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Collective opinion and attitude dynamics dependency on informational and normative social influences

Chung-Yuan Huang[1], **Pen-Jung Tzou**[2] **and Chuen-Tsai Sun**[2]

Abstract

In a continuous opinion dynamics model using a bounded confidence assumption, individuals can only influence each other's opinions when those opinions are sufficiently close. However, we often observe real-world cases in which opinions are very different, yet individuals feel compelled to change their ideas to conform with their peers or superiors (or in rare cases, are willing to change them voluntarily). In other words, individuals tend to consider the practical value of conformity and worry about rejection if they do not adopt the opinions of the majority. To explore the influences of private acceptance of informational social influences and public compliance with normative social influences on collective opinion and attitude dynamics, we have created a model in which attitude and opinion respectively represent an agent's private and expressed thoughts. Results from a series of simulation experiments indicate that our simplified model is as valid as previous opinion dynamics models also based on the bounded confidence assumption, but with different dynamics and outcomes regarding group opinion and attitude. To demonstrate our proposed model's potential value and applications, we briefly discuss two issues of import to sociologists: *pluralistic ignorance formation and destruction* and *minority influence*.

Keywords

bounded confidence, opinion dynamics, pluralistic ignorance, private acceptance, public compliance

1. Introduction

Many agent-based opinion dynamics models are being proposed to determine how groups achieve consensus or how certain individuals or small groups can influence public opinion.[1–4] The creators of agent-based opinion dynamics models often use a number to represent an agent's opinion, and refer to sets of all possible opinion values as *opinion spaces*, taking the form of either a limited integer set[5–7] or a continuous real set between 0 and 1.[1,3,8,9] Recently developed opinion dynamics models generally use the second type of opinion space: these are referred to as *continuous opinion dynamics models*.[10–13]

The designers of continuous opinion dynamics models utilize the bounded confidence assumption when proposing opinion exchange processes. According to this simple assumption, agents only exchange opinions with other agents holding similar opinions. Opinion exchange only occurs when the difference in opinion value is smaller than the confidence bound (also referred to as *uncertainty*). Some researchers have recently used the bounded confidence assumption to extend well-known continuous opinion dynamics models to various applications involving opinion dynamics research (e.g. Hegselmann and Krause's[3] HK model and Deffuant and Weisbuch's DW model[1,8,9]).

[1]Department of Computer Science and Information Engineering and Research Center for Emerging Viral Infections, Chang Gung University, Taiwan.
[2]Department of Computer Science, National Chiao Tung University, Taiwan.

Corresponding author:
Chung-Yuan Huang, Department of Computer Science and Information Engineering and Research Center for Emerging Viral Infections, Chang Gung University, 259 Wen Hwa 1st Road, Taoyuan 333, Taiwan
Email: gscott@mail.cgu.edu.tw

Opinion exchange processes based on the bounded confidence assumption are considered one type of informational social influence. According to this assumption, individuals who are unsure of or unfamiliar with specific issues tend to adopt or be strongly influenced by others' similar opinions or common cultures.[14] However, as shown in Asch's[15,16] famous experiment, even if the answer to a certain question is very clear, if one-third of the test takers in a room observe their fellow test takers choosing the wrong answer, they will also choose the wrong answer regardless of whether or not they know it is wrong. Asch concluded that the test takers in his research were willing to choose wrong answers in order to maintain conformity, gain acceptance, and avoid rejection by other group members – an example of normative social influence.

Later support for Asch's normative social influence findings came in the form of Ajzen and Fishbein's[17] theory of reasoned action. They showed that both private attitudes and subjective norms must be taken into consideration when predicting an individual's behavior in terms of expressing opinions. They also observed that after taking into account the judgments of others surrounding them, individuals frequently express opinions and behaviors that differ (sometimes to a large extent) from what they would normally express – simply put, private attitudes do not necessarily equal expressed opinions or behaviors. According to Festinger's[18] cognitive dissonance theory, individuals whose private attitudes are inconsistent with their behaviors suffer from unpleasant psychological states and cognitive dissonance. To avoid these problems, humans often alter their attitudes to match the current direction of behaviors expressed by those surrounding them, and support behaviors that in other circumstances they would consider contradictory. Individuals rarely change their expressed behaviors to decrease cognitive dissonance, since changing one's behavior is equivalent to publicly acknowledging mistakes – a situation that for many is even less acceptable. When publicly reacting to normative social influences and stating opinions that are very different from their own private attitudes due to a lack of external justification (e.g. succumbing to public opinion or avoiding punishment), individuals may seek internal justification, change their private attitudes, and/or move in the direction of public opinion in order to narrow the cognitive distance between expressed behaviors and private attitudes, as well as to decrease cognitive dissonance and persuade themselves to believe in the opinions they utter.

The influences of collective beliefs on expressed opinions can be significant even when individuals do not change their private opinions.[19] According to the concept of *pluralistic ignorance* – said to occur when members of a group are affected by strong normative social influences[20,21] – those who disagree (or who are hesitant to agree) with mainstream views on specific issues may mistakenly perceive themselves as the only non-conformists in a group, and either choose or feel compelled to publicly proclaim allegiance to group opinions without knowing how many others also disagree with the mainstream view. In some cases the opinions of an entire group may change considerably if a single non-conformist expresses his or her actual opinion, perhaps leading to a complete rejection of the previously dominant opinion. However, in cases where the original mainstream opinion prevails despite disagreement on the part of one or a small number of individuals, then the traditional opinion dynamics model, based on the bounded confidence assumption, fails to explain the pluralistic ignorance phenomenon, since it would mean that non-conformists do not have to worry about their opinions clashing with others. In addition, such a scenario would decrease the explanatory power of the opinion dynamics model to explain why a group doubts or overturns its previous opinions in response to a minority view.

In this paper we will use the social psychology terms *attitude* and *opinion* to respectively represent an agent's private and expressed thoughts.[20,21] We define attitude as an individual's internal evaluation of events, which others cannot directly observe.[22] In contrast, opinion refers to an individual's expression of events in the form of external behaviors, such as utterances, emotions, and body language. Simply put, in order to explore the potential micro-level impacts of informational and normative social influences, a single *opinion* attribute within a traditional opinion dynamics model must be divided into *attitude* and *opinion* attributes to represent richer and more realistic collective opinion dynamics. We will use a series of simulation experiments to verify consistency between our proposed model and previous continuous opinion dynamics models based on the bounded confidence assumption, as well as to reconfirm that group opinions and attitudes have different macro-level dynamics and outcomes. After reviewing the basic properties of our simulation model and discussing sensitivity analyses of two micro-level factors, we will discuss two issues considered important by sociologists to demonstrate our proposed model's value and potential applications: *pluralistic ignorance formation and destruction* and *minority influence*.

2. Simulation model

Our proposal consists of an opinion dynamics model for exploring the influences of two micro-level factors on macro-level collective opinion dynamics and outcomes: the private acceptance of informational social influence and public compliance with normative social influence. Each agent in our simulation model has three major private attributes expressed as real numbers between 0 and 1: opinion (*op*), attitude (*att*), and uncertainty (u) (Table 1). As stated above, attitude and opinion respectively represent an agent's private views on a specific topic and its expressed opinion as shown through external behaviors. The closer the values of the two attributes to 1, the more positive the agent's opinion on a specific issue; the closer the uncertainty attribute to 1, the less definite the attitude toward a specific issue and the more likely the agent will be influenced by or completely adopt an outside opinion.

In this paper we will abide by a definition of public opinion that supports sufficient levels of homogeneity (i.e. the consolidation of public opinions into a limited number of opinion groups), meaning that normative social influence may be formed so as to strongly encourage some group members to follow the majority opinion. The more concentrated a group's opinions or the greater the number of members in a group, the more pressure an agent will feel to follow public opinion. We will describe how this *magnitude of public opinion* is calculated when we introduce the agent opinion update process. All experiment results discussed in this paper represent average values for 50 runs. Simulation system parameters are listed in Table 2. Our simulation model is available as a C language application at http://groups.google.com/group/cans_lab/files; for source code, please contact the authors.

Our model's underlying social network consists of a two-dimensional $N \times N$ cellular automaton with periodic boundary conditions. Each cell represents one agent, meaning that a cellular automaton consists of N^2 agents. During each time step, each agent executes an opinion update process to exchange opinions with its surrounding neighbors. A group opinion update is defined as the execution of all individual agents' opinion updates during a single time step. The process consists of nine steps (Figure 1).

Step 1. Measure each agent's eight surrounding neighbors and calculate an opinion group number g.
Step 2. If opinion group number $g \leq$ threshold G, go to Step 3. Otherwise, go to Step 4.
Step 3. If $agent.u > u\_threshold$, go to Step 6. Otherwise, go to Step 8.
Step 4. Assign the agent's opinion as the agent's attitude, sum the agent's opinion and all compatible opinion values from the agent's eight surrounding neighbors, calculate an average opinion value, and apply the average value to represent the agent's opinion and attitude.
Step 5. Go to Step 9.
Step 6. Assign the agent's opinion and attitude as the center of the opinion group having the most members (equivalent to the average member opinion value of the largest group).
Step 7. Go to Step 9.
Step 8. Based on each group's center (the equivalent of group or public opinion), locate the group opinion that is closest to the individual agent's opinion (Step 8a of Figure 1) and calculate public opinion magnitude based on three factors: number of group members, homogeneity of opinions within a group, and the difference between the agent's attitude and group centers

Table 1. Agent attributes

Attribute	Type	Range	Description
op	Real	[0, 1]	Agent's expressed opinion on a specific issue as shown by external behaviors.
att	Real	[0, 1]	Agent's private views on a specific issue.
u	Real	[0, 1]	Uncertainty. Default value = 0.6
red	Real	[0, 1]	Public compliance in opinion spectrum threshold. Default value = 0.6 (*RED*).
green	Real	[0, 1]	Private acceptance in opinion spectrum threshold.

