Linking social preferences to social network structure and function

Keywords: social networks, generative network modelling, social preferences, human and animal social structuring, methods development

Extended Abstract

Social network structures play an important role in the lives of humans as well as many other species. They affect the spread of disease and information, and the social connectedness of individuals has been linked to their health and wellbeing in both humans and non-human animals [1]. Understanding the processes that drive social structuring is therefore central for understanding social systems and social evolution, and studying these processes in different species is important for gaining a comprehensive understanding. But while the number of studies quantifying social structures in different species has grown rapidly in the last decades, we currently lack a good understanding of how these structures emerge from individual behaviour [2]. More precisely, the central question of how different structural and functional aspects of real-world social networks are shaped by different individual-level social strategies remains open. Answering this question in depth is important for our fundamental understanding of sociality, as well as for predicting how changes in social strategies (for example caused by environmental disruptions) may affect the systems.

Generative network models constitute a central pillar in general network science. Such models provide a useful approach to investigate the link between individual behaviour and social network structure, and empirically-based models have started to emerge as an important tool for understanding the mechanisms driving the diverse social structures observed across species [3].

A central insight from the empirical research in both human and animal social systems is that traits (individual characteristics such as age, sex, etc.) play a key role in real social structures (e.g. [4]). Furthermore, it is well established that humans and non-human animals use the traits of others in their decisions of who to socialise with, and may prefer specific others as social partners depending on their characteristics. This implies that social preferences for traits are a fundamental generative mechanism for social networks. A model that generates social network structures based on explicit modelling of trait preferences could therefore potentially provide important insights into sociality.

This study had two aims: 1) develop a general generative network model based on the empirical knowledge about social systems, and 2) use this model to gain fundamental theoretical insights into how social strategies affect network structure and function. For the first aim, we started from the above-described key empirical insight and constructed a generative network model which is based on social preferences for traits. For the second aim, we took a simulation approach and generated networks from the model, based on different social preferences, and studied how the preferences affect network structure, social transmission, and social robustness.

The model (aim 1), which we call the *trait preference model*, can be used for generation of artificial networks based on different social preferences for traits, and also has the potential to be combined with observed network data. To reflect the real world, the model allows for modelling the simultaneous effect of preferences for multiple traits, which may vary in their importance. It can therefore be used to model networks going from random structures to structures that are strongly driven by different combinations of social preferences. The model thus provides an empirically relevant and flexible approach for modelling social structures.

The model works by determining the *social attraction* between each pair of individuals, where the social attraction depends on the two individuals' trait values and the social preference connected to each trait. Networks can then be constructed from the model by letting the chance of getting a link, and the strength of the link, depend on the pairs' social attraction. The social preferences are explicitly modelled by what we call *preference functions*, which describe mathematically how the trait values affect the social attraction. To model the social preferences, we utilize the fact that they can be categorized into two main types: *similarity preferences*, where individuals prefer others that are similar (or dissimilar) to themselves in terms of the trait (for example, individuals may prefer to socialise with others of an age similar to their own), and *popularity preferences*, where certain trait values - such as higher values - are generally preferred (for example, older individuals may be preferred as social partners).

Human and animal social structures show high diversity, and an ability to generate varied network structures is therefore a prerequisite for a general social network model. We find that a relatively simple version of the trait preference model shows clear structural variation in generated networks, depending on which trait preferences the networks are based on (Figure 1). In addition to generating diverse artificial networks based on social preferences set by the user, the model also has the potential to be used for statistical inference of the importance of different traits (node attributes) in real, observed networks, and to generate artificial networks based on a given real network.

To investigate how social preferences affect network structure and function (aim 2), we generated large ensembles of networks based on different trait preferences, and investigated the structure, transmission efficiency, and robustness of the networks. We did this for the two general types of preference (similarity and popularity), combined with different types of traits (described in Figure 2 legend). We found that the combination of preference and trait has can strongly affect the network structure, which in turn affects network function. Specifically, preferences most often lead to networks with slower transmission (Fig. 2) and with less robustness against fragmenting when nodes (individuals) are lost from the network. This implies that the social preferences that are used in a population, together with the traits they are used with, can have important consequences for the population's effectiveness at transmitting information, risk of disease outbreaks, and risk of structural breakdown.

In summary, we have presented a new generative network model which is based on a key aspect of real social networks, namely social preferences for traits. Given the generality and flexibility of the model, it could potentially be useful more broadly, and we plan to create software to make it easily accessible. We have also presented a simulation study which provides fundamental theoretical insights into how trait-based social preferences can affect network structure and function, and which underlines that understanding in detail the social preferences used in different real-world systems is necessary for comprehensively understanding the emergence of social systems.

