# Modeling Tipping Point Theory
# using Normative Multi-agent Systems

# (Extended Abstract)

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## ABSTRACT

Tipping points occur when a large number of group members radically modify their behaviors in response to small but significant events; after a critical point is reached, the behavior of the entire social system changes irrevocably. This paper proposes that normative multi-agent systems (NorMAS) can serve as excellent computational models for modeling and predicting tipping points. We illustrate how tipping point theory can be modeled with a standard social learning approach and replicate some of the key findings.

## Categories and Subject Descriptors

I.2.11 [**Distributed artificial intelligence**]: Multi-agent systems

## General Terms

Theory

## Keywords

norms; tipping point theory; networked agent societies

## 1. INTRODUCTION

Human societies are simultaneously frustratingly unchanging and yet susceptible to "epidemics" that sweep across the social fabric causing people to adopt previously rare practices. Tipping point theories attempt to explain the subtle triggers behind these social processes. In 2000, Malcolm Gladwell [1] wrote a popular science book summarizing three key factors which trigger tipping points: 1) scale-free networks (the Law of the Few); 2) effective messaging (the Stickiness Factor) and 3) environmental influences (the Power of Context). In normative studies, tipping points are usually denoted as the point of maximum return at which time the behavior has the highest level of acceptability from the population. In both standard multi-agent systems and cognitively-inspired models, existing social theories have been employed toward the construction of normative models. Various stages of the norm life-cycle including recognition,

adoption, compliance and emergence are often modeled on similar concepts in social sciences. This paper relates tipping point theory to the process of norm emergence in multi-agent systems; we propose that normative agent architectures can serve an excellent computational model for expressing many contagious social phenomena, including tipping points and information cascades.

For our experiments, we employ the classic scenario, rules of the road, that is frequently used to study normative behavior in multi-agent systems. In this scenario, there exists a population of agents that do not have any preference toward driving on the left or right side of a two-way road. This scenario represents a two-action stage game that models the situation where agents need to agree on one of several equally desirable alternatives; the norm is observed when the population consistently drives on the left (or right) side of the road. In this scenario agents receive a fixed value reward of +1 for driving on the same side of the road and a punishment value of -1 for driving on different sides of the road. Here we study the impact of Gladwell's three factors on norm emergence and demonstrate practical ways to apply this versatile theory.

## 2. MODEL

**Key Few Members** - First, we consider the effects of key members of an agent society on the rate of norm emergence. These key members are selected using standard heuristics for measuring influence within a network; we evaluate the performance of three centrality measures: degree, closeness, and betweenness. To model the characteristics of a real social network, we use an algorithm introduced in [2] to create a synthetic network which follows power law degree distribution and exhibits homophily, a greater number of link connections between similar nodes. The nodes of the graph represent the individuals (agents) in the simulation, who can be considered as car drivers. We use a weighted voting approach (also known as a structure based method) to determine an agent's decision with regard to its neighbors. The weight for each of an agent's neighbors is computed using a normalized value of that neighbor's centrality value.

The top 10 percent of the population of agents with the greatest centrality values are assumed to be the key elements of a society. At the beginning of our experiments, all of the agents follow a single norm. In our implementation, each agent has a utility value defined for each of four possible cases: Up-Left, Up-Right, Down-Left and Down-Right,
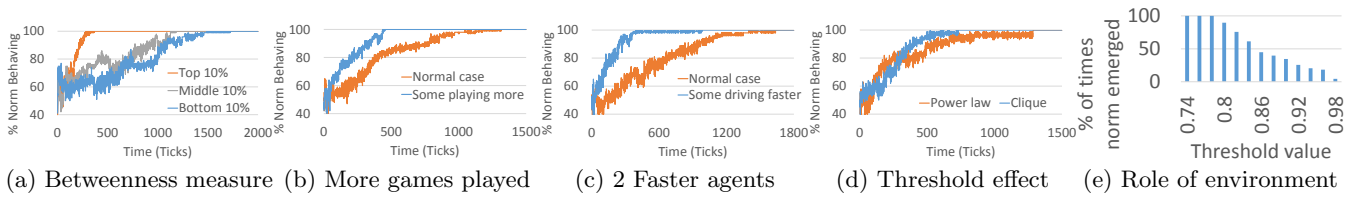
Figure 1: Norm emergence results on a population of 100 agents averaged over 20 runs

