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Forum

Research questions should drive edge definitions in social network studies

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Recently we published a study (Castles et al., 2014) that compared social network metrics that were created from two methods for defining connections (edges) among wild baboon, *Papio ursinus*, individuals (nodes): proximity and interactions. We found that in many (but not all) cases individuals' positions in the proximity networks were not predictive of their positions in the interaction networks and we cautioned researchers about assuming that one is a proxy for the other, which is frequently done in social network studies (e.g. Carter, Macdonald, Thomson, & Goldizen, 2009). In his Forum article, Farine (2015, this issue; henceforth 'Farine') outlines several assumptions that researchers make about how to define edges among individuals that may affect the results of social network studies, before presenting new empirical findings from wild thornbills (genus *Acanthiza*) that he concludes contrast with ours. We are excited that our research has generated such interest, and this new article adds to a growing body of empirical studies that consider sampling issues in social network studies (Castles et al., 2014; Hobson, Avery, & Wright, 2013; Lehmann & Ross, 2011; Madden, Drewe, Pearce, & Clutton-Brock, 2011; see Whitehead, 2008 for a comprehensive summary of sampling considerations). We agree that the 'gold standard' in social network studies should be for researchers to incorporate multiple networks using different methods to determine edges into their analyses. However, while Farine usefully highlights assumptions that are important to consider when choosing how to collect and analyse one's network data, several aspects of his article require further consideration before we extend the discussion to broader issues in social network studies.

First, Farine presents empirical data from mixed-species flocks of thornbills, collected over a 6-week period, in which there are correlations between individuals' network positions in proximity and interaction networks. Farine states that this pattern was in contrast to our general conclusion, and so suggests that our findings are not generalizable across species and that in some cases proximity can be used as a proxy for interactions. We feel the first assertion is misplaced, and we caution against the second. Our results were in agreement with those of the thornbills in some years for some social network metrics, where we also found correlations between some proximity and interaction methods (see Figure 3 and supplementary material in Castles et al., 2014). However, the correlation between the two methods was not found in other years. Thus, our results from two study groups over 3 years suggest that findings from one time period may not be generalized

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to the same group(s) in a different time period, let alone to other groups of a particular study species. Had we measured the social network in one particular year (or group) and found a correlation between the methods, we may have erroneously concluded that we can use proximity as a proxy for interaction in all future studies. To return to Farine's first assertion, we are not seeking to generalize patterns from our study but rather the principle that consistency between groups/years should not be assumed until it has been demonstrated. Thus, with respect to Farine's second assertion, we would reiterate our conclusion from Castles et al. (2014): because of the dynamic nature of social networks, we recommend that researchers take care when assuming that proximity can be a proxy for interactions. This is distinct from the suggestions that (1) proximity can never be a proxy for interactions and (2) proximity cannot be used to create social networks, generalizations that we do not advocate.

Second, Farine explores some methodological considerations that were not addressed in our study. We focused on one decision a researcher could make at the data collection stage, specifically, the behaviours that could be used to create edges in a social network. Yet, as we mentioned in our study (Castles et al., 2014), there are many considerations after the data collection stage, as highlighted by Farine) and outlined in detail elsewhere (Whitehead, 2008). We appreciate that Farine is using our study to illustrate some general points, and agree that had we analysed our data differently (e.g. by using rates, rather than proportions, of dyadic grooming interactions) we may have obtained different results. However, this simply further supports our conclusion that social networks measured (and analysed) using different techniques are not necessarily comparable and care should be taken when generalizing research findings. These considerations in data collection and analysis also highlight more general issues of research design which have perhaps been overlooked in the largely descriptive studies of social networks thus far (Whitehead, 2008). The definition of an edge connecting nodes in a network should first and foremost depend on the research question, and assumptions about correspondence between networks should be tested. In the former case, for example, if the research question relates to the transfer of visual information between individuals in a network, then edges based on shared proximity are likely to be most informative (but see our further considerations below). But if the research question addresses the likelihood of ectoparasitic disease spread between individuals, then instances of physical interaction between individuals may be more appropriate. In the latter case, we would encourage descriptive studies to adopt richer analyses that encompass multiple methods of measuring associations, as do others (Lehmann & Ross, 2011; Madden et al., 2011; Whitehead, 2008). Furthermore, we would return again to the conclusion of our original study that any researchers using proximity as a proxy for interactions (and we appreciate this is often the only available source of data on dyadic associations) should be wary that proximity does not always equal interaction, and vice versa. For example, individuals are able to interact via olfaction, vocalizations and visual signals when not in close proximity, or may be in proximity but not interacting (we develop this further below). Consequently, the appropriateness of using proximity as a proxy for interactions will depend on the type of interaction identified as meaningful and important for the research question in the context of the biology of the study system.