Table 2. Simulation system parameters

Attribute	Type	Range	Description
G	Integer	≥ 0	Normative social influence threshold. Default value = 2.
u_threshold	Real	[0, 1]	Attitude-less agent threshold. Default value = 0.8.
N	Integer	> 0	Number of cells in cellular automata length and width. Default value = 24.

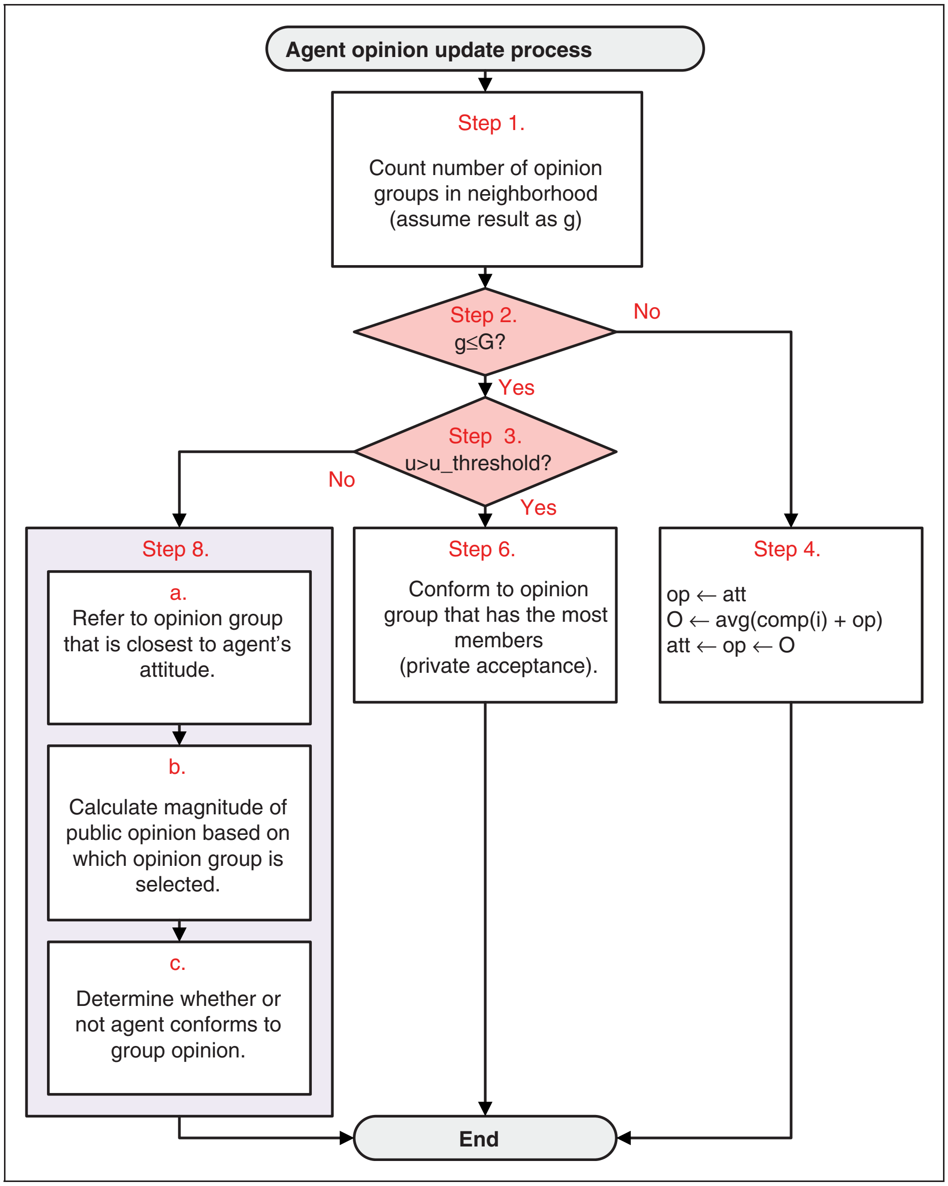

Figure 1. Agent's opinion update flowchart.

(Step 8b of Figure 1). Determine whether or not the agent follows the group opinion (Step 8c of Figure 1).

Step 9. End.

In Step 1 the agent determines the presence or absence of a normative social influence. We assumed that when the opinions of an agent's neighbors exceed the G threshold (Step 2), a group opinion has not yet been formed and the agent is not yet subject to peer pressure. A bounded confidence assumption is reasonable in such situations. The greater an agent's certainty on a specific issue, the less likely the agent will refer to its neighbors' opinions, and vice versa (Step 4).

When one or several opinion groups consisting of an agent's neighbors are formed ($\leq G$) (Step 3), agents who insist on retaining their own ideas risk rejection. Agents with very high degrees of uncertainty (i.e. $agent.u > u\_threshold$) are likely to follow the largest group's opinion (Step 6). When expressing opinions, agents with low degrees of uncertainly must consider their own preferences versus group norms, select a group opinion that is closest to their own, and express corresponding behaviors after calculating the strength of that group's opinion. Agents can disregard insufficiently strong opinions (Step 8).

In Step 1, individual agents use a K-means clustering algorithm[23] to partition their neighbors into K groups. This algorithm requires the assignment of a desired group number K prior to execution; for our experiments we assigned values of 1, 2, 3, 4, and 5, and then applied a square error function (Equation (1)) to evaluate the grouping result following algorithm execution. We interpreted smaller V values as indicating more appropriate grouping results, with the lowest V representing the most appropriate group number for any agent's surrounding neighbors:

$$V = \sum_{i=1}^{K} \sum_{agent_j \in group_i} \left\| agent_j.op - group_i.opinion\_center \right\|^2 \tag{1}$$

Three factors must be taken into consideration when executing Step 8b of Figure 1: (a) the number of individuals in an opinion group (the higher the number, the stronger the opinion) (Figure 2(a)); (b) group opinion homogeneity (greater consistency in group member opinions indicates more strongly held opinions) (Figure 2(b)); and (c) discrepancies between agent attitude and public opinion (more discrepancies indicate stronger public opinion) (Figure 2(c)). Calculating the individual strengths of these factors (expressed as real numbers between 0 and 1) followed by calculating their average value produces a magnitude of public opinion O (also a real number between 0 and 1). Pressure to conform to a group opinion increases as O approaches 1. After calculating public opinion magnitude, agents determine whether or not to comply based on their uncertainty, and decide whether or not they truly agree with public opinion.

We propose using a public opinion spectrum (Figure 3) to simulate mechanisms associated with cognitive dissonance[18] when executing Step 8c of Figure 1. The ranges of two thresholds, *green* and *red* ($green \leq red$), fall between 0 and 1. When the public opinion magnitude $O < green$, it falls into the *Case C* category (green section), meaning the magnitude is too weak for agents to follow groups in terms of either attitude or opinion. When the magnitude $green \leq O < red$, it falls into the *Case B* category (yellow section), indicating a medium strength of public opinion (i.e. agents appear to follow group opinions, but those opinions are not strong enough to provide ample external justification for public compliance). In these situations, agents' attitudes move toward group opinions, and agents move toward private acceptance of public opinion. When public opinion magnitude $O \geq red$, it falls into the *Case A* category (red section), indicating a high magnitude of public opinion and giving agents ample external justification to comply with their respective groups, even if they do not necessarily agree with those groups' opinions (i.e. public compliance).

Agent public opinion spectrums are determined by uncertainty u levels. As shown in Figure 3, green sections are longer for agents with smaller degrees of uncertainty (Equation (2)), meaning that the agents have more certainty on specific issues and require higher public opinion magnitudes to trigger changes in their opinions. Regarding the red section in Figure 3, even though we assume that each agent's *red* strength is a constant, we also acknowledge a lack of research findings in this area. Equation (3) is used to calculate the red threshold:

$$green = 1 - u \tag{2}$$

$$red = \begin{cases} RED, & \text{if } green < RED \\ green, & \text{otherwise} \end{cases} \tag{3}$$

3. Proposed model properties

There are two situations in which it is unnecessary to distinguish between *opinion* and *attitude* attributes or to compare opinion dynamics between our model and Hegselmann and Krause's[3] HK model by manipulating threshold G: when informational social influence is the only factor under consideration, and when an agent's opinion exchange process completely conforms to a bounded confidence assumption. According to our model, as long as threshold G is 0, normative social influence will not occur, since surrounding neighbors form at least one group. As shown in Figure 4, our simplified model's opinion dynamics are very consistent with those of the HK model. In both models, uncertainty is not assigned a fixed value, but gradually increases over simulation time steps ($u = t/100$). Also in both models, initial agent opinion values are evenly and randomly distributed between 0 and 1 when time step $t = 0$. As t increases, agent opinions gradually move toward the center and two extremes. However, when $t = 20$ or higher, agent opinions at the two extremes move toward the center as uncertainty u increases ($u \approx 0.2$). When $t = 40$, all agent opinions become concentrated toward the center of the opinion spectrum, thus forming a normal distribution of consistent opinions.

