Effects of Global Information Feedback on Diversity

EXTENSIONS TO AXELROD'S ADAPTIVE CULTURE MODEL

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Based on Axelrod's adaptive culture model, the effects of the distribution of global information feedback are examined in two simulations. The first model is the generalized other model, where the most preferred features are hypothesized to represent the mental model of the most ordinary person and have the same influential power as real neighbors. The second model is the filter model, where neighbors are influential only when their traits are concordant with the most common trait among whole agents. In both simulations, the global distribution of information facilitated an earlier convergence and maintenance of cultural diversity. These counterintuitive results suggest that information about a global society, for example mass media coverage, would provide support for a local minority.

SIMULATION APPROACH TO SOCIAL DYNAMICS

In recent years with the increasing computational power of personal computers, several approaches have appeared that apply computer simulation techniques to social science research. They have made considerable contributions in testing models and hypotheses on dynamic social phenomena, where empirical experiments and surveys are very difficult or almost impossible.

One of the most recent approaches is adaptive agent modeling. Although the origin of such approaches is relatively old, in recent years, the so-called game of life or Schelling's (1978) model of segregation, the original idea of adaptive agent systems,

AUTHORS' NOTE: The authors wish to express their gratitude to anonymous reviewers and Ken'ichi Ikeda (University of Tokyo) for helpful comments on the article.

JOURNAL OF CONFLICT RESOLUTION, Vol. 45 No. 1, February 2001 80-96

has become common in the field of social sciences. Here we refer to one such work, Axelrod's (1997) adaptive culture model (ACM).

An assumption of Axelrod's model is that social actors have a common tendency to become similar to each other through communication and interaction in local networks. If we assume that this tendency of local assimilation is true, traits of all the actors could converge and one dominant culture could emerge. In many real social settings, however, different cultural groups and intergroup conflicts can be observed, even though they are mutually connected in the same network. To investigate the compatibility of the microlevel convergence mechanism with the macrolevel phenomena of divergence, Axelrod conducted a simple but powerful computer simulation.

In Axelrod's (1997) simulation, hundreds of agents were placed on a fixed lattice. Each agent has four neighbors directly connected by ties in the up-down-right-left directions, holding five attributional features (dimensions) with 10 possible traits (values) in each feature. These features were represented in a five-digit form, which Axelrod called a "culture." The upper part of Figure 1 shows an example of the distribution of agents on a 10×10 lattice. Initial cultural traits of the agents were determined randomly.

ACM simulation follows two steps described below (Axelrod 1997, 208).

1. At random, pick a site to be active, and pick one of its neighbors.
2. With probability equal to their cultural similarity, these two sites interact. An interaction consists of selecting at random a feature on which the active site and its neighbor differ (if there is one) and changing the active site's trait on this feature to the neighbor's trait on this feature.

Cultural similarity was defined as a proportion of shared traits (digits) in five features. For example, the agent at the top left corner (00862) shares only one digit with its neighbor in the right direction (first digit of zero), so their similarity is 20%. Thus the top left agent will change one of its features to that of four different features of the left agent at a 20% chance level. Agents are called "adaptive" because each agent simply adapts to its environment rather than calculates the pay-off rationally.

The lower part of Figure 1 shows the final distribution after 100,000 random selections of agents. Agents formed a few stable cultural groups, and no more interactions across different cultures could occur. Thus, global convergence led to a global polarization of cultures. Kennedy (1998) extended this model to interpret social interaction from the viewpoint of cognitive optimization of individuals.

Another simulation study by Latané and his colleagues presented similar results (Latané, Nowak, and Liu 1994). Their dynamic social impact theory (DSIT) is the same adaptive agent based model on a fixed social network. In their simulation, agents hold a binary "attitude" like pros and cons of some social issue. They communicate their position with their neighbors and affect each other. The result of this simulation was that stable clusters of attitude groups emerged that were quite similar to those of Axelrod's (1997). They also replicated this result by empirical experiments using human subjects (Latané and L'Herrou 1996).[1]

1. In Latané and L'Herrou's (1996) experiment, participants in the lattice network estimated the majority, so the meaning of "cluster" is not the distribution of actual attitudes but that of the perceived majority.

