Emotional functioning in Systems

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My broad goal is to learn what agent-based modeling of emotional functioning in human systems might suggest to us beyond what we already know from just looking at individuals.

As a start, I am trying to cherry pick and choose phenomena easy to model. I began with two observations. 1) From the study of individuals, we know that individuals with more stress or anxiety reactions tend to develop more symptoms of various types, and 2) from watching people in systems like families, organizations, markets, there is a strong tendency for individuals to become stressed or anxious when they see others being anxious.

1. Since the 1940s, it has been known that individuals with persistent, intense stress tend to develop symptoms, physical, emotional, and social symptoms. A moderate association, but solid and confirmed repeatedly. Moderate tells us that some people with intense stress don't develop stress and some without stress do develop symptoms.
2. Anxiety contagion. One can see instances where anxiety or panic can sweep through a relationship network, like a wildfire or epidemic, with resulting symptoms, lapses in judgement, and disruptions in functioning. This can be seen in some families, organizations(like businesses), groups(e.g. peer networks), crowds, belief- based groups, mass hysterias. Some groups seem to become sinks for persistent, intense stress and anxiety, a fertile ground for symptoms of various types.

Modeling that transmission process in a system might give us some suggestions about phenomena to look for in actual relationship networks, phenomena we hadn't seen before.

I am starting very simply, using NetLogo as a platform. Let agents be either anxious or not anxious, on or off, red or green. At each time step of the simulation, each agent inspects other agents in its neighborhood. If they are mostly anxious, he becomes anxious. If they are mostly not anxious, he becomes not anxious. That is, take the average of the agent's neighbors' anxiety. If that is greater than a designated threshold, the agent becomes stressed, red. If less, he becomes not anxious, green. More abstractly, this becomes an exploration of threshold modeling of a behavior in a system of agents.

That's it. Let the simulation play out for variations in different initial parameters. Number and density of agents, different kinds of agent movements, anxiety thresholds, initial degree of anxiety in the whole population, initial configurations of agents and anxiety, differences in individuals' resistance to influence by the anxiety of his neighbors.

What then are the variety of phenomena we observe in these simulations?

Fixed random placement of agents

This first simple model has not movement, it randomly places agents on the field of action. This arrangement is like cellular automata which look at their neighbors, but in this case they are randomly placed, not placed on a grid. Then randomly assign stress, shown as a red agent and no anxiety by green. On/off, red/green. There is an anxiety threshold which can be designated. All runs so far, no matter the value of associated parameters, go frozen in less than 6 time steps. Make the anxiety threshold low and the population goes to nearly all red quickly. High and it goes to nearly all green quickly.

When the anxiety threshold is in the middle, the model still quickly goes frozen, but with more interesting structure. What's left is mixed, structures of either all red or all green. Red structures mostly topologically connected or green connected structures. Like archipelagoes of red or green.

So far, these static simulations with the threshold rule that looks at average stress of neighbors go to all frozen. No cycling behavior, no chaotic regime, no gliders or other life-like second-order structures. Just frozen second-order structures of all red or all green.

Obviously, this is not like what we see in reality, which has some people frozen in one state, others changing their states back and forth. So we begin adding other plausible features.

Agents with random movement

The first one I added was movement and noise, random movement, my aim being to unfreeze things a bit. Each agent assumes a random orientation at each step and a limited but random distance moved. Same random initial placement, same random assignment of anxiety/no anxiety to each agent. And fixed anxiety threshold. However, at each time step an agent moves in a random direction and random but limited distance.

Unlike the static models, these runs never freeze into separate structures of red or green. Every run goes to all red or all green in about 20-400 time steps.

When you stop the run at intermediate steps, you see some of the the structures of connected red or green, as in the Static mode. But when resumed, the model always goes to all red or all green.

The more dense the population, the more quickly the agents go to one color or the other. And low density populations take more steps, but still go to all one color by 400 steps.

When the anxiety threshold is set low, the run goes to all red in just a few steps. Set high and it goes all green quickly. In the middle, the threshold is on a knife-edge. Just a little low and it goes all red, albeit with more steps taken. A little high and it goes all green.

Comments   This is all interesting so far but in real life, most of the time we don't see such rapid all or nothing behaviors. One feature which apriori I knew was not realistic was the fixed anxiety threshold. In real life, individuals vary in their susceptibility to others' anxiety or conversely their resistance to others' anxiety. In fact, resistance to pressured, anxious circumstances tends to be associated with greater emotional maturity.

Random movement with variable anxiety threshold

Assign a random anxiety threshold to each agent in addition to the random initial placement, random anxiety/no anxiety. Making the anxiety threshold variable has a dramatic impact on the model.

The runs lengthen across the board. For low and moderate population densities, they still go all one color but take 6-10 times longer to do it. And for the high densities, they mostly never go to all one color. They go on and on with the shifting structures of connected red or connected green. Adding the variable anxiety threshold has introduced another source of mixing, with remarkable results.