To explore the influences of the u uncertainty factor, we assigned threshold G a value of 2; when $G \leq 2$, the agent in question is affected by normative social influence. This is equivalent to the real-life

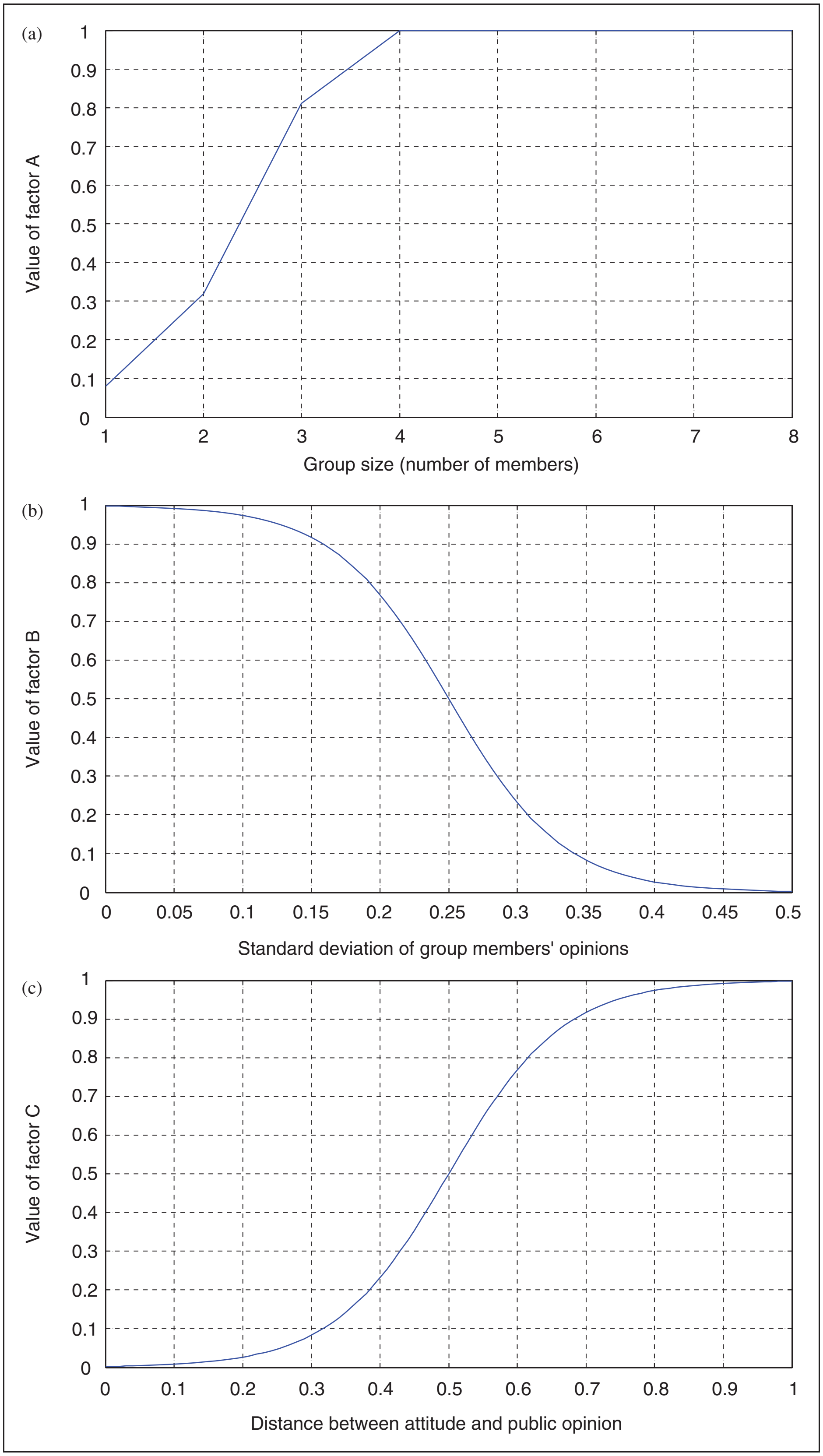

Figure 2. Functions for calculating the strengths of three factors: (a) number of members in an opinion group (adapted from Asch[15,16]); (b) homogeneity of internal group opinion; and (c) discrepancy between an agent's attitude and public opinion.

scenario of choosing between two opinion groups on a specific issue. In Equation (3), the default value *RED* for the *red* threshold of the opinion spectrum is 0.6 – that is, a public opinion value exceeding 0.6 gives an agent sufficient external justification to comply with that opinion (Table 2). To compare differences between *attitude* and *opinion*, the initial values for those micro-level attributes are considered equal (i.e. cognitively consistent). We observed three types of simulation dynamics based on three uncertainty conditions: low ($u \in [0, 0.4]$), medium ($u \in (0.4, 0.8]$), and high ($u \in (0.8, 1]$). Under the low uncertainty condition, the *red* and *green* thresholds are assigned the same $1 - u$ value (Equations (2) and (3)); the smaller the u, the longer the green section and the shorter the red section in the opinion spectrum. Since an agent's public compliance requires a strong public opinion magnitude, we assumed that the attitude and opinion dynamics produced by our proposed model would not produce large discrepancies at low uncertainty levels. As shown in Figure 5, we observed less than 10 (1.6%) instances of public compliance out of 576 ($N^2 = 24^2$) agent opinion update processes during each time step, and those we observed occurred when u was higher. In our model, this scarcity of public compliance results in zero gaps between opinion and attitude dynamics; as shown in Figure 6, very little discrepancy was found between the standard deviations of the two types of dynamics.

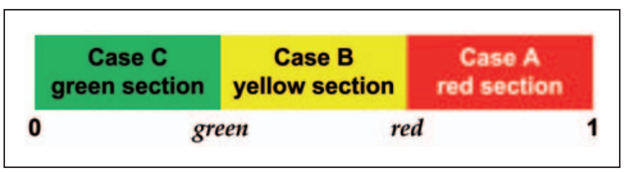

Figure 3. Opinion spectrum.

At a medium uncertainty level, the *green* threshold is assigned a value of $1 - u$ (Equation (2)) and the *red* threshold is assigned a *RED* default value (Equation (3)), meaning that each agent's opinion spectrum contains its own red, yellow, and green sections, with the yellow section lengthening and green section shortening as uncertainty u increases. In short, the higher the level of uncertainty, the more likely an agent will engage in private acceptance, but when public opinion pressure exceeds the *red* threshold, the agent will always choose public compliance. In cases of medium uncertainty levels, public compliance, private acceptance, and non-compliance all have high likelihoods. Discrepancies between opinion and attitude dynamics are easily observed in such environments.

The results shown in Figure 7 indicate that even if all agents have the same initial attitude and opinion settings, during the simulation process they will have different dynamics and outcomes (Figure 8). The primary similarity between opinion and attitude dynamics is that both are initially concentrated toward the middle of the opinion space spectrum

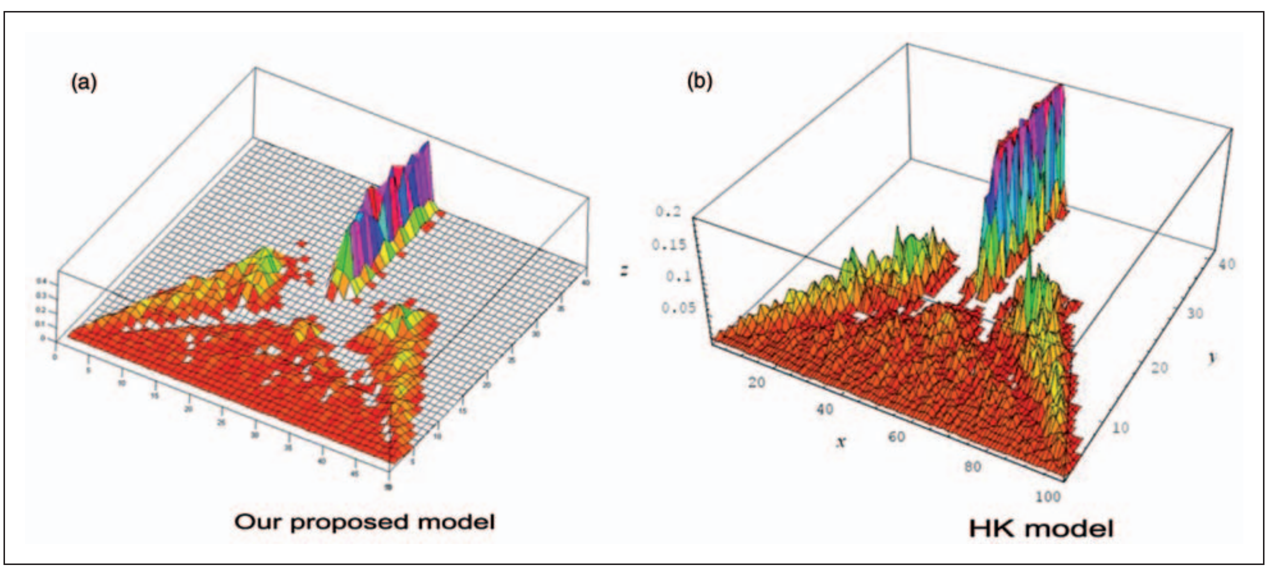

Figure 4. Comparison of simulation results generated by our proposed model and Hegselmann and Krause's[3] HK model. In both models the *x*-axis represents opinion value. In our proposed model, the opinion spectrum of the *x*-axis is divided into 50 intervals between 0 and 1 – that is, each interval has a value of 0.02. In contrast, in the HK model the *x*-axis opinion spectrum is divided into 100 intervals between 0 and 1 (0.01 each). In both models the *y*-axis represents time steps (from 0 to 40) and the *z*-axis the probability distribution of opinions.