<initial distributions>

00862 03734 48759 42764 70101 57436 43958 38013 21437 74456
89057 15717 79333 28015 37276 39835 30523 45720 47482 17698
80468 25305 94199 95249 68633 69365 68475 74043 25155 14728
58830 53675 11989 39795 89438 98883 60075 25855 85075 97294
59351 38450 80942 14504 08356 65477 44088 37543 19390 07351
05094 52875 77166 05709 39978 72560 56009 27405 97494 43142
72687 11119 28995 55947 53852 41773 12144 31979 40162 34363
88441 65936 83536 20890 23364 44950 05281 05824 19357 82702
19833 51471 51532 60283 37426 25144 22359 29483 39006 97995
36022 50869 67910 92502 75613 81300 20485 92917 93803 61032

<final distribution after 100,000 steps>

59400 59400 59400 59400 59400 59400 59400 38013 59400 59400
59400 59400 59400 59400 59400 59400 59400 59400 59400 59400
59400 11187 11187 59400 59400 59400 59400 59400 59400 59400
59400 59400 11187 59400 59400 27942 27942 27942 27942 27942
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05094 27942 27942 27942 27942 27942 27942 27942 27942 27942
72687 27942 27942 27942 27942 27942 27942 27942 27942 27942
27942 27942 27942 27942 27942 27942 27942 27942 27942 27942
27942 27942 27942 27942 27942 27942 27942 27942 27942 27942
27942 27942 27942 27942 75613 81300 27942 92807 92807 27942

Figure 1: Example of an Adaptive Culture Model (ACM) Simulation and Its Results
NOTE: These are the actual results of an ACM simulation conducted by the authors.

SOCIAL NETWORK AND THE MASS MEDIA AS INFORMATION SOURCES

These models are quite impressive because of their counterintuitive results from the simple underlying mechanism of local convergence. Also the results of these simulations have an important implication for the process of generating cultures in the real world. Many cultures are observed in the form of clusters, for example, nations, ethnic groups, local communities, and so on. The important point is, in these cultural clusters,

most members are mutually similar and in the majority in their own networked society even if they are in the minority in the whole world. Many empirical studies found that attitudinal similarity could be observed in intimate personal networks. Huckfeldt and Sprague (1995), for example, showed that political attitudes of spouses tend to be similar, although this similarity is explained by information exchange through informal and unintentional communication rather than persuasive communication. Under such circumstances, the correct estimation of an entire social distribution would be difficult for each member. In the field of social psychology, Ross, Greene, and House (1977) reported a "false consensus effect,"the egocentric bias of consensus estimation at the societal level (for a review see Marks and Miller 1987).

In modern societies, however, we not only interact with our neighbors in personal networks, but also acquire information through various communication media about other people who are not connected by direct ties. We can hear people's opinions in the results of opinion polls or interviews in the street, which are distributed in television programs and newspapers. Such information enables us to know how others or the majority think outside our directly connected networks. Also, we watch the news of other countries on television and have direct communication with distant others online via computers. Thus, it is safe to say that in the contemporary world we are usually exposed to information from a global society that includes other cultures beyond a spatial distance.

From this standpoint, we tried to extend Axelrod's (1997) culture model using one important mechanism of modern societies—global information feedback through agents, or the function of the mass media.[2]

THE FUNCTION OF THE MASS MEDIA

Mass media, such as newspapers, radio, and television have long been believed to be very powerful devices to change and control people's attitudes and opinions to homogenize society. Although the mass media are believed to be essential for democracy to enlighten the public or to keep watch over the government, they are also believed to be potentially dangerous by controlling people's minds and behavior like the "big brother" described in Orwell's famous novel *1984*. This is not only at the level of lay beliefs. Many countries and governments have tried to control and regulate the mass media for various reasons, for example, to protect their people from "cultural invasion" or maintain regimes against antiestablishments.

At least in the sense of short-term persuasive effects, however, little empirical research has supported the influence of the mass media. It has been concluded that the mass media only strengthen one's previous attitude, and that personal communications are more effective in changing one's attitudes, especially for ordinary people (Katz and Lazarsfeld 1955; Rogers 1982). On the other hand, current studies have indicated that the mass media have much impact on the perception of a public agenda or social distri-

2. This extension was referred to as "public education and broadcasting" in Axelrod (1997). Not only broadcasting but also education has a function to transmit information to agents broadly and equally.

bution, which could affect individual attitudes eventually. For example, agenda-setting studies have shown that news coverage affects the cognitive salience of issues on the public agenda (Iyengar and Kinder 1987; McCombs and Shaw 1972), and issue salience influences how political actors are evaluated (Iyengar 1991). It also has been pointed out that people perceive or predict social distribution through the mass media (e.g., Noelle-Neumann 1993; Davison 1983). Noelle-Neumann hypothesized the public opinion process model called the "spiral of silence," which insists that, based on this perception, people would not necessarily change their attitudes but at least hold their tongues for fear of being opposed publicly to the perceived majority. To sum up the findings of these studies, the mass media have an impact on individuals' perception of society, even though the evidence of attitude change mediated by perception is relatively weak (see Mutz 1994 for a review).

