MULTIPLE ATTITUDE DYNAMICS IN LARGE POPULATIONS

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ABSTRACT

A multi-agent simulation for studying opinion dynamics in the context of two opinion dimensions is presented. The agent rules that describe changes in opinion are based on a theory about persuasion and distinguish between central and peripheral processing. Central processing is formalized as assimilating or contrasting the opinion of a contacted agent, depending on the initial (dis)agreement with the other agent. Peripheral processing is formalized as a source effect: If an agent agrees with another agent about one issue, it will also assimilate the position of this agent about another unrelated issue, regardless of the initial difference. Experiments show that the correlation between opinions on the two dimensions increases if agents engage in peripheral processing on one dimension. In addition, some experiments are performed with a meta-actor influencing the whole population.

Keywords: Social simulation, agent-based simulation, opinion dynamics, social judgment theory, elaboration likelihood model

INTRODUCTION

The recent rejection of the European Constitution by the voters in France and The Netherlands (2005) instigated a debate on how this could happen in countries having a basically pro-European-Union attitude amongst the population. We hypothesize that the complexity of the constitution, along with the limited information on its potential effects, caused many people not to process the arguments in defining their vote but instead to use the position of other people, and in particular that of major politicians, to determine their position. Especially the fact that the unpopular leaders of the government strongly campaigned in favor of the constitution may have resulted in a contrasting effect on this topic, despite the population's initial pro-European attitude.

Experimenting with the dynamics of attitude or opinion dynamics is not possible by using laboratory studies. Field data on the contrary are too complex to identify the causalities of observed dynamical processes. Multi-agent simulation provides a tool allowing experimentation with these dynamics, because large series of experiments can be performed systematically by varying assumptions on how people change their opinion and on conditions of the initial opinions of the population. This has resulted in an increasing body of research on opinion dynamics from using multi-agent simulation. Several researchers have worked on simulating how opinions, attitudes, or voting behavior in groups emerges from locally interacting people. Some work on binary opinions (e.g., Latane and Nowak 1997; Galam 1999), and some use

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continuous opinions, where influence depends on distance (using a threshold, e.g., Deffuant et al. 2001, 2002; Weisbuch et al. 2002; Hegselmann and Krause 2002).

These studies mainly used attraction of opinions as a mechanism to generate opinion dynamics, and hence did not use existing behavioral theory on attitude change to formalize agent rules. More recently, researchers have started to use behavioral theory in formalizing these rules. For example, they have used social judgment theory (SJT) as a formalization of both assimilation and rejection effects (Jager and Amblard 2005) and self-categorization theory in studying meta-contrast effects (Salzarulo 2004).

To study the dynamics involved in attitude change, we formalize relevant social psychological theories in the architecture of agents. The field of persuasion, social influence, and attitude change provided us with a rich theoretical perspective on how people change their attitudes and on the factors determining the degree and stability of these changes. In particular, SJT (Sherif and Hovland 1961) is relevant in understanding how people assimilate or contrast their opinion after being confronted with another position. The basic idea of this theory is that a change of a person's attitude depends on the position of the persuasive message that is being received. If the advocated position is close to the initial position of the receiver, it is assumed that this position falls within the *latitude of acceptance* of the receiver. As a result, the receiver is likely to shift in the direction of the advocated position *(assimilation)*. If the advocated position is distant to the initial position of the receiver, it is assumed that this position falls within the *latitude of rejectance* of the receiver. As a result, the receiver is likely to shift away from the advocated position *(contrast)*. If the advocated position falls outside the border of the latitude of acceptance but is not that distant that it crosses the border of the latitude of rejectance, it will fall within the *latitude of noncommitment*, and the receiver will not shift its initial position. Formalizing this SJT in an agent-based model allowed us to study the conditions under which the attitudes in populations tend to polarize, converge, or display pluriformity (Jager and Amblard 2005). One main result was that when the latitude of noncommitment gets small, which has been found to happen in crisis situations (O'Keefe 1990), our model produces polarization effects.

However, both the experimentally based laboratory studies and the social simulations addressed processes where only a single attitude is taken into consideration. Yet the example of the vote on the constitution indicates that often more than one attitude is taken into consideration. Many people reported to have voted against this constitution not because of their negative attitude toward this constitution but because of their negative attitude toward the political leaders advocating a positive vote.[1] In this paper, we study to what extent processes such as congruity affect attitude dynamics in large populations. In the work that we present in this paper, we focus on (1) two attitude dimensions rather than one, (2) cognitive effort in processing information, and (3) possible effects of mass-media performances of popular versus unpopular leaders.

People may spend more or less cognitive effort in elaborating on the attitude position of another person. This is captured in the *elaboration likelihood model (*ELM; Petty and Cacioppo 1986), which discerns a *central* and a *peripheral route* to attitude change. The central route pertains to the elaboration of pure arguments in a persuasive message and/or new information. Here people are motivated and capable of processing the arguments of the message,

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[1] Actually, also a lot of people reported to have voted in favor of the constitution because they disliked the political position of politicians advocating to vote against the constitution.

whereas peripheral processing is more likely when people's motivation to elaborate is low and/or their cognitive processing ability is limited (i.e., complex issues). The peripheral route is concerned with the elaboration of form aspects or cues of a message, such as the number of arguments and the credibility and attractiveness of the source. The attractiveness of the source is related to similarity of attitudes. Generally, people like to have opinions similar to those of people with whom they interact (Festinger 1954). This implies that when engaging in peripheral processing, people may compare on one attitude dimension how similar they are, and depending on that observed (dis)similarity, either accept or reject the information of the other attitude dimension.

In the following text, we outline the formalization of this theory in rules that apply to the agents we use.

THE MODEL

For the formalization of the SJT, which refers to central processing, we follow the model as used by Jager and Amblard (2005). This formalization implies that we have a population with N individuals. Each individual i has an opinion (an attitude) x_i, a threshold determining the latitude of acceptance u_i, and a threshold determining the latitude of rejection t_i, with $t_i > u_i$. Varying the values of t_i and u_i allows for modeling agents having different attitude structures. For example, an agent having a high ego-involvement can be formalized as an agent where t_i is slightly larger or equal to u_i: The agents are scheduled to communicate on a random basis by scheduling random pairs for each time-step of the simulation. During the interaction between individual i and individual j, the following rules are applied:

If $|x_i - x_j| < u_i$, then $dx_i = \mu.(x_j - x_i)$.

If $|x_i - x_j| > t_i$, then $dx_i = \mu.(x_i - x_j)$.

where the parameter μ controls for the strength of influence. The same rules are applied for the update of the opinion of the individual j.

For the formalization of peripheral processing, we formalize two attitude dimensions that agents discuss. After encountering another agent, the attitudinal shift on one dimension will affect the shift in the other dimension, thus indicating peripheral source effects. A assimilation or contrast effect on the first attitude dimension will also translate in a similar assimilation or contrast effect in the second dimension. Here agents select attitude A for the interaction process, and depending on the outcome (assimilation, noncommitment, or contrast), they will also apply this outcome to dimension B. The rule describing peripheral processing is:

If $|xA_i - xA_j| < u_i$, then $dAx_i = \mu.(xA_j - xA_i)$ and $dBx_i = \mu.(xB_j - xB_i)$.

