they collaborate) [Formaux et al. 2022], to gain a deep understanding of the emergence of conventions in animal social networks. The main goal is to perform and analyze experiments reproducing the emergence of conventions using the protocol developed by Formaux et al. under controlled conditions to validate critical masses models. This will be done in three main steps.

Firstly, tailored models of the emergence of conventions will be developed to reanalyse the results of Formaux et al. and shed light on how the emergence of convention was impacted by the social network.

Next, the same models will be used to make predictions regarding the critical mass and the key individuals that could lead the group to adopt new conventions. These predictions will be empirically tested by performing corresponding experiments with the group of baboons. For instance, we can train a specific minority to use one convention, while the other individuals in the group are trained to use a different convention. We can then put all the individuals together and study whether or not the minority manages to convince the majority. This procedure can be used to create various configurations, such as training the highest degree individuals as a minority, or one cluster, or several individuals in each cluster, etc. The results of these experiments, combined with realistic models of convention formation, will allow us to identify those critical properties of the social network that influence the formation of conventions.

Finally, previous studies involving the group of baboons that we will study have shown that there is a link between social interactions in the enclosure and the behaviour of baboons during cognitive tests [Claidière et al., 2015, Gelardi et al., 2019]. Interestingly, the theory suggests that individuals that share a common convention should ‘stick together’ i.e. tend to perform experiments together to benefit from the shared convention. Since non-human primates can adjust their social relationships to the benefits and costs that interacting with others can have [Fruteau et al., 2009], we can expect individuals that share a convention to increase their social bonds, and the bonds between individuals with different conventions to become weaker.

Using experiments on conventions combined with the RFID infrastructure that can monitor the social network of the group, we will test the adaptation of the baboons’ social network to the establishment of conventions.

Such studies combining the dynamics of the establishment of conventions on the network and the effective modification of the social relationships in the animal group represent the most challenging, the most ambitious and the most promising aspect of this project.

To study the social network of the baboons we will use a proximity tracking system developed by the SocioPatterns collaboration ([www.sociopatterns.org](http://www.sociopatterns.org)) recently adapted to study the social network of baboons and its temporal evolution [Gelardi et al., 2019, 2020], and newly developed social network analysis tools.

To study the emergence of conventions, and to manipulate the social network, we will use the fully automatized system developed by Joel Fagot and modified by Nicolas Claidière [Formaux et al. 2022]: the social-automated learning devices for monkeys.

The crucial asset of the project is to combine the data gathered from these two infrastructures to study the co-evolution of conventions and of social network properties. Within the project, the role of the PhD student will be as follows:

- To perform a review of models for the emergence of a shared convention in a social network and to implement the most relevant ones numerically;
- To devise experiments for studying the emergence of shared conventions in the group through binary interactions in the computerized experiments; to create “committed” minorities of animals that favor a certain convention, to study how the position of the minority members in the social network impacts the dynamics and whether a globally shared convention is reached;
- To compare these dynamics with the theoretical models reviewed;
- To gather social network data from the proximity tracking system, to analyse the resulting data using social network analysis and temporal network tools, and to study the co-evolution of the social network and of the conventions;
- To devise and implement procedures necessary to enhance or suppress the social relationships of the baboons through computerised testing, and to verify their impact on the social network data.

## References

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- Claidière N., Gullstrand J., Latouche A., Fagot J. (2015). Using Automated Learning Devices for Monkeys (ALDM) to study social networks. *Beh. Res. Met.*, 1-11.
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- Iacopini I., Petri G., Baronchelli A., Barrat A. (2022). Group interactions modulate critical mass dynamics in social convention, to appear in *Comms Phys* (2022); preprint arXiv:2103.10411

The first PhD supervisor, Alain Barrat (CPT), is a statistical physicist expert in complex networks, in particular in the study of time-resolved contact networks and in the development of dedicated analysis tools. He has co-developed an infrastructure to measure networks of human contacts and obtained many results in their characterization and use, ranging from theoretical advances to results relevant to social sciences and also to

epidemiology. He is an expert on dynamical processes on networks (he has co-authored a book on this topic) and has published many works on the dynamics of emergence of convention on networks: he has participated to pioneering efforts on the understanding of the Naming Game model, which has become one of the benchmarks models in the field and has recently investigated the impact of committed minorities in the emergence of a shared convention in a social group.

The second PhD supervisor, Nicolas Claidière (LPC), studies the cognitive capacities of a group of 25 baboons located in the Station de Primatologie in Rousset-sur-Arc, using a unique testing facility developed by Joel Fagot and himself. The team has made important contributions to the understanding of individuals' cognitive performances and in the study of the influence of specific social relationships on these performances. For instance, they have shown that cognitive performance is affected by an individual's emotional state, the nearby presence of a better or worse off conspecific and the sex of the conspecific. This expertise in primate cognition needs however to be complemented by the understanding of the social context in which the cognition takes place, considering the network as a whole and not only focusing on specific individuals or even dyads. Currently, the team is exploring new issues in social cognition using a novel system that allows computerised dyadic interactions.