However, it is not clear whether the perceived distribution caused by the mass media might have long-term influences on the whole of society. Usually the micro persuasive effects of a media message can be tested by certain kinds of controlled experiments, and the effects of media in real social settings can be examined by randomly sampled surveys. But applying these approaches can reveal only a small part of the mass media effect. First, by applying these methodologies, the long-term, group-level accumulative effect, such as "what society and culture will be like under the mass media" cannot be solved properly. The unit of analysis is individual in most cases, and the cumulative effect cannot be detected in one-shot samples or even a panel design of several surveys. Second, mass media messages are not received by individuals in a vacuum as many media researchers often implicitly assume. On the contrary, media information is socially processed through personal networks. These problems cannot be adequately explored by traditional social surveys.[3]

From these standpoints, we conducted a series of research experiments to investigate the nature and effect of the mass media in personal network settings by extending already existing adaptive agent models of social process. These extensions enabled us to observe the long-term history of virtual society by flexible modeling of the media effect without noise. To examine the long-term effect of the mass media, we added the parameter of "plurality information" to Axelrod's (1997) model.[4] Here we assumed the plurality information, which is defined as the sequence of the most preferred features, to be referred by the target agents equally. In other words, the status of each agent would be summarized and referred to in the feedback system.[5]

We made our extensions of this feedback mechanism to the ACM in the following two ways, based on how the feedback of the plurality information affects each agent. In the first extension, the plurality information is summarized and referred to as one constituent of an agent's personal network. Plurality information works here as a "generalized other," which regulates individual behavior (cf. Mead 1934; Mutz 1998) and simply acts as one source of influence in personal networks. In other words, the plurality

3. Personal network models of media effect are discussed later in the discussion section.

4. The word *plurality* was used because the size of the feed-back trait was the largest among others but not necessarily the majority in the exact sense of the term.

5. So "plurality information" here is global information in two ways: information about a global society that is distributed globally.

information is considered a hypothesized individual in direct networks. This is a simple and straightforward model of the media effect as the feedback information directly affects agents.

In the second model, the plurality information acts as a filter of influence caused by personal networks. In this model, only the influence that is concordant with plurality information is likely to emerge. The assumption of this model is that the mass media do not have direct influential power but indirect power, which reinforces the effect of personal networks. In this model, influences of global information and personal networks are assumed to intensify each other when they are concordant (Oshagan 1996). From the standpoint of the focal agent, it is likely to be affected if the direction of pressure from the personal network is consistent with global pluralities, but is likely to resist the pressure if it is inconsistent (e.g., believe/do not believe neighbor's word, for it is/is not confirmed by television news). Detailed information of the two extensions and the results will be presented in the following section.[6]

SIMULATION 1: GLOBAL INFORMATION AS GENERALIZED OTHER

In the original ACM, one of four neighbors of an activated target was randomly selected for interaction with the target with the probability of a linear function of cultural similarities. If the target and the selected neighbor share two of five cultural features, an interaction will occur at a 40% chance level, and as a result of this interaction, one of three different features will be shared (one trait of the selected neighbor will be copied to the target).

THE GENERALIZED OTHER MODEL

In our first simulation, the fifth neighbor of an activated target was assumed to examine the effect of global information feedback. This generalized other model is based on the idea that our social behaviors are regulated by the internal hypothetical generalized other, that is, the personified social norm (cf. Mead 1934; Mutz 1998). To put it in our simulation, the fifth neighbor, which does not exist as an actual agent, is hypothesized to represent the global plurality of cultural features. Here the fifth neighbor has influential power equal to the other four actual neighbors. A graphic presentation of this model is shown in Figure 2.

6. It may be worth pointing out here that these extensions seem to violate a basic assumption of adaptive agent models. In these models, agents would not calculate the situation rationally but adapt simply to local environment, which is mainly created by other surrounding agents. Also, no central unit is assumed that governs and affects all agents, and group-level phenomena will emerge or self-organize through the behavior of each agent. The feedback mechanism of plurality information, however, can be regarded as a central unit that exists independently from agents' behavior. In this sense, the feedback function examined here might be said to be a controlling system over agents. However, information distributed to each agent depends only on the distribution of the agents themselves and, in a broader sense, agents still simply adapt to the environment that they create themselves.