If $|xA_i - xA_j| > u_i$, then $dAx_i = \mu.(xA_j - xA_i)$ and $dBx_i = \mu.(xB_i - xB_j)$.

RESULTS

In experimenting with the model, we use a research design that uses three basic experimental conditions. In experiment 1, we replicate the experiments of Jager and Amblard (2005), only here we formalize two attitude dimensions instead of one. Three conditions are tested, which lead in the original single dimension experiment to polarization, convergence, and pluriformity. In experiment 2, we introduce peripheral processing on attitude dimension B. The same three conditions are run. Finally, in experiment 3, we explore how a meta-actor that is capable of addressing all agents simultaneously affects the attitude dynamics. Also here we explore these effects for the three conditions, and we explore the effects of extreme versus average positions of the meta-actor on the two attitude dimensions.

Experiment 1: Central Processing on Two Dimensions

In the first experiment, agents engage exclusively in central processing on both dimensions according to the principles of SJT. Sixteen hundred (1,600) agents are positioned on regular lattice and randomly contact one of their four neighbors, either south, east, north, or west (Von Neumann neighborhood). The contact implies a comparison and resulting shift first on attitude dimension A, and subsequently on dimension B.

If $|xA_i - xA_j| < u_i$, then $dxA_i = \mu.(xA_j - xA_i)$.

If $|xA_i - xA_j| > t_i$, then $dxA_i = \mu.(xA_j - xA_j)$.

If $|xB_i - xB_j| < u_i$, then $dxB_i = \mu.(xB_j - xB_i)$.

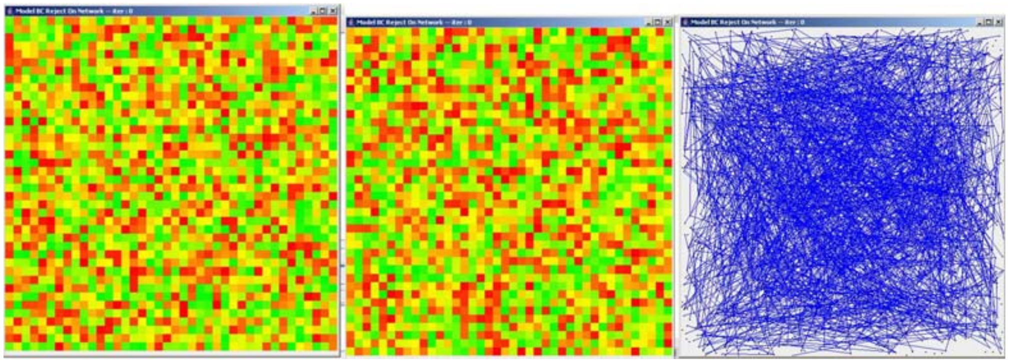
If $|xB_i - xB_j| > t_i$, then $dxB_i = \mu.(xB_j - xB_j)$.

Conditions for Experiment 1

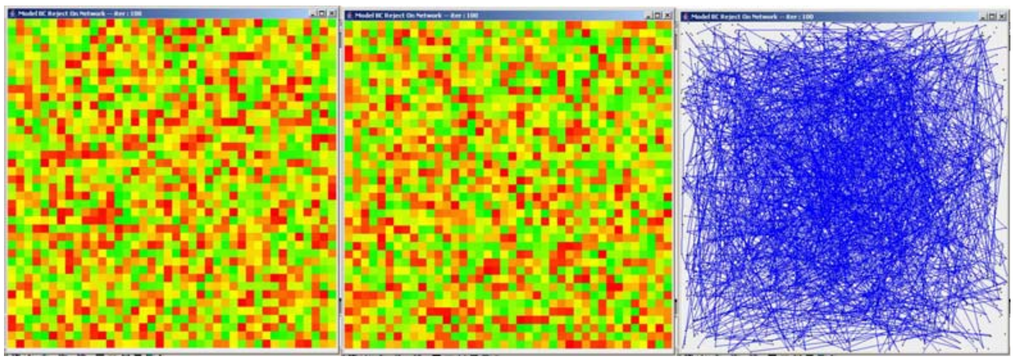
In this experiment, we create a condition where the latitude of acceptance is high and the noncommitment is high, by setting U at 1.0 and T at 1.5. In the single attitude condition (Jager and Amblard 2005), this condition stimulated convergence to a single attitude position.

Results of Experiment 1

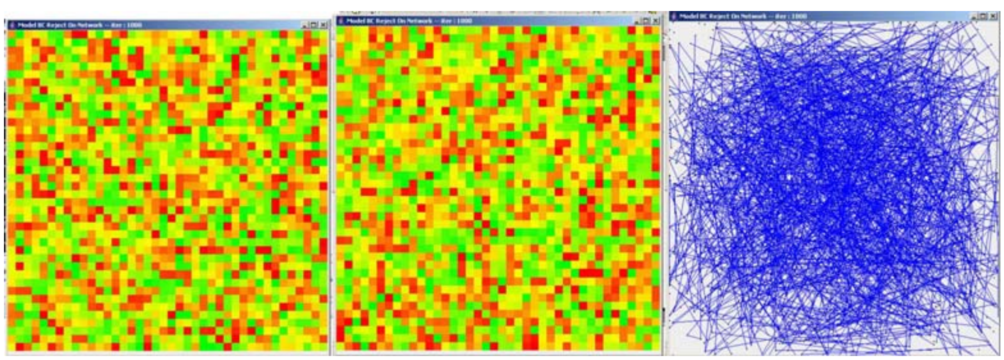
Figure 1 presents the developments on both attitudes for different time-steps of the simulation. In every time-step, a single agent is randomly selected. This agent randomly interacts with one of its four neighbors. Hence, in 1,600 time-steps, each agent on average had two interaction contacts, one because it was selected to engage in an interaction, and one because it was selected by another agent. On each grid, the color figures the opinion of the agent between –1 (red) and +1 (green) coding for opinions near 0. The right-hand figure positions agents on the basis of their attitude position on A (horizontal axis) and on B (vertical axis), thus indicating the relation between positions on A and B. The blue lines here indicate the social network (i.e., the links between the agents).