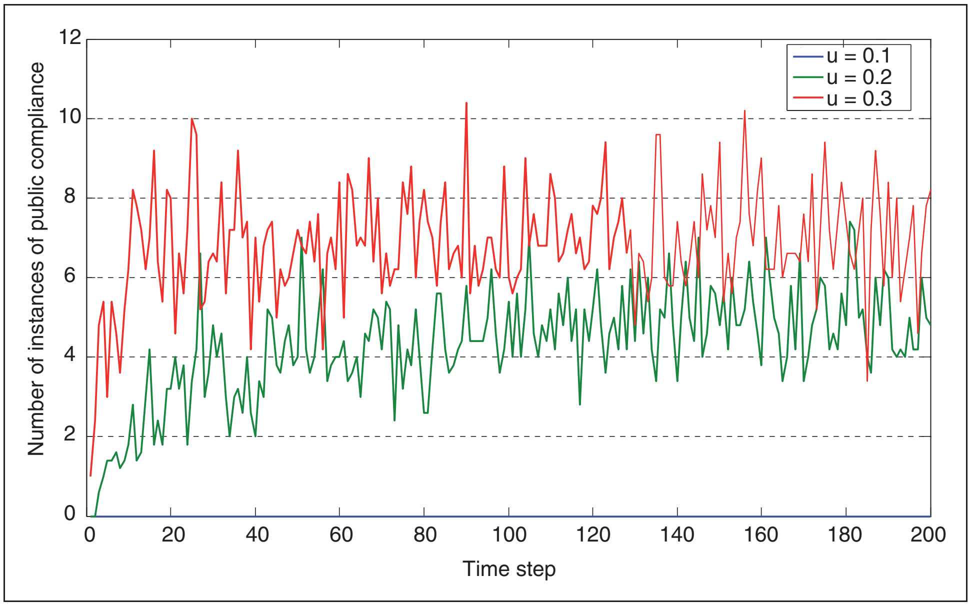

Figure 5. Comparison of public compliance instances at low certainty levels. Note: **under** the lowest uncertainty condition $u = 0.1$, public compliance is zero for all 576 agent opinion update processes (blue curve – **color online only**).

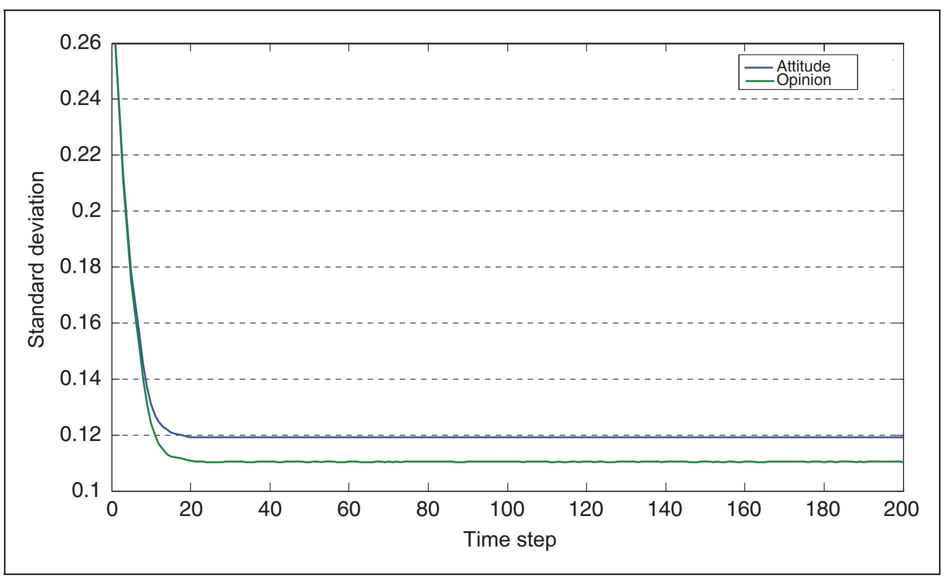

Figure 6. Comparison of standard deviations of opinion and attitude dynamics under low uncertainty conditions ($u = 0.3$). After time step 20, the average values for both dynamics are the same (0.5) and their standard deviations are within a very narrow range.

(t approximately 1–10); the biggest difference occurs during the later stages, when opinion clearly becomes more concentrated than attitude. We applied a standard deviation equation to quantify how scattered the opinion and attitude dynamics are at each time step. As shown in Figure 9, when uncertainty $u = 0.5$, the respective standard deviations of opinion and attitude dynamics are 0.0867 and 0.1304 ($t \geq 10$) – that is, opinion dynamics are more concentrated than attitude dynamics.

Opinion dynamics have scattered distributions prior to the tenth time step, indicating that agents are likely to be surrounded by more than two opinion groups (Figure 10). In such cases, informational social

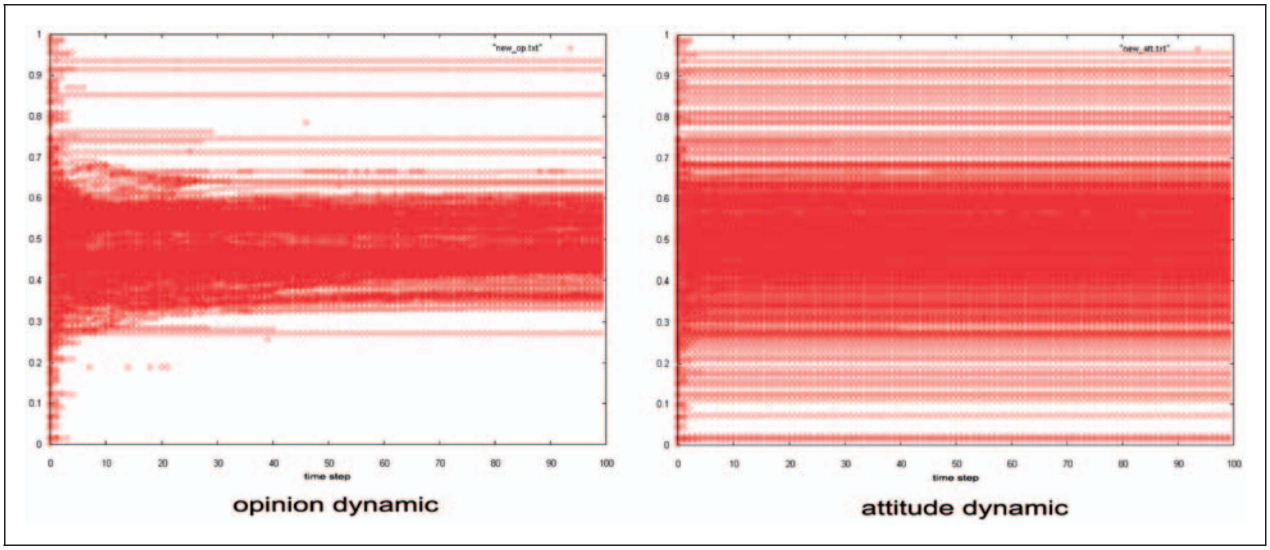

Figure 7. Comparison of opinion and attitude dynamics under medium uncertainty conditions ($u = 0.5$).

