Editorial: Social networks analysis in primates, a multilevel perspective

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Social network analyses and studies are booming since 2000's, not only in humans but also in many other animal species. Primates are not an exception with the record count of the keywords "Social Networks Primates" increasing tenfold from 2000 to 2017 (fig.1a, source: Web of Knowledge). Studies are in domains such as Psychology, Behavioral Sciences, Sociology but also Neurosciences and infectious diseases (see fig.1b for details, source Web of Knowledge). To our knowledge, several special issues and books were in animals (Croft et al. 2008; Whitehead 2008; Krause et al. 2009; Sheldon 2015; Sueur and Mery 2017) but only one special issue was done on Primates (Sueur et al. 2011). In the last ten years, studies have evolved from describing structures (Manno 2008; Carter et al. 2013; Bret et al. 2013) and topologies of social networks or centrality of group members according to their sociodemographic characteristics (Lusseau and Newman 2004; Kanngiesser et al. 2011) to a more holistic approach where the function and evolution of networks is linked to ecological factors, behavioral mechanisms, networks topologies and vice versa (Brent et al. 2013; Fisher et al. 2016; Balasubramaniam et al. 2018). In this new special issue, we wanted to take this integrative and multilevel approach and introduce state of the art methodologies and theoretical approaches for the study of primates' social networks.

Statistics applied to social network analysis have greatly evolved in the last ten years (Hoppitt and Laland 2013; Farine 2017; Finn et al. 2017; Sosa 2018). Whilst it is commonly accepted now to use permutations tests to avoid dependence of social data (Koyama & Aureli, this issue; Kawazoe & Sosa, this issue; Rodrigues et al., this issue), new tools emerged to study the social position of individuals inside their network (i.e., egocentric network; Grampp et al., this issue), the multidimensional nature of the networks (i.e., multiplex networks; Aguilar et al, this issue) and their dynamics (through ERGMs, exponential random graphs models for instance; Lutz et al., this issue). Researchers also more and more use modeling to simulate the social transmission of a disease or an information (thanks to Network-based diffusion analysis, Wild & Hoppitt, this issue) or to simulate network resilience through targeted deletion (Puga-Gonzales et al. this issue).

These new tools allow first a better understanding of how complex a network is. Indeed, social relationships are the interplay of many types of interactions (grooming, aggressions, proximity, genetic relatedness) and multiplex networks gave a better information about the social position of group members, as shown by Aguilar et al. (in this issue) on wild spider monkey (*Ateles geoffroyi*). Yan et al. (this issue) also showed that in rhesus macaques (*Macaca mulatta*) matriline is more important than genetic relatedness for grooming and proximity relationships. Roberts et al. (this issue) studied the importance of gestural communication to manage social relationships in chimpanzees (*Pan troglodytes scweinfurthii*) and proved that individuals having equitable relationships (based on dominance) used communications patterns to reduce uncertainty about signaler intentions.

The tools developed during the last decade also bring new possibilities to compare species even when differences due to group size or group composition exist. In this way, Lutz et al. (this issue) studied play network organization in three species (brown capuchins, *Cebus apella*; hamadryas baboons, *Papio hamadryas*; diademed sifakas, *Propithecus diadema*). Dynamic of networks, meaning how they change through time, seasons or group compositions, is also a booming topic giving the availability of tools that can tackle this matter nowadays. Xia et al. (this issue) studied the seasonal dynamics, specially the impact of reproductive season, on grooming networks in Tibetan macaques (*Macaca thibetana*) whilst Kawazoe & Sosa (this issue) observed how social relationships affect male immigration and vice-versa in Japanese macaques (*Macaca fuscata*). Finally, social network analysis is also useful tool for applied ethology since it can assess how captive conditions and unnatural group composition influence the social relationships of group members as reported by Koyama & Aureli (this issue) and Rodrigues et al. (this issue) in chimpanzees and bonobos (*Pan paniscus*).