Time-step 0 Attitude A Attitude B relation A and B

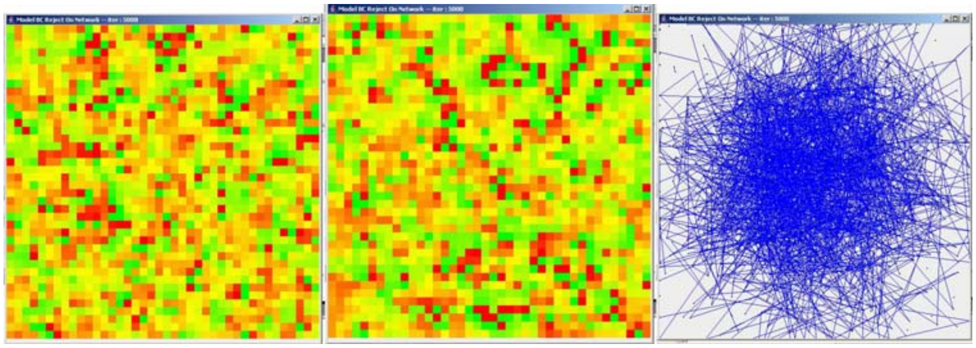


Time-step 100 Attitude A Attitude B relation A and B

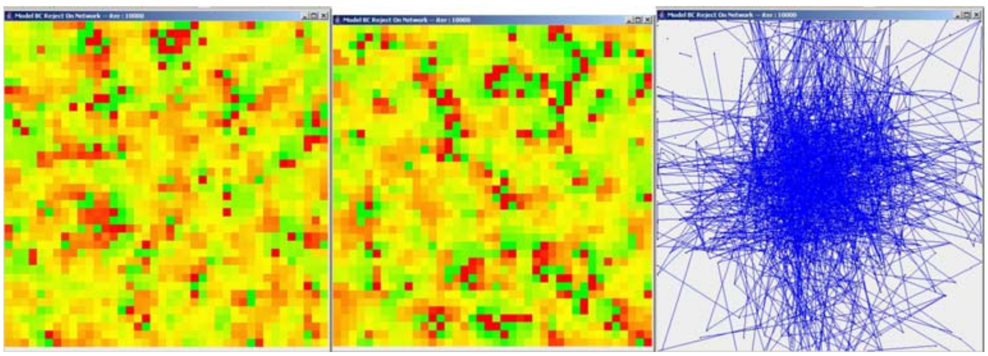


Time-step 1,000 Attitude A Attitude B relation A and B

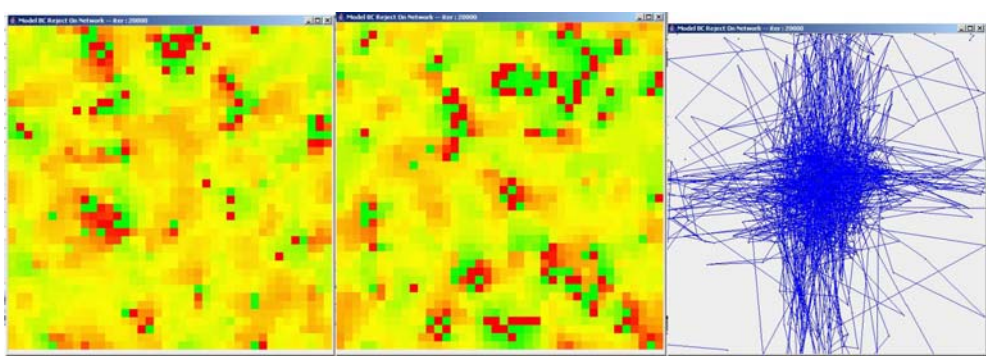
FIGURE 1 Attitude position on A and B over time



Time-step 5,000 Attitude A Attitude B relation A and B

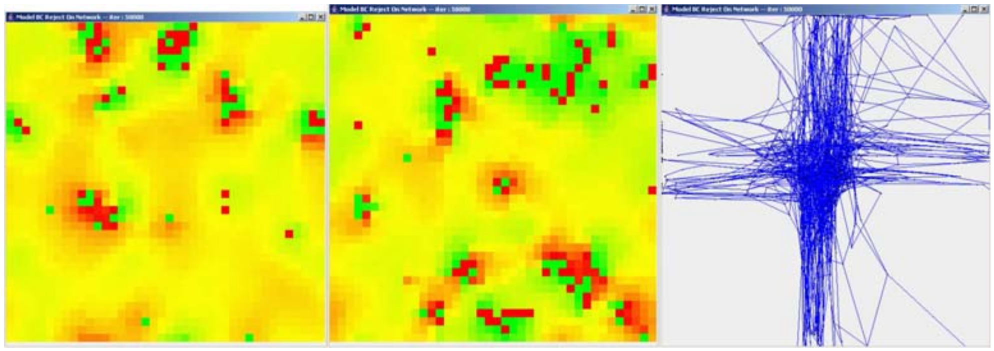


Time-step 10,000 Attitude A Attitude B relation A and B

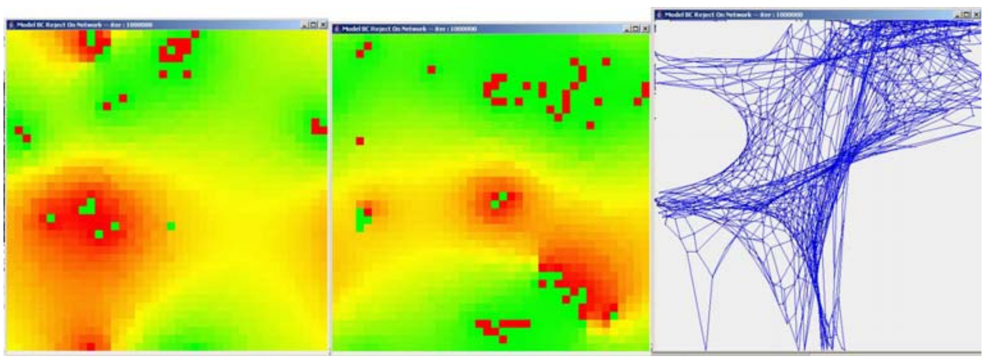


Time-step 20,000 Attitude A Attitude B relation A and B

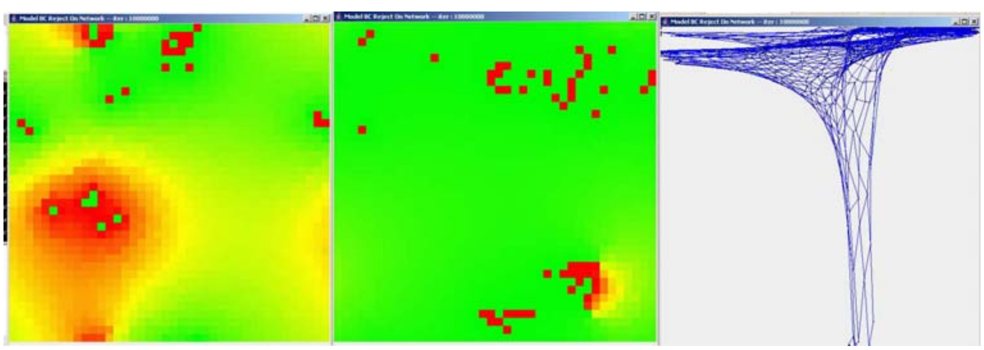
FIGURE 1 Cont.



Time-step 50,000 Attitude A Attitude B relation A and B



Time-step 1,000,000 Attitude A Attitude B relation A and B



Time-step 10,000,000 Attitude A Attitude B relation A and B

FIGURE 1 Cont.

