A society's cultural practices shape the structure of its social networks

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It's unlikely that someone born today could independently think up all the necessary steps it would take to send a rocket to the moon. They would need to learn from those who came before them.

"There are so many things you would need to learn, engineering and chemistry and astronomy," says Marco Smolla, an evolutionary biologist and postdoctoral researcher in the Department of Biology in Penn's School of Arts and Sciences. "It's the 'standing on the shoulders of giants' idea."

Individuals can innovate, coming up with their own ways to advance a society's knowledge, but, perhaps more often, they learn from those with whom they are connected.

In a new paper in *Science Advances*, Smolla and theoretical biologist Erol Akçay, an assistant professor of biology, show how this learning process triggers a feedback that affects the network structure of societies. Societies in an environment that favors generalists, who have a wide range of skills, are less well-connected than those societies that favor specialists, who are highly skilled at a smaller number of traits.

While other researchers have studied how a society's social structure could influence its cultural dynamics, this is the first time that researchers have shown how cultural selection could impact how the group's social network was formed and maintained.

Putting these theoretical societies under certain pressures—such as changing a generalist-leaning environment so it favors specialists and then goes back to favoring generalists—revealed a tendency for densely networked clusters of specialists to arise, forming "echo chambers" resistant to learning new skills. Such societies can get stuck being highly specialized in a few skills, even when the environment requires a larger variety of skills.

The findings could inform how businesses and even academic fields encourage networking, the authors say.

"There's an idea in business and science and so on where people say networking and more connectivity is important because you get more diverse traits in the network," says Akçay. "What we show is the opposite, that in fact if you get more networked and well-connected, you amplify this echo chamber. You learn what you observe, and if everybody is connected that means everybody learns the same things."

Smolla and Akçay set out to create a simple model of cultural evolutionary dynamics, working off the idea that cultural practices are passed through a social network. They focused on the trade-off between a generalist culture that favors a wide range of skills, for example a hunter-gatherer society in which everyone may be comfortable with a number of practices, versus a specialist-favoring culture, for example a fishing society, in which everyone specializes in that livelihood.

"We asked, how does the thing you need to learn affect how you interact with others," says Smolla. "If you're a generalist where you have a lot of different skillsets to acquire, or you're a specialist who learns one thing but learns it really well, how does that affect the networks?"

The researchers used a social-network model borrowed from a previous study by Akçay and his former postdoc Amiyaal Ilany based on hyena societies in which social ties are passed through generations. They also borrowed a feature of social-network analysis by Penn's Damon Centola known as "complex contagion," which assumes that a person requires multiple exposures to a skill or behavior to learn it.

Their first main finding, that specialists formed efficient, dense networks, while generalists formed sparser networks, came as something of a surprise.

"We had thought it might be the other way around," says Smolla, "that if you wanted to be a generalist with a broad spectrum of skills you would

interact with a broad spectrum of individuals. But the reason that's not the case is complex contagion, the fact that you have to observe traits repeatedly. In the dense network of specialists, you're more likely to learn a specific skill that everyone around you is specializing on as well."

Also surprising to the team was the fact that generalists developed repertoire sizes that were only slightly larger than those of specialists. But again, it depends on complex contagion: The generalists were less likely to encounter others with the same trait multiple times, which means they had lower rates of learning overall. Specialists, on the other hand, had far higher proficiencies than the generalists, thanks to a combination of individuals innovating and then learning from their highly-skilled friends and neighbors.

Smolla and Akçay also observed that being subject to environmental changes can harm specialists, sealing them off from opportunities to learn. They point to examples of this on, for instance, social media where groups tend to be highly connected, or even in tight-knit specialties of science.

"There is even an interesting recent paper that shows that, in scientific communities where everybody coauthors with the same people, those scientific fields are less likely to produce replicable findings," says Akçay.

Looking ahead, the researchers are continuing to example cultural evolution by adding complexity to their model. In one line of study, they're examining what happens when there are different values placed on the various skills learned and taught in a group.

"Let's say right now it's better to be a scientist, but later it might be better to be a farmer," says Smolla. "We're interested in how that affects a society's networks."

More information: "Cultural selection shapes network structure," *Science Advances*, DOI: 10.1126/sciadv.aaw0609 , advances.sciencemag.org/content/5/8/eaaw0609

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