where Up and Down determine the section of road, and Left and Right determine the direction an agent drives. These values are updated while receiving payoffs. We compare the penetration of norm changing behaviors that emanate from key members of a society vs. other cases. At the beginning of the simulation, the agents are ranked based on their centrality values to determine the top, middle, and bottom agents. The utility value of these agents is kept fixed. Neighbors of these agents continue updating their behavior until a new norm emerges in the system. Our experiments showed betweenness had the fastest emergence time, and Figure 1a show the number of iterations for this case. According to the results, when the norm propagation starts from the top 10% of the population, the norm emerges much faster compared to the other cases. Moreover, the magnitude of difference between the top and middle 10% is more than the difference between the middle and bottom.

**Stickiness Factor** - According to the tipping point theory, the extent and rate of emerging social norms in a society is also related to the content of the message. An effective message needs to be interesting or "sticky" enough to remain in agents' minds. As Gladwell [1] points out, one characteristic that is common to sticky ideas is that they frequently return to a person's mind. We assume that the stickiness is represented by the number of games that an agent plays with another agent. Therefore a higher number of games will have the same effect as a stickier belief. We evaluated this idea in two different ways: 1) increasing the number of games that agents play and 2) having some faster-driving agents who are exposed to more cars. Figures 1b and 1c show these results. In both cases, the scenario contains a mixture of mutable agents plus a group of agents who have a fixed preference to drive on one side. In the first scenario, one group of agents plays two games each time it encounters another agent, and in the other, one group of agents moves faster. Both of these scenarios lead to the same effect: increasing the number of times that an agent is exposed to an idea. In both cases, when the stickiness factor is implemented, the entire system converges to a single norm faster.

**Power of Context** - The third element of the tipping point theory refers to the power of context. The idea is based on the theory of *broken windows*, which states that slight changes in the environment can result in tipping effects over the entire society. In order to apply this aspect of tipping point theory, first, we construct a network of agents using the same approach described previously. Then, we assign a threshold value for each agent. Similar to the probabilistic information cascade models, if the cumulative value of the perceived cascade is less than the threshold, nothing changes. If it's higher, the agent will change its current behavior, which in our scenario would result in driving on the other side of the road. Figure 1e shows the percentage of

times that a norm emerged in the system for a set of threshold values. Agents were selected randomly as a source of a small initial shock in the network, which results in negating the current payoff values for driving on each side of the road. The frequency of shocks is determined randomly. The system runs until it reaches some fixed iteration number (50,000), unless a different norm is observed. This experiment illustrates how minor shocks can shape a population fad, resulting in a population-level behavior change. The shocks (pulses) in this model can be viewed as any of the small changes that tipping point theory predicts can result in large changes in the whole society. According to the results presented in Figure 1e, norms emerge even when the thresholds are high.

There is a second aspect to the power of context, which refers to the number of people in groups. The Rule of 150 in Gladwell's book states that the size of groups is a subtle contextual factor that makes a big difference. This number is also referred as *Dunbar's number*, after the anthropologist who originally proposed the idea. In our model, we use a clique structure, in which each node is fully connected to the other nodes in the clique, to replicate this effect. We compare the emergence of driving norms in a network generated using the method described for implementing the role of key few members. It should be noted that having more edges does not result in faster convergence. Figure 1d shows the number of iterations that were required on average for the two cases to reach norm emergence. The driving norm emerged faster in case of the clique structure than in the power-law degree distribution network. This shows the potential benefit of such a structure in constructing agent systems, at least for ideal cases.

## 3. CONCLUSION

This paper presents a normative model encompassing the most important elements of tipping point theory, as applied to networked agent populations. We illustrate how three of the principal ideas, key few members, stickiness factor, and the role of environment, can affect the process of norm emergence.

## 4. ACKNOWLEDGMENTS

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