What can be observed in this experiment is that after a large number of time-steps, attitudes appear to converge on both attitude dimensions. There are still a minority of agents having an extreme position. However, an agent having an extreme position on one dimension is most likely to have a mid position on the other dimension, resulting in the emergence of the cross-like figure in the relational graph. One has to be aware that this cross-like figure is not a systematic outcome of this condition. Sometime, the population converges quickly toward an extreme on the first attitude A, and then the second dimension B stays quite uniformly distributed between –1 and +1. Instead of a cross-like figure, convergence to an extreme on attitude A results in a vertical line either on the left (A = –1) or the right (A = +1) of the figure. Looking at Figure 1, we observe that whereas at *t* = 50,000, it appears that the attitude dimensions tend to grow toward a convergence, the number of extremists is still large enough to generate large attitude shifts, as the results of *t* = 1,000,000 and 10,000,000 indicate. Here we observe that despite the initial tendency toward convergence, a polarization on dimension B emerges, with a large majority adhering to the green position. Also it can be observed that in the most extreme attitude areas (red or green), small numbers of dissidents show up. Here a sharp polarization effect emerges on the very local level.

In addition, the results do not indicate a string correlation between the attitude position on A and B. To get a better view of the relation between A and B, we calculated the correlation between A and B over time for 10 simulation experiments (see Figure 2).

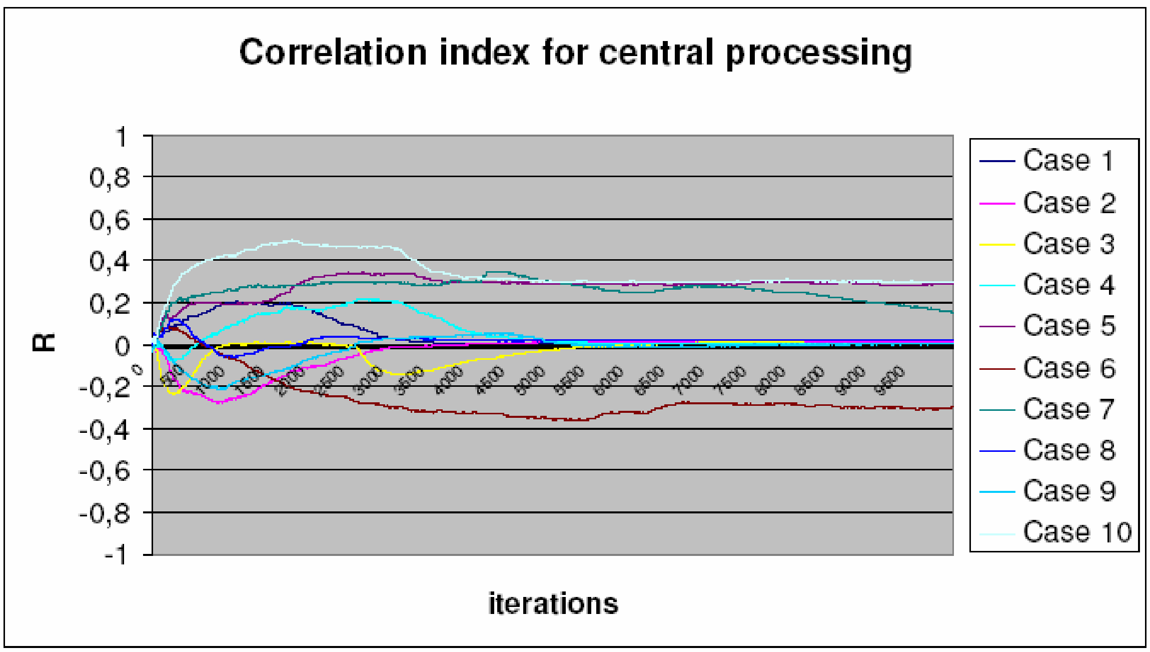


FIGURE 2 Correlation between A and B over time for 10 simulation runs

Experiment 2: Central and Peripheral Processing

In the second experiment, we implement central processing on dimension A according to the SJT, and peripheral processing on dimension B. Here we select at random existing relationships on the social network, and we let the agents interact on dimensions A and B. They apply the central processing rule for attitude A. For attitude B, they apply the peripheral rule as follows:

If $|xA_i - xA_j| < u_i$, then $dAx_i = \mu.(xA_j - xA_i)$ and $dBx_i = \mu.(xB_j - xB_i)$.

If $|xA_i - xA_j| > t_i$, then $dAx_i = \mu.(xA_i - xA_j)$ and $dBx_i = \mu.(xB_i - xB_j)$.

Conditions for Experiment 2

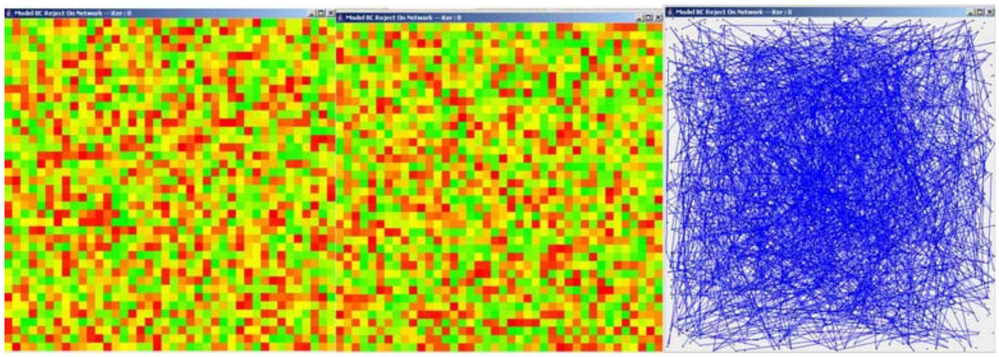
Experiment 2 replicates experiment 1 by setting the latitude of acceptance and the noncommitment high (U at 1.0 and T at 1.5).

Results of Experiment 2

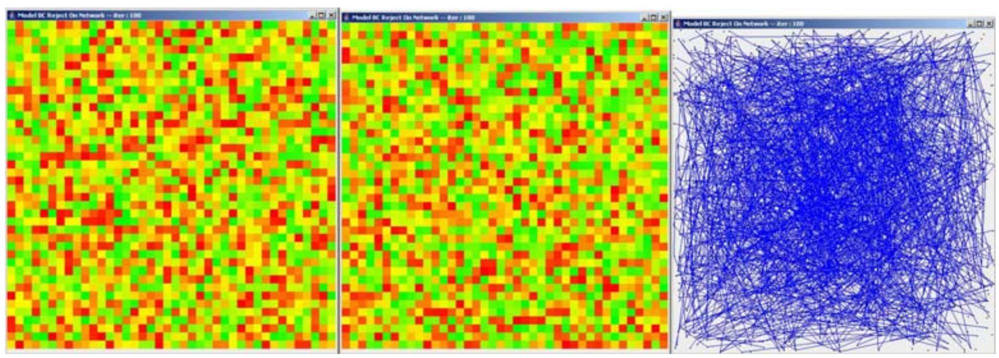
Figure 3 presents the developments on both attitudes for different time-steps of the simulation. The figures again represent the position on attitude dimension A, attitude dimension B, and the relation between positions on A and B, respectively.