Comments I keep emphasizing these structures of all connected one color because of the potential real life implications. Many of the agents in one of these connected structures will stay one color or another for quite a while. In real life, stay anxious for a long time and you will likely develop some symptoms. Stay not anxious for a long time and you lower your chances of developing symptoms.

I now wanted to add one more complication. So far, our models move the agents completely independently of each other. That is, in no relationship to each other. In reality, people order themselves with respect to each other in a variety of ways. Kinship, social class, clans, business colleagues, Red Sox fans. I selected one way of bringing some order to agents interacting, the flocking algorithm. It integrates with movement, it is easy and available, and has some degree of plausibility. In flocking birds and schooling fish, individuals monitor and try to maintain a balance between separation and closeness with nearby individuals. Human beings do some of that monitoring of spatial distance-closeness and monitoring of emotional distance-closeness. We can quibble about flocking. I just wanted to introduce some kind of ordering relationship to other agents as they all move.

Flocking agents with fixed anxiety thresholds

Or as my son called it, Boids with Anxiety.   We take the random movement with fixed threshold and substitute a flocking algorithm for the random movement. I used one from Uri Wilensky.

This model ends up with results that look a lot like the random movement model with fixed threshold. Same results on population density, anxiety threshold. The models go to all red or all green. The only difference is that at intermediate steps, the red groups and green groups stay more coherent, they stick together more than was the case with Random movement with variable threshold. That makes sense now that you have flocking to keep the individuals together to some extent.

Flocking agents with variable anxiety thresholds

Add the variable anxiety threshold to the flocking movement. There is one difference in dynamics. We've already seen that Random movement with variable threshold takes quite a bit longer to get to one color than Random movement with fixed threshold. Flocking with variable threshold takes even longer, if they ever get to one color at all. Most of the time the run goes on and on without reaching all one color.

A big point is that in both Random and Flocking with variable threshold, small groups don't turn to the opposite color so quickly when surrounded by the opposite color. Dissecting a few of these small groups, you can see that they have some individuals with the variable threshold relatively far from the middle. This in effect biases the group toward one color. Those individuals tend to influence their coherent little group to stay that same color, even when assaulted by the opposite color surrounding them.

General Discussion

So far, what makes a difference in these simulations? Population density and the value of the fixed anxiety threshold, for sure. Flocking makes the simulation look a bit more like the reality of social life. It keeps groups somewhat coherent, but doesn't really affect the dynamics of transmission of anxiety to be substantively different from those of just random movement.

However, what does affect those dynamics is inserting the random variation in anxiety threshold. We see that in how both the Random Movement and Flocking with variable anxiety threshold differ dramatically from those with fixed anxiety threshold.

The Flocking with variable threshold to my eye looks dynamic and lifelike. Dissecting the coherent groups, it appears that both the flocking and the individuals with thresholds away from the middle biases the group color. Flocking drives spatial coherence. The biased individuals support the one color of the group, as if anchoring the group's color.

The modeling has so far affected my thinking in a few ways.

1) I had not properly appreciated how quickly that connected groups of one color would form and then be so instrumental in sustaining a connected structure of one color. These connected groups are important because by remaining in one color, they become either breeding grounds for symptoms or islands free of symptoms.
2) The introduction of random resistance to anxiety for each agent had way more impact on model results than I expected. Afterwards, I read the point made by Miller

and Page about heterogeneity vs. homogeneity in models. That's the same idea. One of the next things to consider will be nonrandom ways to assign anxiety thresholds. In human beings, it appears that anxiety resistance or emotional maturity are not randomly assigned. Individuals at one level of maturity moderately tend to be connected to individuals with a similar level of maturity.

3) This modeling's agent updating function makes changes to nonanxious states equivalent to changes to anxious states. In these simulations you see the spread of nonanxious states and also connected groups of nonanxious agents. Does this jive with reality? Does nonanxiety or neutral calm spread in the same way that anxiety does? With the same dynamics? This is leading me to look more closely at nonanxious individuals and groups and trying to observe how they influence others or even whether they do.
4) This modeling has simplified my practical everyday thinking. Perhaps I should be more aware of the emotional field around me. We are more influenceable than we think. Hanging around stressed groups may be perilous to your health. One might consider not hanging around them so much or working to increase one's resistance to anxiety.

Other future possibilities Assign some degree of initial connection to agents, kinship or otherwise, and/or explore other ways of assigning placement on the field.

Explore other kinds of anxiety updating functions. It was suggested to me that I try some kind of smoothing filter that considered history of the agent so that the changes of state wouldn't be so immediate and abrupt. This is a good suggestion. As I said to the person, this is another phenomenon related to emotional maturity. Low maturity individuals are way more likely to make abrupt immediate changes of state in the presence of others' states. High maturity individuals are the ones who take longer to change states in the presence of others.