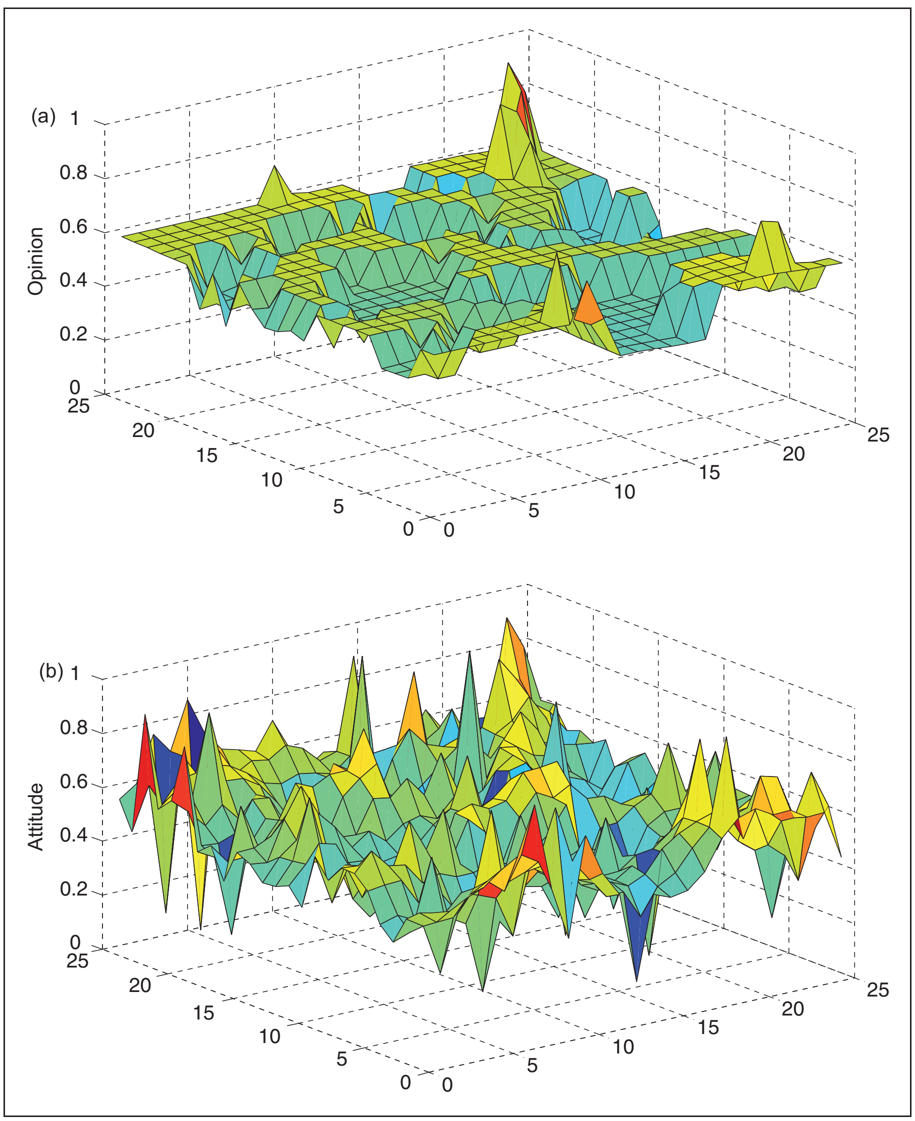

Figure 8. (a) Final opinion distribution and (b) attitude distribution. Spikes indicate opinion and attitude values. Attitudes are clearly more dispersed under medium uncertainty conditions ($u = 0.5$).

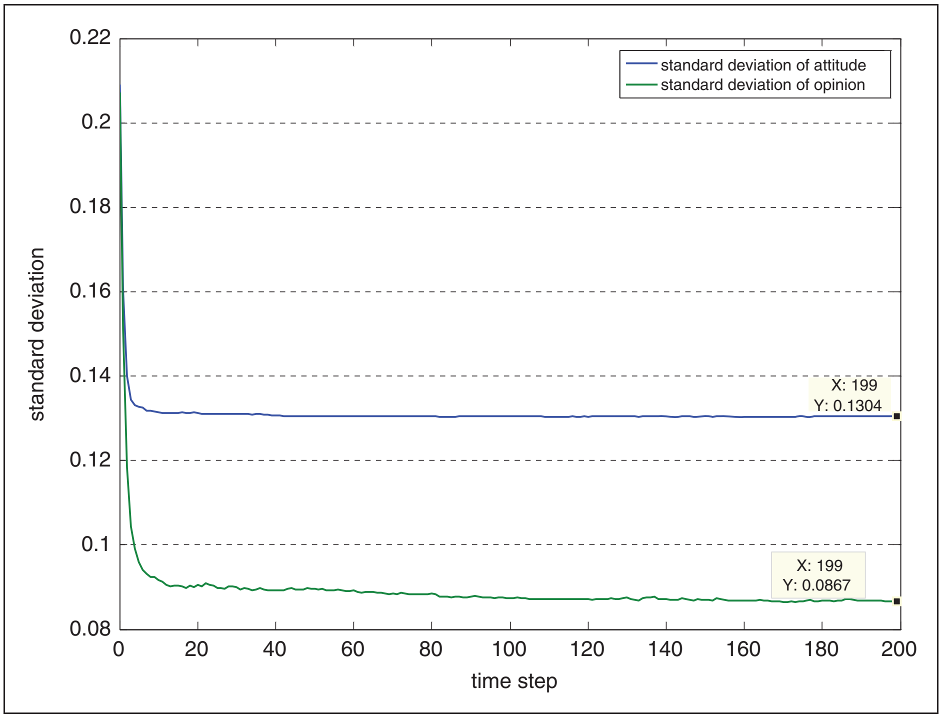

Figure 9. Comparison of standard deviations of opinion and attitude dynamics under medium uncertainty conditions ($u = 0.5$). After time step 10, the average values for both dynamics are the same (0.5), but their standard deviations are significantly different.

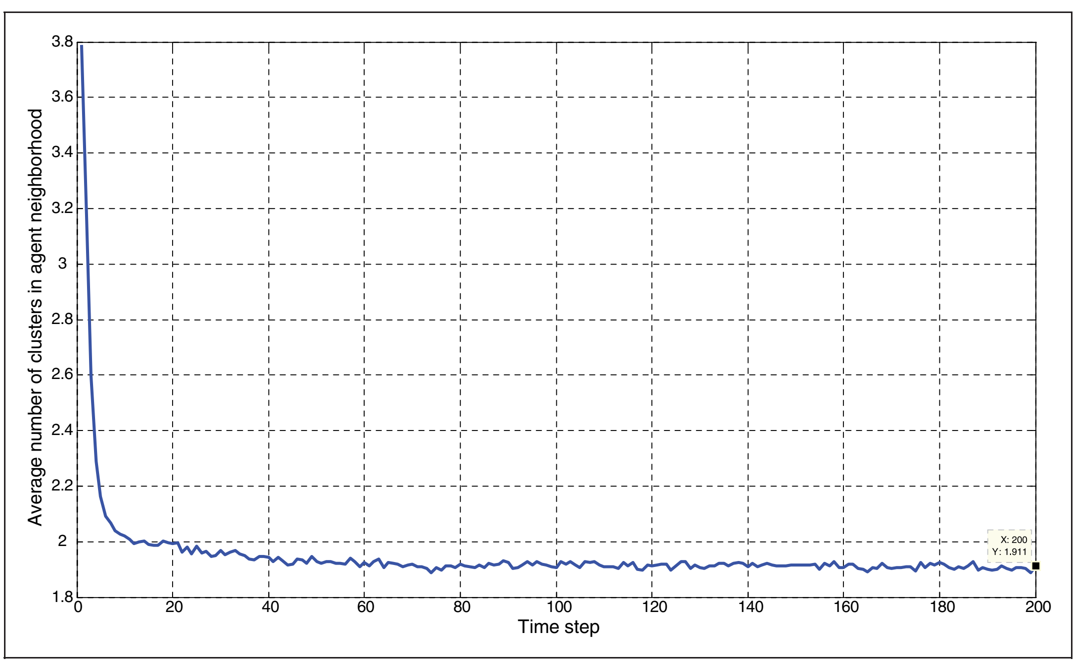

Figure 10. Number of clusters surrounding an agent plotted against time under medium uncertainty conditions ($u = 0.5$).

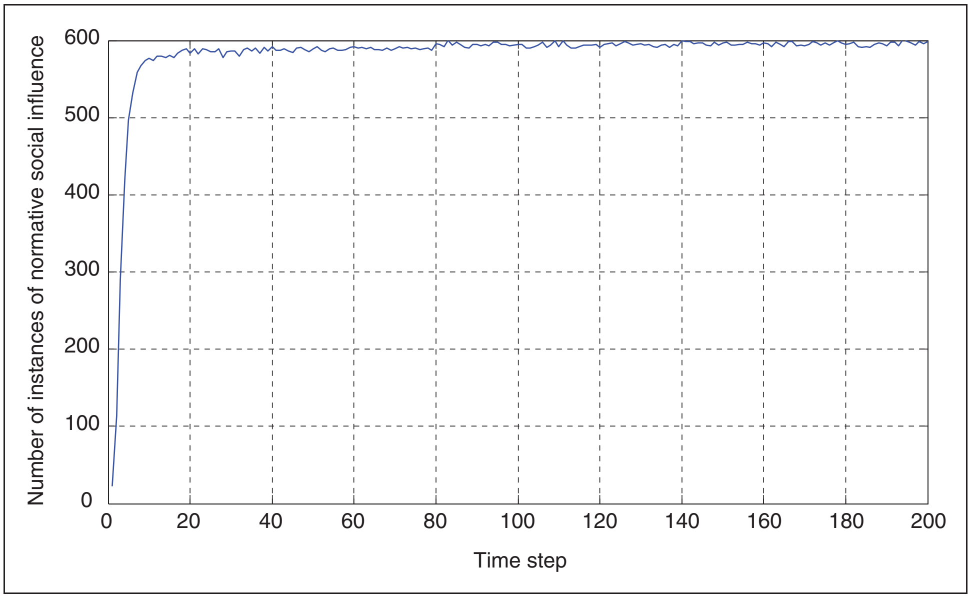

Figure 11. Instances of normative social influence plotted against time under medium uncertainty conditions ($u = 0.5$).