This experiment shows that when agents engage in peripheral processing on dimension B, the attitude positions on A and B are becoming related. Whereas most agents tend to converge toward a mid position, we observe especially during time steps 5,000 to 20,000 that a proportion of agents having an extreme position on attitude dimension A also develop an extreme position on dimension B. This is the result of the peripheral processing on B, where contrast and assimilation effects on A translate to the same effects on B. Initially there appears to be no strong correlation, as having an extreme positive position on A may coincide with a extreme positive or negative position on B, as indicated by the X-shaped relation graph. However, developments in later time-steps show that a virtually perfect (in this case negative) correlation between the attitude positions emerges. This can be seen in the color distribution on dimensions A and B, where the B figure is almost a perfect negative of the A figure (red is green and vice versa). Whereas here we observe that a positive position on A is coupled with a negative position on B, for other simulation runs, we may find an equally strong positive correlation. Therefore, we conducted 10 experiments and recorded the correlation over time (Figure 4).

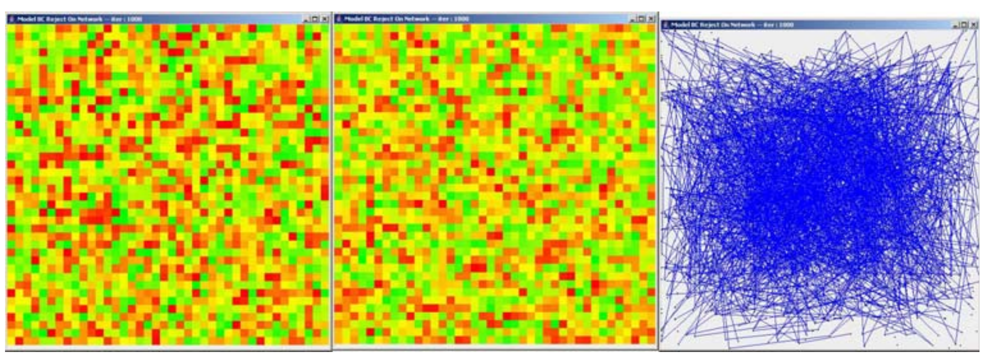
Figure 4 indeed shows that the correlations between A and B are much more prominent than in the condition of only central processing. Moreover, it can also be observed that this correlation may be positive or negative. It can also be observed that the correlations are not stable over time, indicating that attitude dynamics are continuous. In Figure 3, this can be seen at t = 10,000,000, where a number of agents have an extreme negative position on both A and B (left bottom corner of the relation graph), thus indicating a positive correlation between both dimensions for these agents, which originally was negative. This is being explained by the



Time-step 0 Attitude A Attitude B relation A and B

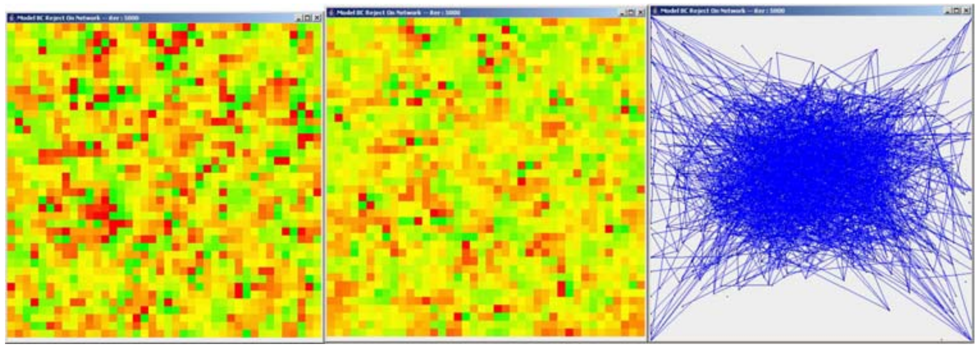


Time-step 100 Attitude A Attitude B relation A and B

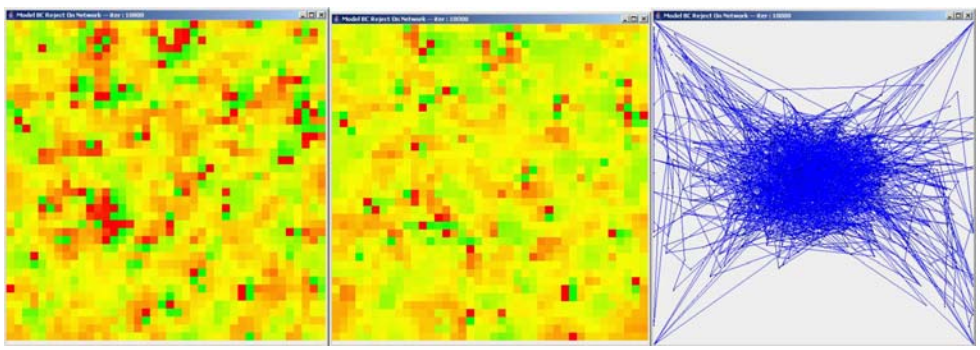


Time-step 1000 Attitude A Attitude B relation A and B

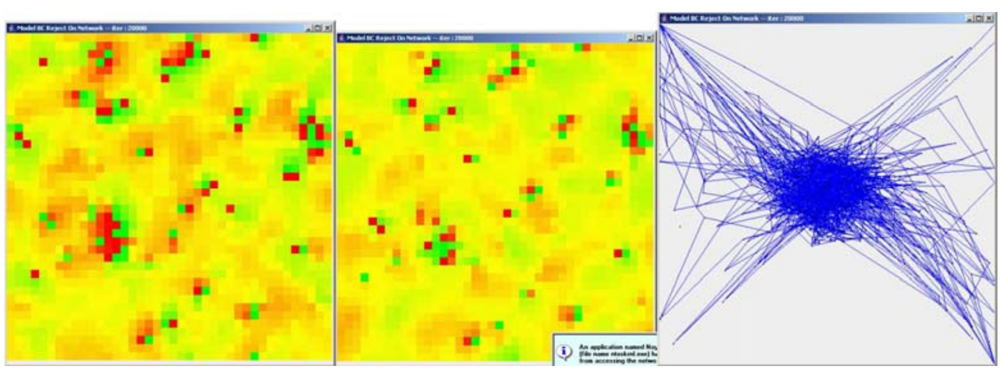
FIGURE 3 Attitude position on A and B over time