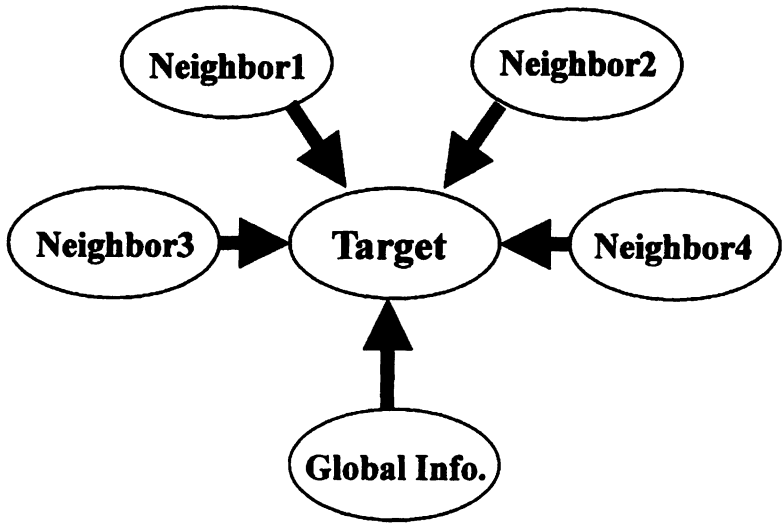

Figure 2: Simulation 1: Generalized Other Model
NOTE: Probabilities of referring global information are experimental conditions.

The fifth neighbor, the generalized other, has the most preferred feature of each trait. That is, when "5" is the most common trait of the first feature among all agents in the simulation, the fifth agent has as its first feature the trait "5", and so forth. When several traits are shared equally in the *N*th feature, one of them is selected randomly. Although the hypothetical agent is common to every target agent, it is not always the same with the largest cultural sets. For example, if the culture "25073" is shared by 40% of agents, 72518 by 30%, 34068 by 20%, and 92327 by 10%, the attributes of the fifth global information neighbor will be 25078 or 22078 (the trait of the second feature will be selected randomly because the traits "2" and "5" have the same share of 40%) and do not represent any actual cultural group.

Incorporating the plurality information feedback as the fifth agent in the model, we made five experimental conditions according to the relative chance (RC) that they are selected as an interactant. One of the conditions is RC = 1, which means that the fifth agent has the same chance of selection with each of the other four neighbors. The absolute probability of selection is 20% (1/5). The other four conditions are RC = 0 (no chance of selection, virtually a replication of the original ACM), RC = 0.5 (the selection chance of the fifth agent is half that of its actual neighbors or 0.5/4.5 = 11.11% probability), RC = 4 (the same selection chance as the sum of all four neighbors, or 4/8 = 50% chance of selection), and RC = 8 (a two-times greater selection chance than the sum of all four neighbors, 8/12 = 66.6% of probability). When the RC increases, the chance that plurality information is selected as an interactant agent becomes higher, that is, the influence of global information becomes larger.

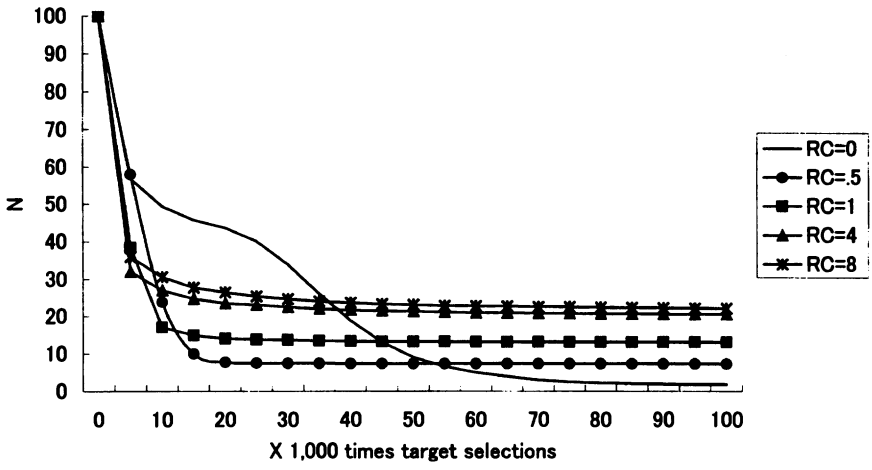

Figure 3: Number of Different Cultures in Simulation 1
NOTE: RC = relative chance.