References

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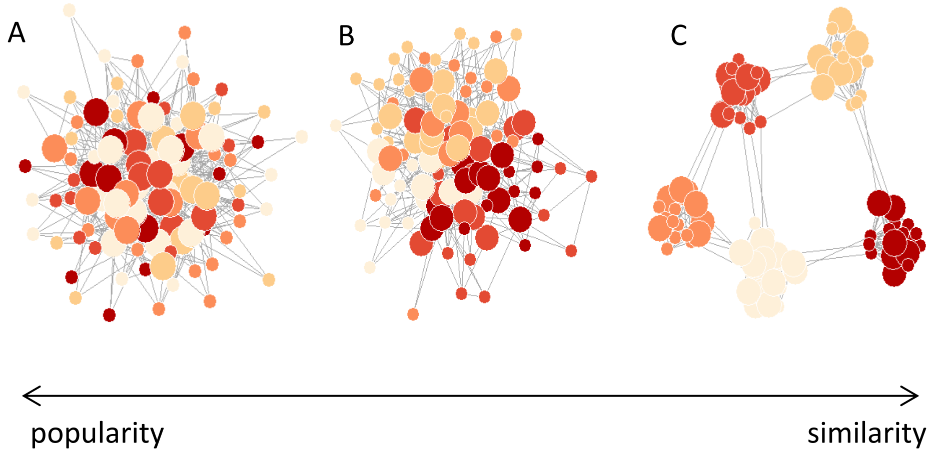

Fig. 1. Structural diversity in networks generated with the trait preference model. Examples of networks created with the model. The networks were generated with a relatively simple version of the model that includes two traits – one used with similarity preferences (where individuals prefer to socialize with others whose values of that trait that are similar to their own), and one used with popularity preferences (where individuals prefer to socialize with others that have high values of that trait). A: High importance of popularity preferences, no importance of similarity preferences; B: Equal importance of popularity and similarity preferences (the two preferences are acting simultaneously); C: High importance of similarity preferences, no importance of popularity preferences. Both traits are here categorical, with node colours corresponding to trait categories of the trait that is used with similarity preferences (5 categories) and node sizes corresponding to trait categories of the trait that is used with popularity preferences (2 categories).

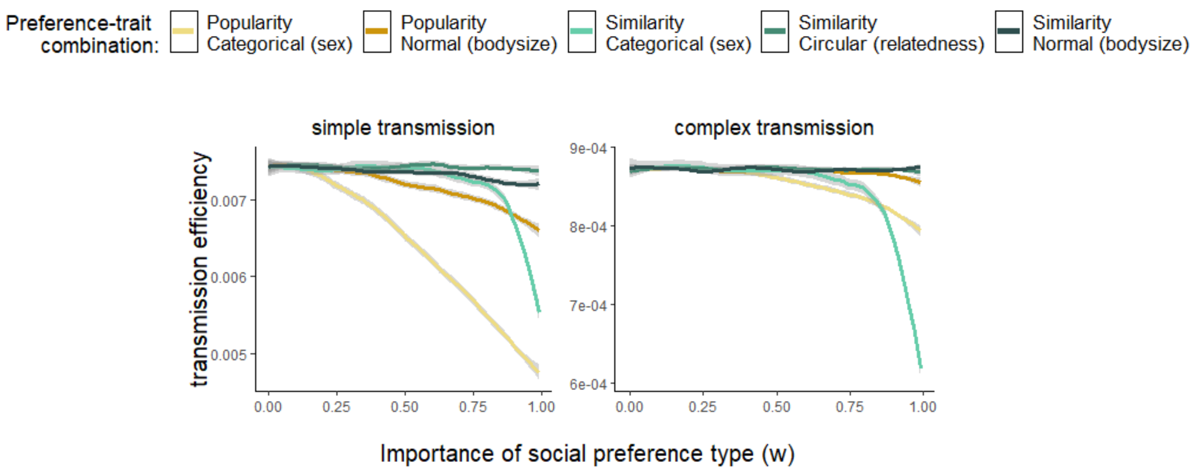

Fig. 2. Effects of social preferences on transmission efficiency of networks. The change in transmission efficiency with increased importance of social preferences. Each line is for a different combination of preference type (similarity or popularity) and trait type (defined by different trait value distributions that correspond to traits of key importance in human and/or non-human animal social systems; see legend). Results are shown for two types of transmission: simple transmission (relevant for disease and information spread) and complex transmission (relevant for spread of information and behaviour).