Time-step 5,000 Attitude A Attitude B relation A and B

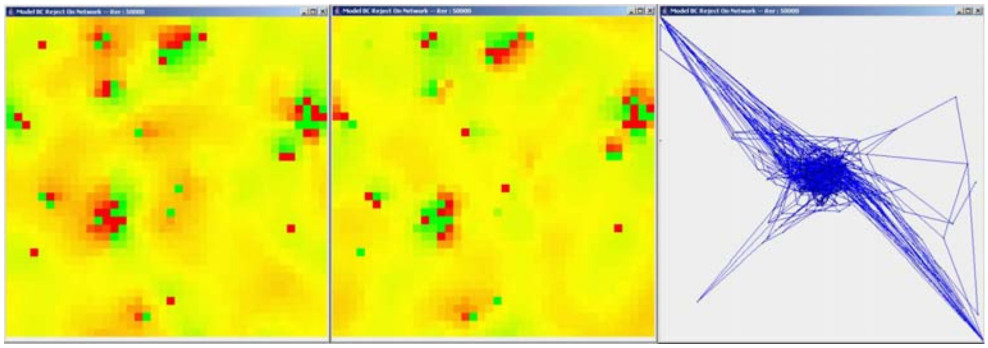


Time-step 10,000 Attitude A Attitude B relation A and B

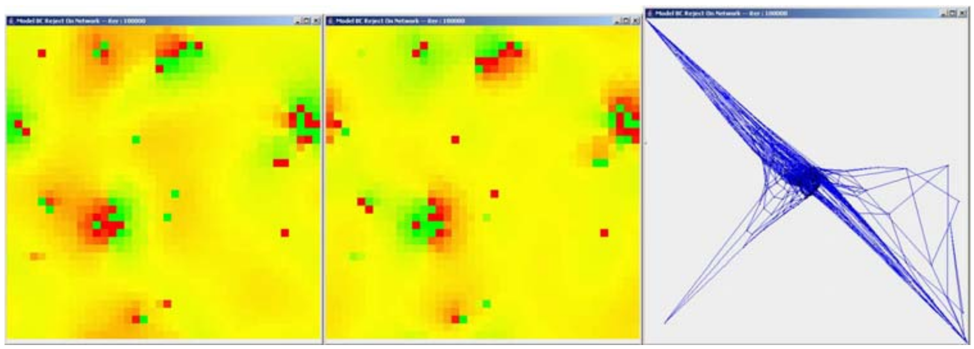


Time-step 20,000 Attitude A Attitude B relation A and B

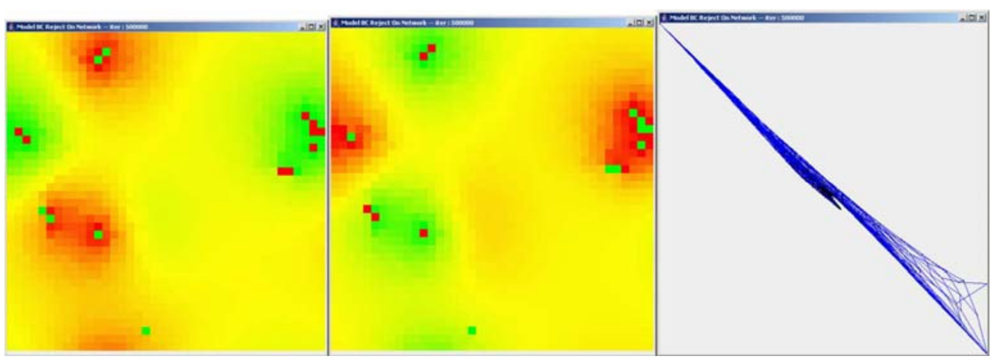
FIGURE 3 Cont.



Time-step 50,000 Attitude A Attitude B relation A and B

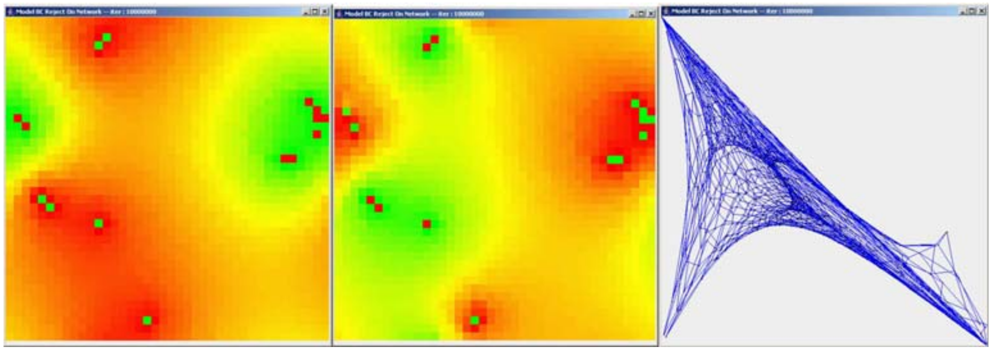


Time-step 100,000 Attitude A Attitude B relation A and B



Time-step 500,000 Attitude A Attitude B relation A and B

FIGURE 3 Cont.



Time-step 10,000,000 Attitude A Attitude B relation A and B

FIGURE 3 Cont.

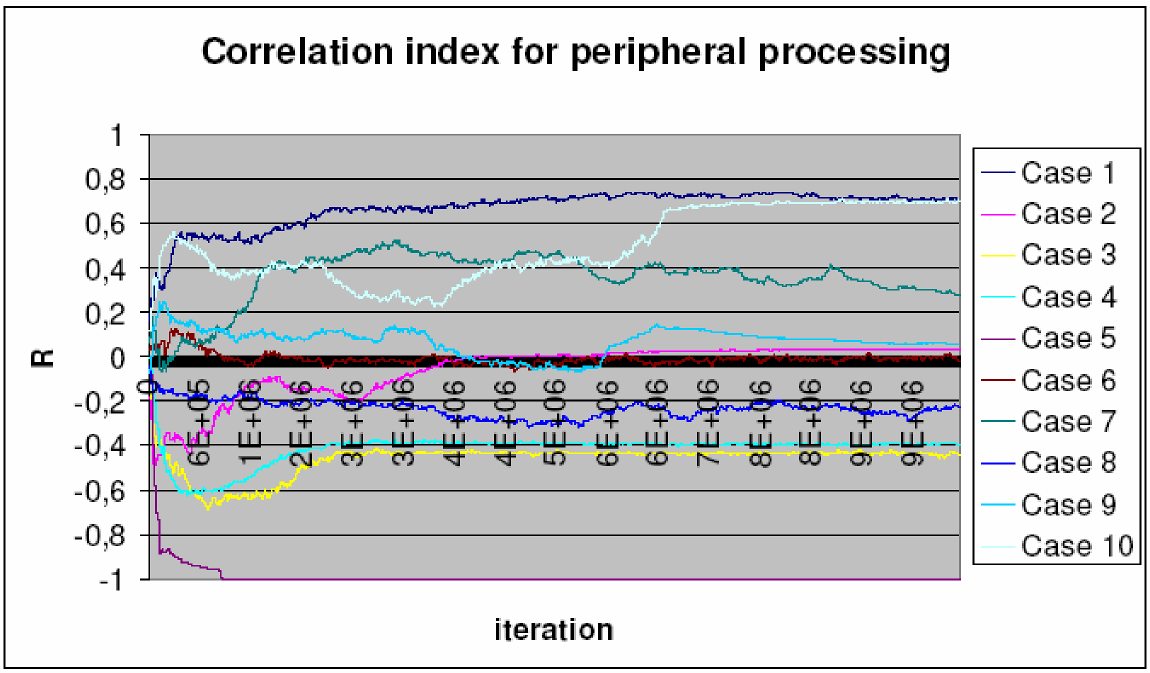


FIGURE 4 Correlation between A and B over time for 10 simulation runs

contrast effect, as elicited by the green position on dimension A of the single (green) agent located at the center bottom. It can be observed that agents in the neighborhood of this agent respond with reactance — in this case turning to red. Because this reactance effect translated to dimension B according to the peripheral processing, we also observe this reactance effect on dimension B, where the neighboring agents also turn to red. These results indicate that the dynamics on the second attitude are quite unstable, as singularities (like the green dot) tend to get amplified depending on the dynamics on the first attitude. In other words, the dynamics on the first attitude control the dynamics on the second one, but in a different context. This may lead to situations where in one region, the correlation between A and B is positive, whereas in another region, this correlation is negative. Agents that are located in a transitional zone between these two contrasting situations are thus experiencing instability concerning the direction of the peripheral processing on attitude B, and thus may move hence and forth on this dimension.