Other parameters of the simulation are almost the same as the original ACM. There are 10×10 (= 100) adaptive agents in a fixed square-shaped site with no boundaries.[7] Each agent has neighbors in four directions, and they have five cultural features with 10 randomly selected initial traits of each feature, so each agent has one of the five-digit attributes from 00000 to 99999. In each experimental condition, 100 trials were conducted with different initial cultures, and in every trial 100,000 target selections were performed.

RESULTS OF SIMULATION 1

Figure 3 indicates the time-series trends in the number of remaining different cultures during 100,000 target selection trials. The number of cultures shown here is averaged for each experimental condition at every 1,000-selection step. One curve represents the averaged number of 100 trials in one condition.

In the feedback conditions (RC = 0.5, 1, 4, 8), rapid drops of the number of cultures are observed in earlier steps than in the original ACM (RC = 0). Under these conditions, the number of cultures reaches an equilibrium faster with more remaining different cultures than in the original ACM. In addition, this tendency became stronger as the RC increased. When the RC was 8.0 (the fifth agent was referred at double the probability as the sum of the reference probability of all four neighbors), the number of clusters at the end was the largest.

7. Four edges of a lattice are "wrapped" or connected to the other side. Axelrod (1997) tested two conditions: a lattice with and without boundaries, but there was no substantial difference in the results.

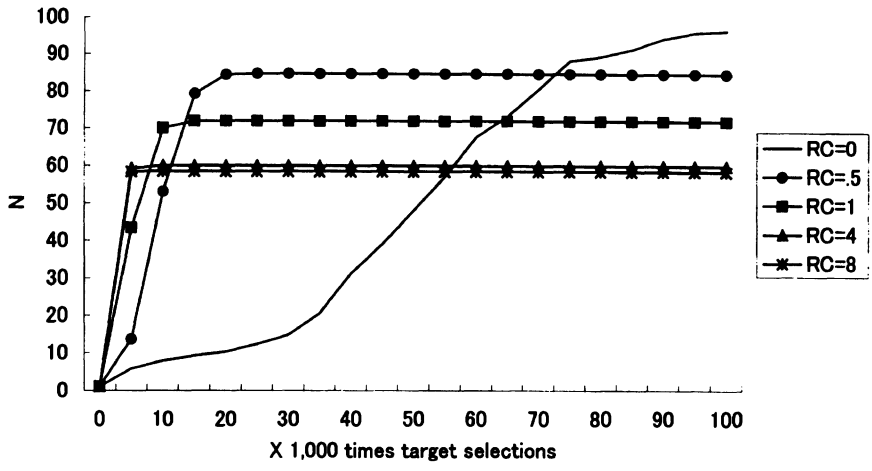

Figure 4: Proportion of Dominance by the Largest Culture in Simulation 1
NOTE: RC = relative chance.

TABLE 1
Averaged Status at the Formation of Final Largest Culture

Condition	*Averaged Selection Steps*	*Number of Remaining Cultures*
Control	61,900.08	4.69
Simulation 1		
RC = 0.5	4,524.84	63.74
1	1,609.01	84.36
4	362.48	97.69
8	267.69	98.16
Simulation 2		
FR = 0.25	12,890.00	40.21
0.5	7,288.42	57.00
0.75	5,110.13	75.02
1	3,742.54	95.18

Figure 4 indicates the time-series trends of the averaged sizes of the dominant (largest) culture, presented in the same way as Figure 3. This figure suggests the same story. In a control condition without the feedback mechanism (RC = 0), the dominant culture at the beginning spread its area with repeated selections. However, even under the most powerful circumstance of the plurality feedback (RC = 8 but almost no difference with RC = 4), dominance by plurality was held at most around the 60% level, and more varied cultures survived.