The biology of a study species is likely to influence the appropriateness of different edge definitions for answering specific research questions. The definition of an edge should be dictated not solely by what is possible for a study species, but by what is appropriate for it with respect to the study question and the species' biology; one should not use instances of close proximity to infer grooming when the research question is 'does social rank influence grooming equality?', for example, unless this link has been empirically demonstrated (preferably repeatedly) beforehand. Since, for some study systems, building the social network that is most appropriate for a given research question can be prohibited by logistical constraints on data collection, while other methods may be more practical, Farine's question remains: can proximity networks be a proxy for interaction networks? Before we expand on this in more detail, we would mention again that this question is distinct from the value of proximity measures to describe social structure/organization: we find proximity measures valuable for both this task and for hypothesis testing in networks (but see Macdonald & Voelkl, 2015; Whitehead & Dufault, 1999). As we mention above, we are in agreement with Farine that the gold standard in network studies requires a multinetwork framework. In our original article (Castles et al., 2014), we were largely concerned with issues of comparability between studies that use different methods to define an association, and raised the issue of using proximity as a proxy for interactions in the discussion of our findings. Where we disagree with Farine is in his assertion that proximity edges can sometimes be used to infer interaction edges or vice versa without prior testing of this assumption. This does not preclude the use of proximity edges to determine, for example, individuals' preferred associates (for an example, see Carter et al., 2009).

Below, we consider under which circumstances we might reliably expect a correspondence between proximity and interaction networks in an effort to provide guidelines for researchers wishing to use proximity as a predictive surrogate for interaction (see also Whitehead & Dufault, 1999). This need not be limited to difficult-to-observe species, but could also apply to different methods of collecting data that involve remote rather than direct observation, such as the use of global positioning system collars to assign group membership by some measure of proximity. We also appreciate that understanding how and why different networks may or may not correspond or interrelate is an important research topic in its own right. However, we have not yet imagined any case in which one could assume a correspondence between networks without testing for it, although our thought experiment provoked some overlooked considerations in social network studies: (1) some interactions can occur between individuals of different subgroups, (2) proximity networks describe only opportunities for interaction and (3) individuals are likely to vary in both their gregariousness, i.e. their propensity to be in proximity to others, and their sociability, i.e. their propensity to take the opportunity to interact with others when in proximity to them. We use the baboon system as a worked example of our reasoning by way of explanation where necessary, and we assume for this exercise that the hypothetical proximity network that is putatively predictive of the interaction network is well sampled and representative of the 'true' proximity network.

Before we address these points in more detail, we should first take a brief digression to define the term 'group' here. Up to this point, we have used the term to mean a set of behaviourally connected individuals in which the majority of individuals are connected to most others; this is what Whitehead (2008) refers to as a 'community' and is the equivalent of a troop in baboons. From here, however, we use the term to refer to a 'subgroup', a subset of a group that is behaviourally connected (either by proximity or interaction) at a particular point in time (Castles et al., 2014), that is, the level of observation at which social network data are collected. To return to our first consideration then, it is important to address the assumption that researchers make about the proximity needed for interactions (Whitehead & Dufault, 1999). As we mention above, individuals are able to interact via olfaction, vocalizations and visual signals when they are not in close proximity, but this is rarely