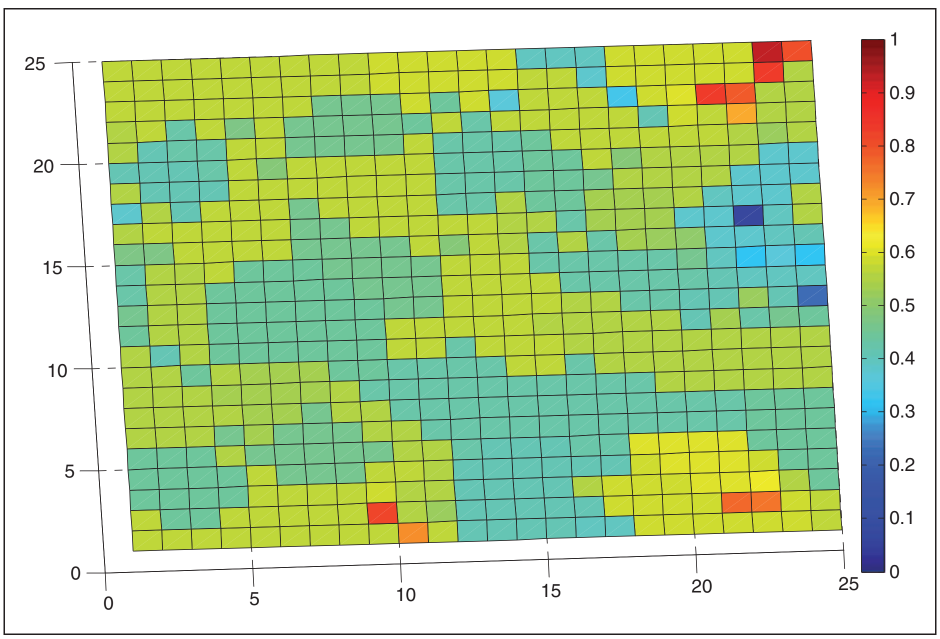

Figure 12. Birds-eye view of overall final stage opinions after stability is achieved (medium uncertainty conditions, $u = 0.5$, time step $t = 199$). Most individuals are slightly for or slightly against the issue in question. The few individuals holding extreme views are neighbors who form several small clusters.

influence prevails and opinions can be exchanged freely. Through continuous opinion exchange, group opinions sharply converge after the 10th time step, and the number of opinion groups sharply decreases. In most cases, when the number of surrounding opinion groups decreases to two or one, the amount of normative social influence sharply increases (Figure 11).

When opinions move toward the center of opinion spaces and only two clusters ($g = 2$) remain, normative social influence begins forcing group members toward the center. However, clusters cease moving toward each

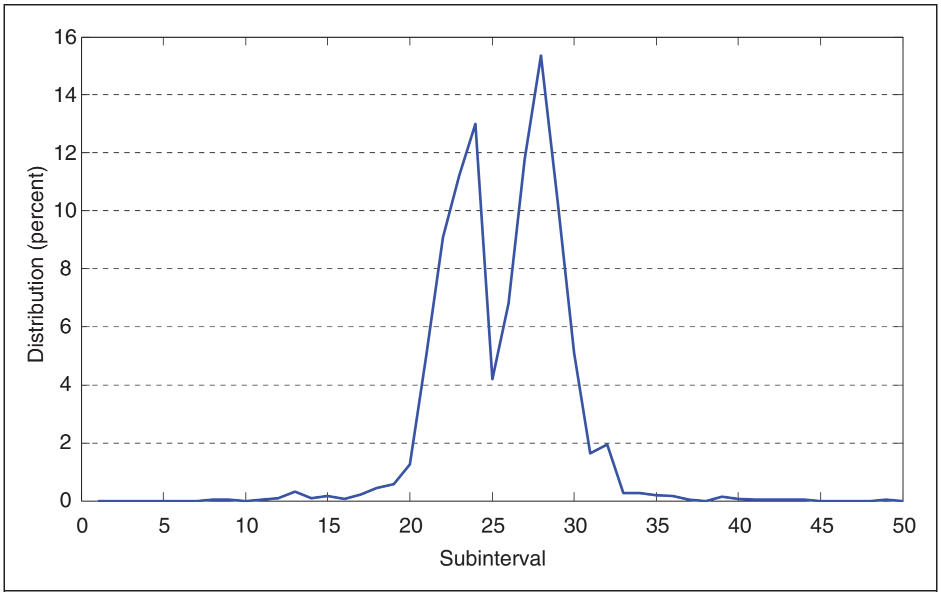

Figure 13. All individuals are divided into two similar clusters under medium uncertainty conditions ($u = 0.5$, time step $t = 199$).

other, resulting in coexistence between formerly competing clusters. Note that the two cluster centers in Figures 12 and 13 are slightly closer to 0 and 1.

Our simulation results are similar to real-life scenarios in which individuals hold customary views on specific issues that have been discussed over a period of time. When they express opinions in a group setting, they often take social norms into consideration, even if they do not completely agree with them. For most people, no major differences exist between the two; therefore, their opinions gravitate toward public opinion. For example, in many elections the majority of centrist voters do not take strong political stances, which is similar to the discussion and simulation experiments we discussed in an earlier section. To a certain degree our simulation results demonstrate pluralistic ignorance – that is, even though group members appear to express consistent opinions or behaviors, they may not necessarily share the same private attitudes.

In the face of normative social influence, agents with high degrees of uncertainty do not calculate public opinion magnitude (i.e. $agent.u > u\_threshold$), but follow the opinion that has the highest number of supporters (Step 6 of Figure 1) – that is, attitudes and opinions move in the same direction with no discrepancies.

According to these three uncertainty levels, the greatest discrepancy between attitude and opinion occurs when the population in question has a medium level of uncertainty. Our simulation results are consistent with real-life scenarios. Imagine a society of individuals with no personal opinions who believe whatever they hear – in other words, their only rule is to follow the actions of others, therefore no discrepancies exist between their attitudes and opinions. In contrast, it would be difficult to formulate public opinion in a society where most individuals do not follow others' opinions, since any localized public opinion would be insufficiently strong to encourage self-confident individuals to comply instead of expressing their attitudes openly and directly. Societies often exist at a medium level of uncertainty, with only minorities capable of comprehending complex issues or handling ambiguity; the majority have their own ideas, but are neither certain nor confident about them. When there is no obvious pressure to follow public opinion, individuals in societies marked by medium levels of uncertainty may voluntarily exchange ideas with others and determine how much they want to integrate others' opinions into their own. However, when strong pressure exists to follow public opinion, most people choose public compliance but not private agreement – a common occurrence in daily life.

4. Realistic sociological simulations

In this section we will illustrate the potential value and applications of our proposed opinion and attitude dynamics model in terms of *pluralistic ignorance* and *minority influence*. To observe the influences of a small number of newcomers on an opinion group that has already achieved consensus on an issue, we randomly selected seven (1%) agents from a