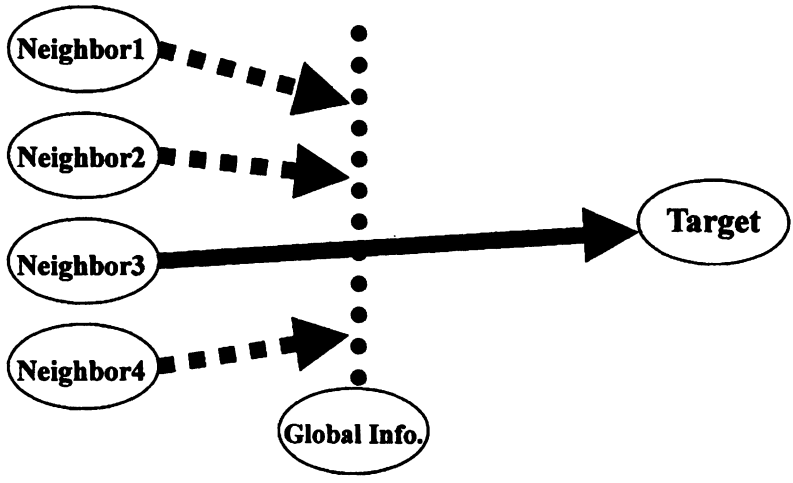

Figure 5: Simulation 2: Filter Model
NOTE: Filterability rates of neighbors' influence are experimental conditions.

This result was somewhat surprising and counterintuitive. Considering that plurality information affected all agents beyond the constraint of personal networks, it is natural to suppose that the dominant culture would achieve the broader dominance in the condition of global information feedback. Nevertheless, the result of the simulation was the opposite. One possible explanation may be the rapid drop in the number of cultures in Figure 3. Rapid convergence caused by global information feedback in the early stage of simulations facilitated the formation of the largest cultural group. Thus, the cleavage of cultural cliques between the largest culture and others has become more and more distinctive.

Table 1 shows the averaged times of target selection when the largest culture at the end of each trial was stably formed and the averaged number of remaining cultures at that time. Largest cultures were formed rapidly as the probability of referencing the plurality information increased, and the formation was achieved in more diverse cultural environment. Thus, rapid convergence can be assumed to help the maintenance of diversity.

SIMULATION 2: GLOBAL INFORMATION AS A FILTER OF NETWORK EFFECT

THE FILTER MODEL

In the first simulation, pluralities of five features were combined and acted as the "virtual" fifth neighbor, affecting the target directly. In the second simulation, on the other hand, this representative plurality is assumed to play an indirect role to moderate the

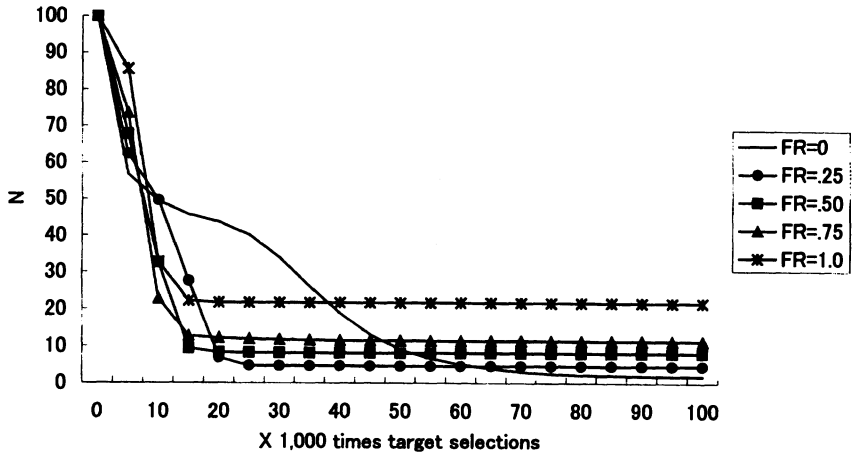

Figure 6: Number of Different Cultures in Simulation 2
NOTE: FR = filterability rate.

four real neighbors' influence. The process of the second simulation is the same as the original ACM, but neighbors will be influential only when they are accordant to pluralities. That is to say, global information that is fed back works as a filter of local neighbors' influence. See Figure 5 for a graphic presentation of the second model.

As in the original ACM, a target agent and its neighbor are selected randomly and interact with the probability equal to their similarity of cultural features. In the process of interaction, one feature of the different traits between the two agents is selected, and the target agent's trait is changed to that of the neighbor. Here the concordance of the trait of the focal neighbor and that of the plurality is taken into account in this filter model. If the trait of the focal neighbor is a dominant one, that is, the same as that of the plurality, the focal feature of the target agent will be changed to that of the neighbor. However, if there is an inconsistency between the neighbors and the plurality, the target agent will not change. This model assumes that agents are generally resistant to the influence of neighbors but, at the same time, are more likely to adopt a neighbor's concordant traits with pluralities. In other words, people will not change their attitude to that of their surrounding neighbor's as long as the mass media report that their neighbor's attitude is not the plurality in all of society.

