First mathematical network model for the Battle of the Sexes

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Why is it easier to bridge conflicting interests in one neighbourhood than in another? Social scientists think that the residents' social networks may play an important role in the answer to this question. Sociologists and theoretical physicists from Utrecht University have recently created a theoretical model for this complex problem. Using the popular game Battle of the Sexes, they have shown how different social network structures have different effects on overcoming conflicts of interest. The results of their study were recently published in *Scientific Reports*.

The amount of influence someone has in a social network appears to be predictable based on the number of contacts that the person has, as well as the structure of the entire network. "The fact that the number of contacts is important is not such a surprising result. But their dependence on the rest of the network is a much less intuitive finding," explains Vincent Buskens, Professor of Theoretical Sociology at Utrecht University. "Using mathematical models, we can study how these kinds of mechanisms work in society at a much more fundamental level."

In the Battle of the Sexes game, men want to go to a movie, while women want to go to the theatre. However, both would rather do something together than alone. Each player chooses the most favourable option for all of the social contacts that he or she has, but the choice of one person can influence the options of another, and the conflicts of interest make the situation even more complex. That makes this one of the first mathematical models for how social networks determine the results of these types of asymmetric games. The model was used to study groups numbering from 20 to 1,280 players, with similar results for each network size.

The inspiration for the model and its analysis was provided by the field of physics. "If we know the characteristics of a particle, then the behaviour of two particles is often fairly simple to predict. But of course, it becomes more difficult for a large number of the particles," explains Henk Stoof, professor of theoretical physics.

"Take water, for example. Two water molecules simply attract one another from large distances, but repel one another at short distances. The fact that many water molecules together can form vapour, liquid water or ice is however far from trivial. We call that a complex system. The mathematical equations for particles are a bit different than for players in the Battle of the Sexes, but the mathematical analysis of their behaviour as a network is very similar."

Using this physics approach to study the problem, the researchers have found a mathematical standard for how the clustering within the network determines the behaviour of the network as a whole. "In extreme cases, there are just a few central figures who tie the network together. When that happens, the entire community arrives at the same choice. On the other extreme, there are networks of small cliques with few mutual ties, in which case each clique makes its own choice," Buskens explains.

The next step in the study will be to test the model using real human players. "We included some assumptions in the model, so the question is to what degree they correspond with reality," Buskens adds. To that end, participants in an experiment will enter into an artificial interaction comparable to the Battle of the Sexes. Ph.D. Candidate Joris Broere, the main author of the publication, will be able to use for these experiments the laboratory facilities of Anxo Sanchez, one of the guests of the focus area Complex Systems Studies. This will involve him conducting an internship in Madrid.

Stoof is also working on follow-up research that takes the human factor into consideration. "In this model, everyone behaves extremely rationally, but in reality it's likely that people don't make the most optimal choice, for example due to a lack of time. In physics, you could model that by using an energy landscape and a temperature. That would make it a static physics problem, which can often be solved analytically. If we can do that, then we can obtain much greater insight into the underlying mechanisms of the system than with simulations alone."

Complex Systems Studies conducts research on situations in which minor changes can have major consequences. To do so, the researchers use theories and models from the fields of physics and mathematics, combined with knowledge from other fields, such as sociology or climate studies.

More information: Joris Broere et al. Network effects on coordination in asymmetric games, *Scientific Reports* (2017). DOI: 10.1038/s41598-017-16982-2

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