Experiment 3: Influence of a Meta-actor

In the previous experiments, the agents only interacted with their direct neighbors. However, often politicians or other spokesmen have a large audience they address on a frequent basis. Hence, before elections or votes, people not only discuss issues with their local peers but are also influenced by what we call "meta-actors." In the model, we formalize a meta-actor as an agent having a fixed position; hence, it is not susceptible to influences of the opinion of others. In selecting an interaction partner, each agent randomly contacts either one of the four neighbors or the meta-actor. Hence the meta-actor has a chance of 20% of being contacted every time-step. In the experiments, the agents process centrally on attitude A, and peripherally on attitude B, thus replicating the conditions of experiment 2.

Conditions for Experiment 3

For the meta-actor, we formalize an extreme position (−1, or red) on dimension A (central processing) and a neutral position (0 or yellow) on dimension B (peripheral processing). We use different settings for the agents. In experiment 3A, the population is rather accepting by setting U at 1.5 and T at 1.7. In experiment 3B, the population is less accepting by setting U at 1.0 and T at 1.2. Furthermore, the population is set at 10,000 agents. Concerning the interaction structure, we connect the meta-actor to all agents in the population. Each individual agent is now connected with five agents: North, South, East, West, and Meta-Actor.

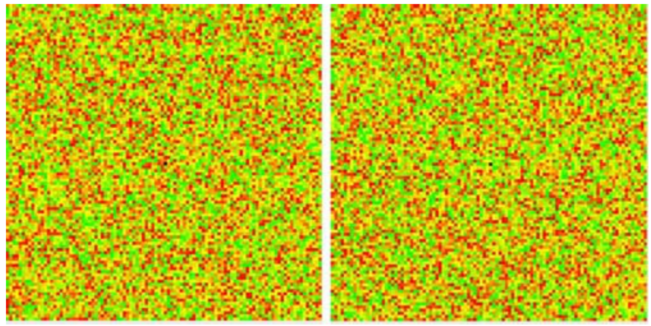
Results of Experiment 3a, An Accepting Population

Figure 5 presents the developments on both attitudes for different time-steps of the simulation. The figures represent the position on attitude dimension A (left) and attitude dimension B (right). The black dot in the middle represents the meta-actor.

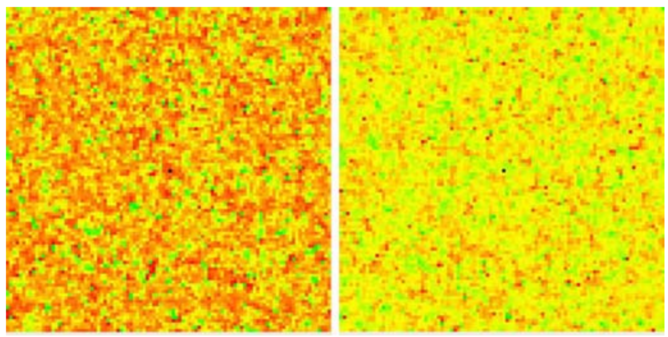
These results show that under conditions of an acceptable population, the vast majority of the population accepts the attitude position of the meta-actor. Only a few agents contrast with the meta-actor on attitude A (the green dots), and because their neighbors contrast themselves with these particular agents on dimension A, they also contrast on dimension B, resulting in the more red position of the neighbors on dimension B.

Results of Experiment 3b, A Less-accepting Population

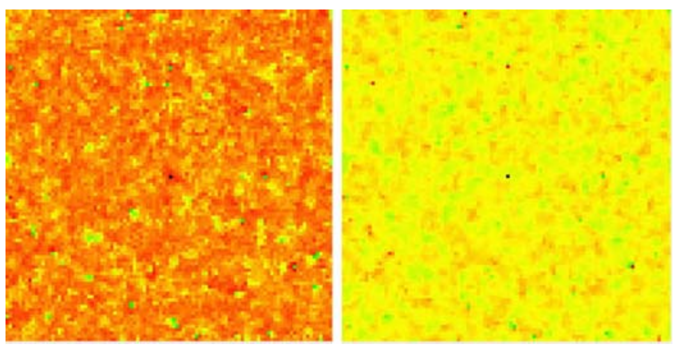
Figure 6 presents the developments on both attitudes for different time-steps of the simulation. The population is less accepting by setting U at 1.0 and T at 1.2. The figures represent the position on attitude dimension A (left) and attitude dimension B (right). The black dot in the middle represents the meta-actor.



Time-step 0 Attitude A Attitude B

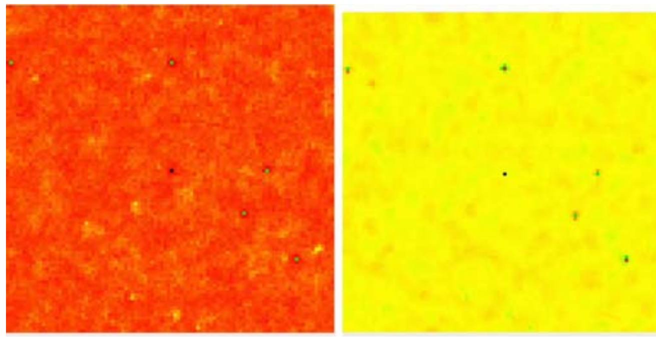


Time-step 50,000 Attitude A Attitude B

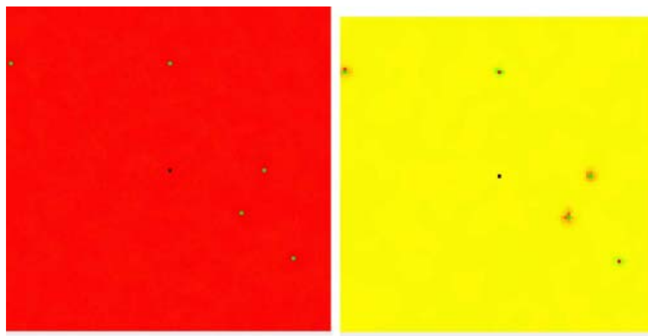


Time-step 100,000 Attitude A Attitude B

FIGURE 5 Experiment 3a developments on both attitudes for different time-steps



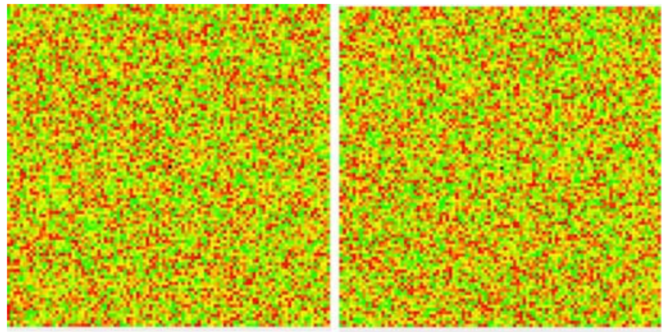
Time-step 200,000 Attitude A Attitude B



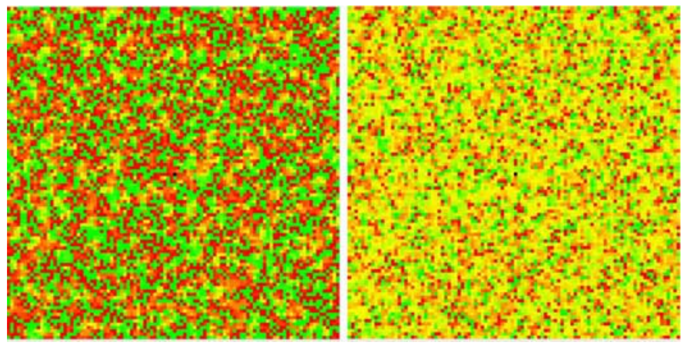
Time-step 500,000 Attitude A Attitude B

FIGURE 5 Cont.