Suppose that the target's feature was 45367, and that of the selected neighbor was 62367. In the first simulation of the generalized other model, both agents would interact at the level of 60%, and as a result of the interaction the first (or second, depending on random selection) feature of the target will be changed to that of the neighbor, for example, the trait of 4 is changed to 6. In the second simulation of the filter model, on the other hand, the dominant trait among overall agents function as the moderator of the neighbor's influence. Again, suppose that the most dominant traits of the five features are 5, 8, 3, 6, 7, respectively. Here the dominant trait of the first feature is 5. It is

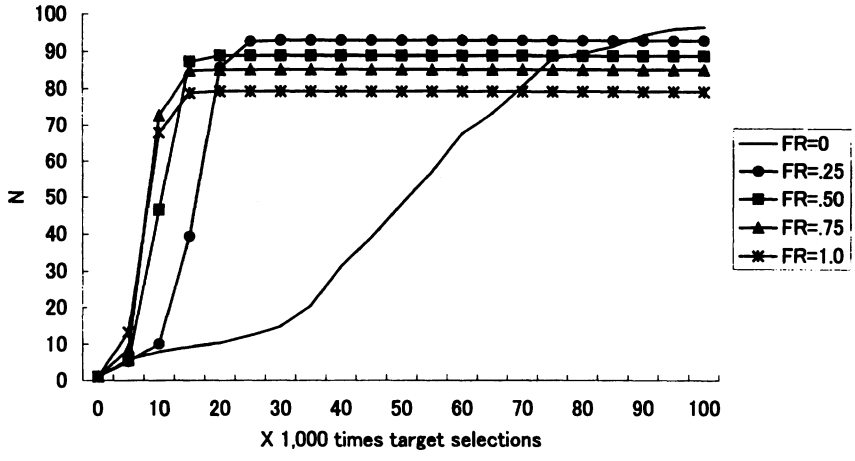

Figure 7: Proportion of Dominance by the Largest Culture in Simulation 2
NOTE: FR = filterability rate.

TABLE 2
Final Distribution of Cultures

Condition	*Number of Remaining Cultures*	*Largest Culture Size*
Control	1.81	96.70
Simulation 1		
0.5	7.40	84.76
1	13.18	72.02
4	20.66	59.95
8	22.26	58.46
Simulation 2		
0.25	4.62	93.07
0.5	8.08	88.94
0.75	11.35	85.19
1	21.72	79.28

different from the trait of the focal neighbor (6), and the change described above will be rejected at a prefixed probability. In our simulation, this probability (filterability rate or FR) took five values from 0, no filtering effect (this is a replication of original ACM and was not actually performed but substituted by the result of RC = 0 in the first simulation) to 1.0 (any influence occurred only if the neighbor's trait was the same with that of the plurality) with 0.25 steps. All other details in the procedure were identical to those of the first simulation. For four experimental conditions according to the probability, 100 trials were conducted, respectively, where 100,000 target selections were performed.

RESULTS OF SIMULATION 2

Figures 6 and 7 correspond to Figures 3 and 4 in the first simulation. The averaged times of target selection at the formation of the largest stable culture are shown in Table 1. Also, averaged final distributions of cultures in both simulations after 100,000 steps are shown in Table 2. As they can be easily understood, these results were essentially the same as the results of the first simulation, even though the results of the second simulation are closer to that of the original ACM than the first simulation. When the feedback mechanism of global plurality was assumed, more diverse cultures were likely to survive through the trials. This implies that global information distributed through the mass media may maintain local diversity. The mechanism of rapid convergence in a diverse environment can also be observed in Table 1. As in the first simulation, the largest cultures were formed rapidly as the probability of filtering increased, and the formation was achieved in a more diverse cultural environment. Thus, the maintenance of diversity is helped.

The difference between the results of the two models is the degree of dominance shown in the table and figures. In the second simulation based on the filter model, dominant cultures were spread in a broader area than in the first simulation based on the generalized other model. The reason might be that local convergence power was stronger in the second simulation because the indirect influence of global information is assumed. Nevertheless, the similarity of the main results of the two types of simulations suggests that the phenomenon of media-generated diversity would be robust, regardless of the types of implemented feedback mechanisms.