Network studies are not just a matter of topologies or dynamics but also of influence. We can study how networks topologies influence different collective or social phenomenon. Social learning is one of the most studied events linked to social network analysis. We might use network-based diffusion analysis or Markov chain models to understand which social characteristic (kinship, proximity, grooming, etc.) influence the information social transmission. However, data collection of social interactions or associations is most of the time incomplete (because we are not 24/7 with animals or because we cannot observe all group members) and uncertainty may produce some errors in our conclusions about which social characteristics influence information diffusion. In this issue, Wild & Hoppitt took network-based diffusion analysis further by studying the trade-off between including as many individuals as possible (whatever the time each individual was observed) and having reliable data. This cut-off point maximizes the power of the analysis. Grampp et al. (this issue), on their side, observed the social biases influencing social learning in juvenile vervet monkeys (*Chlorocebus aethiops pygerythrus*). Kinship emerged as the most important focus of attention in juveniles, followed by dominance. Same approach was applied to understand information transfer in collective decision making such as group movements (Fratellone et al., this issue). The authors studied how social networks influence the speed of collective movements in Tibetan macaques move together: females seem, thanks to their connectivity, to favor decision efficiency.

Social transmission is not only important for information but also for pathogens. In this special issue, Tiddi et al. assessed whether parasite infection was better predicted by naturally occurring spatial networks (i.e., during natural observations) or by provisioning spatial networks (i.e., during experimental provisioning). In their study, network centrality increased during experiments but this increase (closeness and betweenness) did not affect patterns of parasite infection. Puga-Gonzalez et al. (this issue) found a contrary effect of centrality (in this case degree and eigenvector) on diffusion. Indeed, they simulated the deletion of targeted group members (with highest centrality) and the deletion of group members chose randomly, and found that network topology (e.g., modularity, diameter, efficiency) was more affected by the removal of central individuals. However tolerant (less aggressive) and intolerant (more aggressive) societies appeared both to be robust to the loss of group members, even if tolerant societies have more efficient networks than intolerant ones.

This efficiency and robustness of networks may have important consequences for fitness of group members. This raises the question of the evolution of networks, with some topologies favoring the transmission of information and decreasing epidemics. Sueur et al. (this issue) discussed about how evolutionary driving forces (genetic and cultural) may result in specific composition of individuals social strategies, with these social strategies producing network topologies optimized to specific socio-ecological conditions. The authors used “collective social niche construction” when referring to these evolutionary processes driving network structures.

To conclude, this special issue introduces new results and methodologies, but more importantly, it delivers new perspectives and concepts that we hope researchers will profit from in the future.

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Figure legends

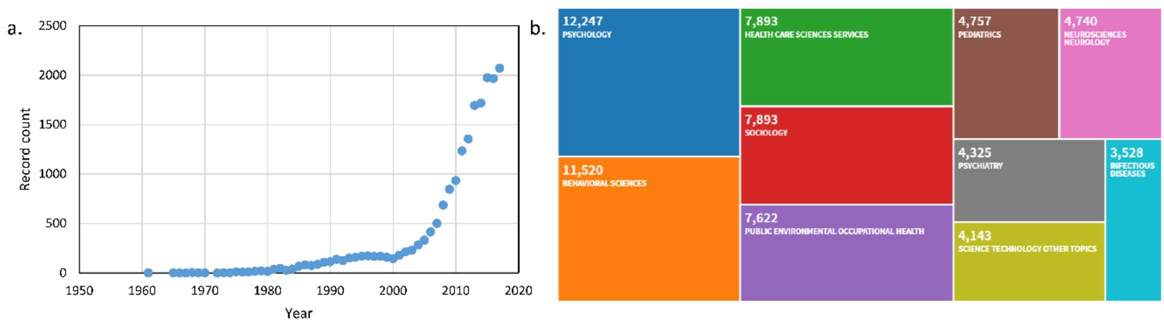

Figure 1: Record count of the keywords “Social Networks Primates” (a.) per year and (b.) per topics. Source: Web of Knowledge.