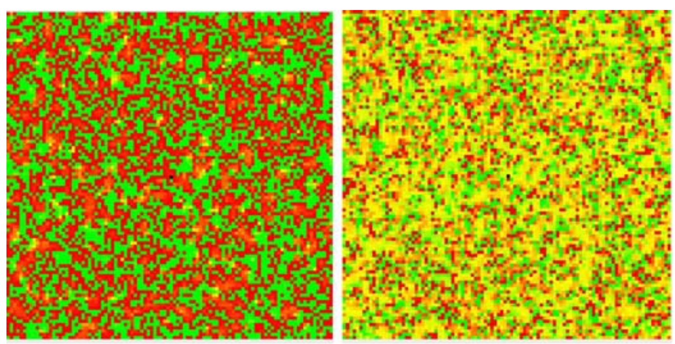
It can be observed that when the attitudes on dimension A polarize, agents either become red or green. Apparently, the reds are having a slight majority because of the systematic influence of the meta-actor. Concerning dimension B, we see heterogeneity. This is due to the fact that when agents contact the meta-actor and assimilate his position, they also assimilate the meta-actor's position on B. Close observation indeed reveals that the agents contrasting with the meta-actor on A (the green ones) also have an extreme position on attitude B, whereas for many actors, being red on A holds that they are yellow on B, showing the systematic effect of the meta-actor. A particular case concerns those agents having a red position on both A and B. Interacting on dimension A with a green agent results in a contrast effect on both A and B, thus also stimulating a red position on B. However, interacting with the meta-actor results in an assimilation effect, which draws them to the yellow position on attitude B. The dynamics are then stable on both attitudes for the opponents of A (the greens) but rather unstable for the followers of the meta-actor on A (the reds), resulting in alternating positions between red and yellow on attitude B. Hence the meta-actor succeeds only in drawing people to his position on B for the agents that agree with him on A.



Time-step 0 Attitude A Attitude B

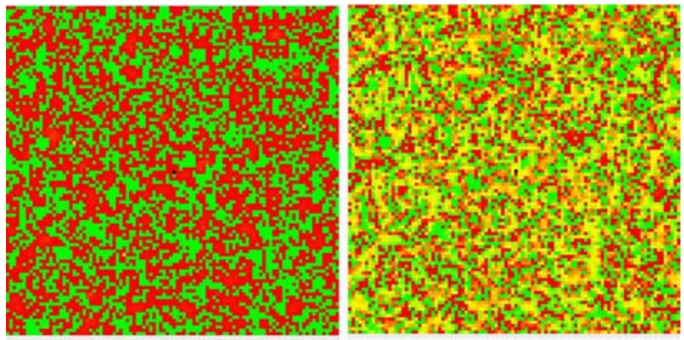


Time-step 50,000 Attitude A Attitude B

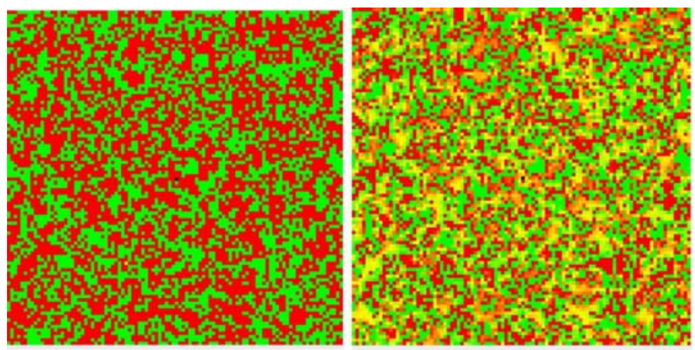


Time-step 100,000 Attitude A Attitude B

FIGURE 6 Experiment 3b developments on both attitudes for different time-steps



Time-step 200,000 Attitude A Attitude B



Time-step 500,000 Attitude A Attitude B

FIGURE 6 Cont.

GENERAL DISCUSSION

Although an increasing number of scientists study attitude or opinion dynamics by using multi-agent models, up until now, there has hardly been any attention on multiple attitude dynamics. Both in experimental laboratory settings and in simulation studies, researchers have focused on single attitudes/opinions. Yet observations from the field indicate that many people use a position on one attitude as a determinant for selecting a position on another, often unrelated, dimension. These effects may pertain to simple consumer preferences, where people may have a tendency to have the same preference for a variety of unrelated consumer goods, thus generating subcultures where people have about the same preferences on basically unrelated issues. Especially when people have to select a position on an issue that is complex and/or less personally important, they may engage in simple processing, taking the behavior of their peers to select a position. In the experiments as presented in this paper, it can be observed that such decision strategies — here formalized as peripheral processing — have major impacts on the attitude dynamics. Basically, we observe that peripheral processing is often responsible for the emergence of a correlation between originally unrelated issues. Hence the assimilation or rejectance of other people's attitudes on the basis of a perceived (dis)agreement on another, more important issue causes attitudes on different issues to become correlated. Because people are interacting with other people on a multitude of issues, it is expected that this relatedness of attitude dynamics may be important in understanding why certain clusters of people having the same opinion on various issues emerge, and how these clusters change over time (as formalized in the culture dynamics model of Axelrod, with discrete tags on each dimension).

In addition, the first experiments with the meta-actor demonstrated that under conditions of high acceptability of the population for deviant opinions, the meta-actor was capable of attracting virtually all agents in the populations to its own position on both attitude dimensions. The situation changed, however, when the population was less accepting. Here we observed that a polarization emerged on the dimension on which agents processed centrally, whereas heterogeneity emerged on the dimension where agents processed peripherally. These results differ from situations where no meta-actor was available, showing that such an actor may have a considerable impact on the attitude/opinion dynamics that emerge.

These first experiments reveal the importance of including several attitude/opinions simultaneously in understanding these dynamics and the effect a meta-actor has on these dynamics. Many experiments have to be conducted to get a better understanding of these multi-attitude dynamics and the critical factors that determine clustering effects. Some issues that remain to be studied are (1) the differences and heterogeneity between agents with regard to their tendency to assimilate, contrast, and firmness of opinions; (2) the effects of the connectivity between agents (social network effects); and (3) strategies that can be employed by meta-actors in affecting these dynamics.

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