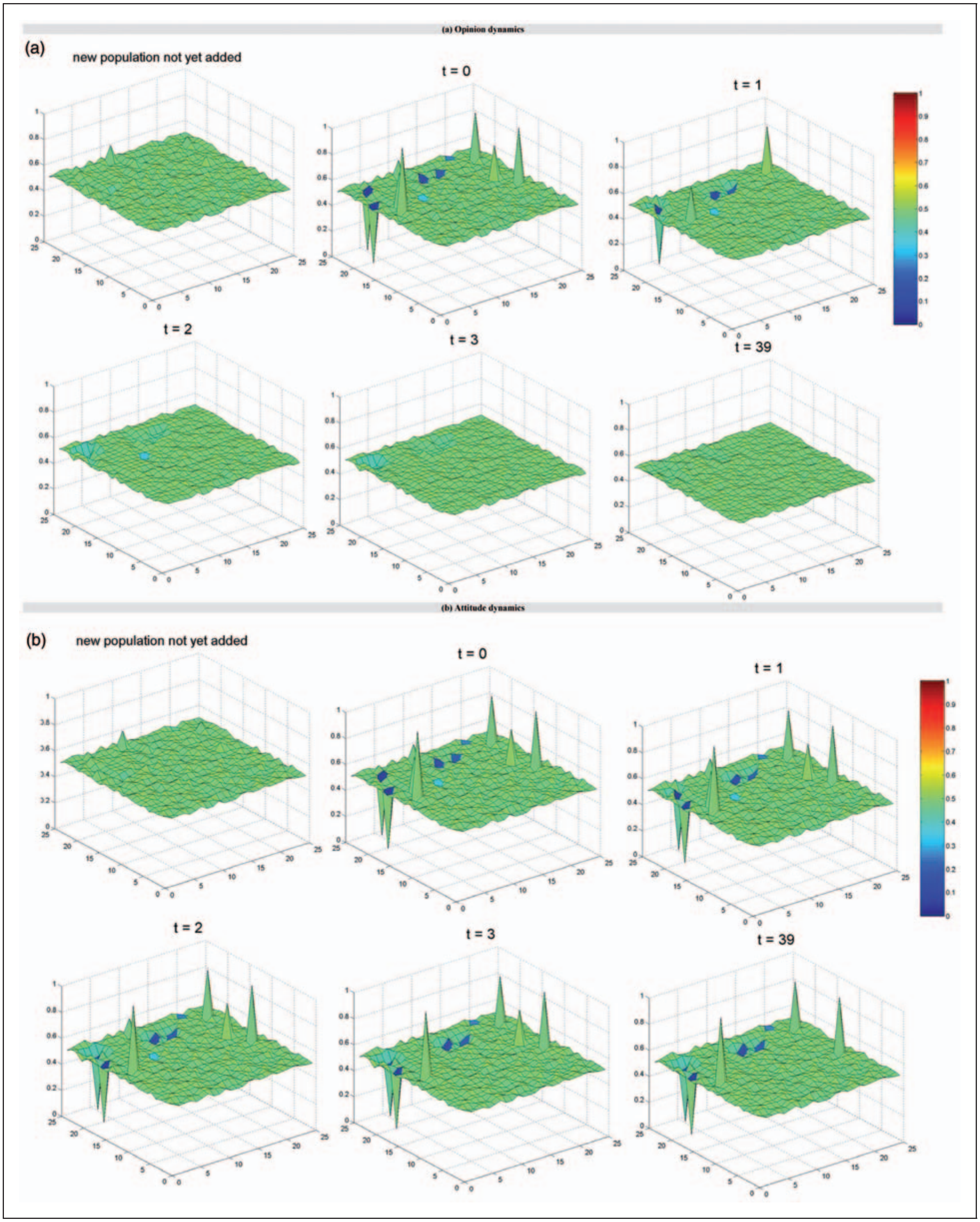

Figure 14. (a) Opinion dynamics before and after a small number of newcomers are added to the original (opinion returns to consensus). (b) Attitude dynamics before and after a small number of newcomers are added to the original population (attitude dispersal increases slightly).

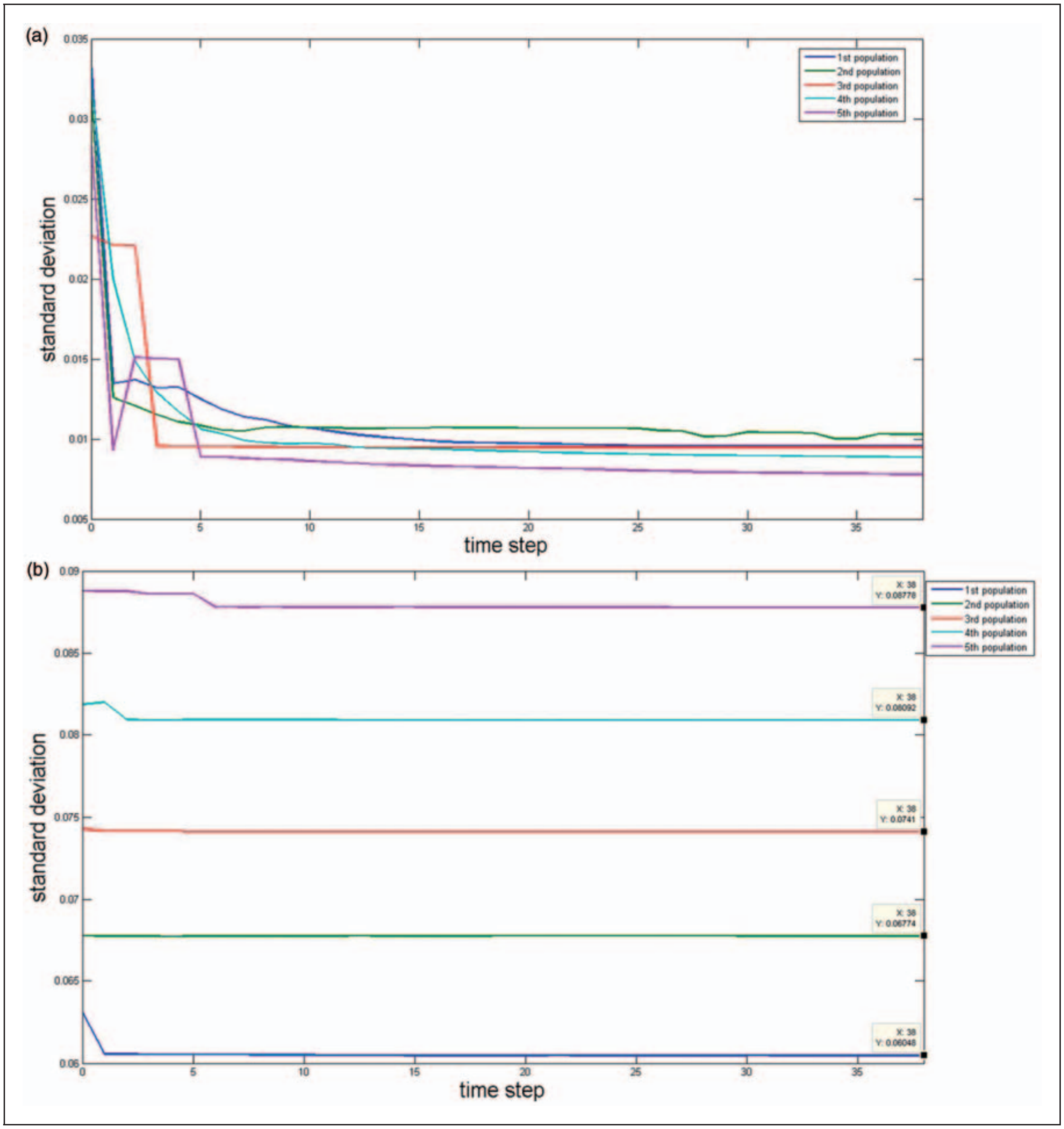

Figure 15. (a) Influences of the addition of five new agents on the standard deviation of opinion dynamics (slight increase). (b) Influences of the addition of five new agents on the standard deviation of attitude dynamics (gradual increase).

two-dimensional cellular automata and reset them so that their opinions and attitudes were identical; the opinion exchange process was then restarted ($t = 0$) (Figure 14(a) and (b)). Newcomers in such scenarios are likely to comply with public opinion, since they are dealing with group norms that have already been established. When the model regains stability, the opinion dispersal level does not change (Figure 14(a)), while the attitude dispersal level increases slightly (Figure 14(b)). After multiple repetitions, opinion dispersal increases slightly and then stops (Figure 15(a)), while attitude dispersal continues to increase over time (Figure 15(b)). In other words, an increasing number of group members are identified as holding different opinions from what they express publicly. However, in light of their neighbors' expressions of support, these individuals still maintain public conformity, meaning that the degree of pluralistic ignorance continues to remain unchanged. In the previous simulation experiment it was important to ensure that two newcomers with similar views were never situated as neighbors, since that might increase the potential for resisting compliance with public opinion, establishing small opinion clusters, and increasing opinion dispersal.

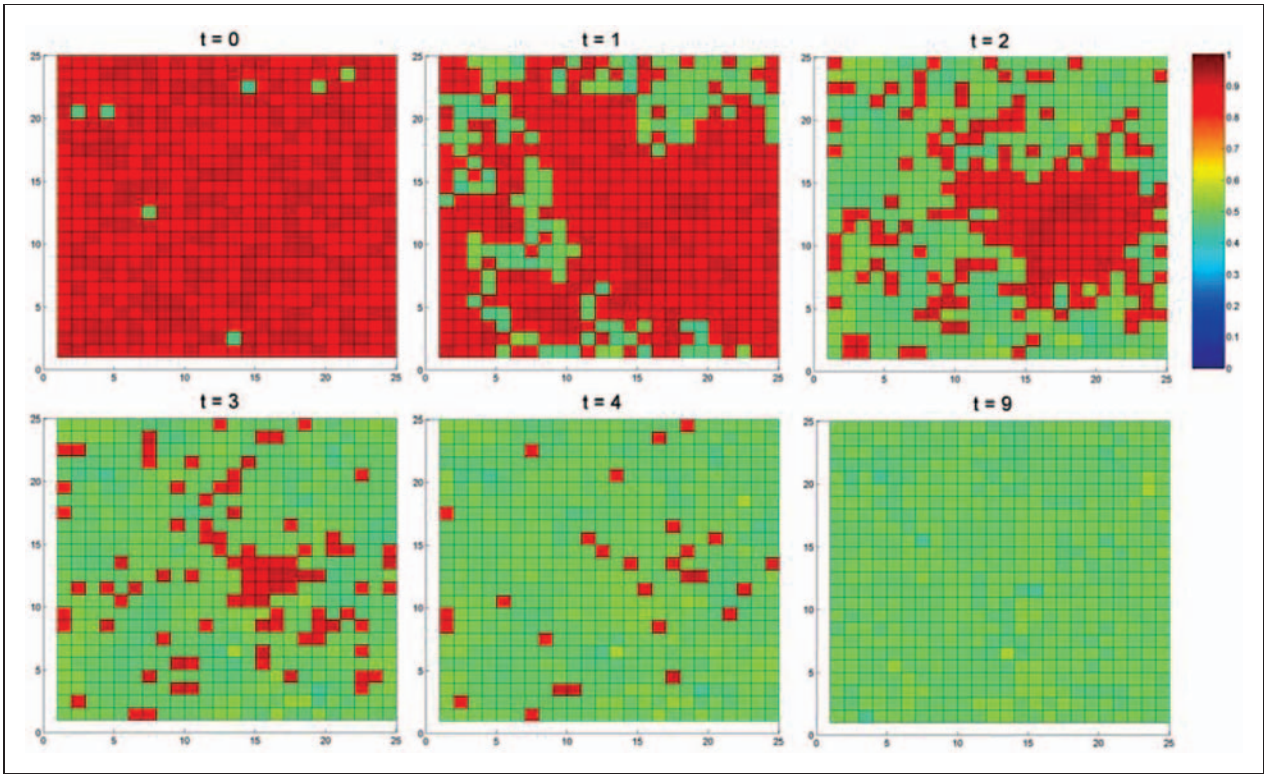

Figure 16. Elimination of pluralistic ignorance.

In societies marked by pluralistic ignorance, individuals may decide to tolerate the status quo because they do not see others taking action. The appearance of only one individual who is willing to speak out has the potential of creating a viable structure for public complaints. These initiators disrupt group homogeneity, thus supporting the decisions of others to overcome pluralistic ignorance. Results from a simulation of this type of scenario are shown in Figure 16. We initially assumed that most agents had an opinion value of 0.9 and attitude value of 0.5, and that approximately 1% of all agents ('pioneers') share a 0.5 opinion value and 0.1 attitude value. We expected that in the absence of these pioneers, all newcomer agents would be surrounded by neighbors with 0.9 opinion values, and therefore continue to conform to public opinion; this would result in ongoing discrepancies between opinion and attitude. However, if a small number of pioneers start to express their shared opinion, their surrounding neighbors are likely to follow them because the opinions of the pioneers and their neighbors are similar. Such a chain reaction supports the overturning of group opinion within a short time period. As shown, it only takes one individual to break group homogeneity and to exert disproportionate influence. This phenomenon is difficult to explain when observations are limited to expressed opinions and behaviors.

There are many real-life examples of minority influences that do not involve pluralistic ignorance, including environmental, human rights, and women's rights activism. To demonstrate how a minority view can influence the majority, we conducted a what-if experiment in which the opinion group's threshold $G = 0$ – that is, members of a society are completely free to discuss ideas because no normative social influence exists. In such cases, all opinions can be considered as long as they sit within the public's confidence bounds, and as ideas are exchanged, the public is gradually influenced by extremist views. In contrast, the presence of a social network means that minority viewpoints must be disseminated one by one, resulting in a very slow change process (Figure 17(a)) and increasing the importance of minority access to media (Figure 17(b)). In the extreme example shown in Figure 17(b), a dictator or small number of politicians can control public opinion by controlling the media – that is, by disseminating ideas beneficial to their regimes and banning all public discussion of sensitive issues in an effort to prevent the formation of a collective opinion.

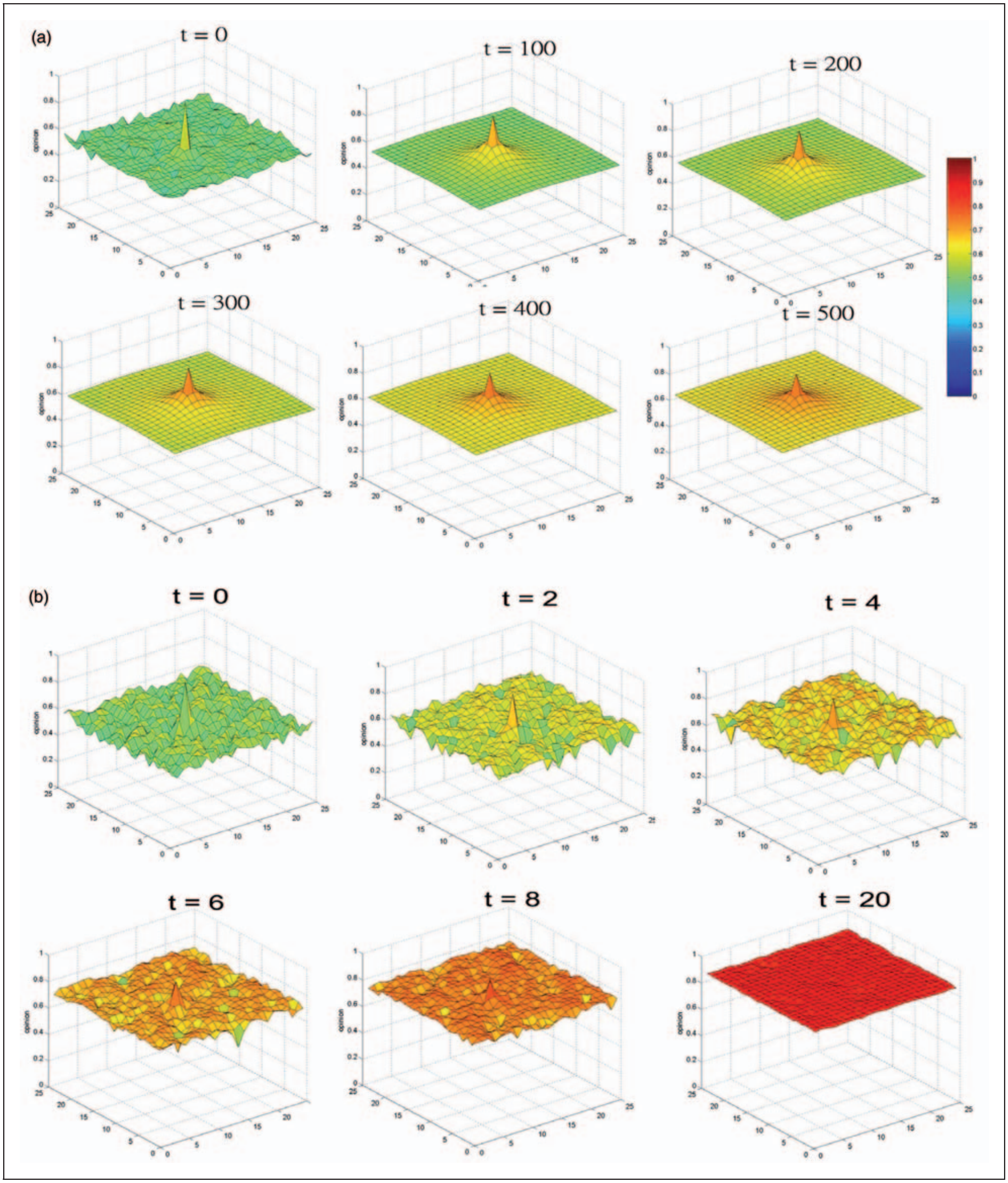

Figure 17. (a) Opinion dynamics when a society is completely free to discuss ideas. We initially assumed that the minority would consist of only one agent. The bulge represents minority time step 0. (b) Opinion dynamics when individuals in a society can freely discuss ideas and when the minority has access to the media to disseminate its ideas.

5. Conclusions

We incorporated public compliance with normative social influence into a continuous opinion dynamics model with a bounded confidence assumption to explore collective opinion and attitude dynamics. According to our simulation results, if a small number of newcomers are added to a group in which a consensus has already been achieved, and the newcomers' initial opinions and attitudes are randomly distributed, most of the newcomers will choose public compliance due to the magnitude of public opinion. Consequently, all group members will express identical opinions, but their attitudes may not be identical. Attitudes will become more scattered as the process is repeated, even if opinion homogeneity remains stable – that is, the degree of pluralistic ignorance will remain unchanged. If most people have the same attitude, a small number of individuals whose opinions are the same as the public's attitudes may cause group opinion to be overturned.

In our proposed simulation model, when normative social influence exists and when opinion and attitude are equal, it is very difficult for individuals with a minority view to change public opinion. However, we acknowledge that in the real world there are many examples in which a small number of individuals have successfully influenced public opinion; therefore, we conducted a what-if experiment that allowed for public opinion to be affected by a minority viewpoint – that is, permitting all individuals to openly discuss their opinions, and controlling the media so as to disseminate ideas beneficial to the minority.

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Chung-Yuan Huang received his MS in Computer Information and Science (2000) and his PhD in Computer Science (2005), both from the National Chiao Tung University, Taiwan. He is currently an Associate Professor in the Department of Computer Science and Information Engineering and a member of the Research Center for Emerging Viral Infections at Chang Gung University, Taiwan. His research

interests include complex adaptive networks and systems, agent-based modeling and simulation for social science research, and computational epidemiology.

Pen-Jung Tzou is a MA graduate student in the Department of Computer Science at National Chiao Tung University, Taiwan.

Chuen-Tsai Sun received his BS degree in electrical engineering (1979) and his MA in history (1984) from the National Taiwan University. He earned his PhD in Computer Science (1992) from the University of California at Berkeley. From 1991 to 1992 he worked for the Lawrence Livermore National Laboratory, where he participated in research on fuzzy neural networks. He joined the faculty at the National Chiao Tung University in 1992. He is currently a joint Professor in the Department of Computer Science and Graduate Institute of Education, National Chiao Tung University, Taiwan. His research interests include creative evolutionary systems, web-based collaborative learning, and computer simulation in the social sciences.