DISCUSSION

The results of our extensions to the ACM showed that the plurality information feedback to agents forms more diverse cultures. It accelerates the convergence of the largest group but, at the same time, maintains diversity as a whole and the stability of minor groups. Although these results seem to be counterintuitive, the point is that any simulation research should be a good simulation of the real world with a small number of key concepts. Here the compatibility of our results with the findings of existing media research is discussed.

In their monumental and seminal works, Paul Lazarsfeld and his colleagues introduced a "two-step flow of communication" model, based on evidence that the mass media were not likely to change receivers' initial voting intentions (Lazarsfeld, Berelson, and Gaudet 1948; Katz and Lazarsfeld 1955). They found that people were selectively exposed to mass media messages according to their political predisposition, and that influence on voting intention was much stronger through personal communication than mass media exposure. Their model captured the mechanism of the mass media effect in the broader context of personal networks. According to the model, information flows from the mass media to opinion leaders first. Opinion leaders are eager to be exposed to more varied news sources than their followers, who are selectively exposed to information according to their predisposition. At the second step of

communication flow, opinion leaders have an influence on their followers through personal communications. A long-standing research trend called "limited effect" models followed their model.

The two-step flow of communication model and its successor "diffusion of innovation" studies developed by Rogers (1982)[8] are virtually unique models that captured the media effect in the context of personal networks. The personal network model of the mass media made it possible to explain the stability of attitudes against media power and the variability and dynamics of attitude change at the same time from one simple mechanism. Individuals are mutually protected against the mass media influence in the web of a network, but sometimes a change could occur through opinion leaders in the networks. In other words, personal networks can serve as a buffer for the media effect.

The results of our simulations show new implications for the media effect in personal networks and are confirmed by traditional research. First, the limited effect of the mass media was reproduced in our simulations. Plurality information feedback (which is one of the functions of the mass media) did not facilitate cultural convergence. On the contrary, it enhanced the maintenance of a greater number of cultures. The reason seems to be as follows: the feedback of global information accelerates the convergence of one (in most cases, the largest) culture, and the convergence made cultural boundaries clear at an earlier stage. Once the largest culture is stably formed, however, plurality feedback also functions to maintain cultural diversity because the information of global status has different meanings among different cultural cliques. The same plurality information helps both convergence and differentiation. We think the latter is an important function of the mass media because the media have been mostly regarded as a converging power, not only in lay beliefs but also in effect models.

Our simulations have novel features and advantages over the classical personal network models described above. Our simulations dealt with the emergence of cliques in the flat network, whereas the personal network models were developed on given prefixed network cliques. In our simulations, there was no difference of status between agents, such as opinion leaders and followers. Agents were all the same and simply adaptive. They cocreate cliques with no central agent, such as opinion leaders. There was also no assumption of selective exposure to inconsistent information, which was an essential concept of the personal network models. Agents were exposed to the same feedback information, but the effects were different among network cliques, as discussed above. To summarize, our simulation models showed limited effect and the emergence of network cliques, created by both the local convergence mechanism and the plurality information feedback, were based on simpler and more parsimonious assumptions than classical models. Our models also offered an interesting aspect of media function: differentiation and maintainance of diversity. The mass media, contrary to lay beliefs of their strong uniforming power, would rather contribute to creating differences in the long run. In the real world, it seems to be very rare that social cleavages have disappeared and that the consolidation of opposing groups have been

8. Rogers (1982) states that media effects consist of two different factors—"information" and "influence," and that information flows directly to everyone in a single-step from the mass media. In the meantime, an influence flow occurred in multistages between opinion leaders and several hierarchies of followers.

achieved by the power of media. Things are often contrary. These phenomena can be explained by our results.

Our results also have several implications for conflict and its resolution. Although mere local interactions facilitate polarization and the convergence of a few cultural clusters, feedback of global information leads to coexistence of more diverse cultures. In modern societies, the mass media can be assumed to play a key role in this feedback mechanism, and cultural diversity seems to be maintained. Such cultural diversity without dichotomous borders might reduce global conflicts or antagonism among a few major cultural groups. However, on the other hand, local conflicts are likely to increase under the condition of cultural diversity. So it can be hypothesized that growth of mass media coverage may reduce global conflicts but increase local conflicts among various cultures, political ideologies, or local groups. Considering that social conflicts are essential for media issues and coverage of conflict itself might influence social structures (cf. Olien, Donohue, and Tichenor 1995), the shift of the level of conflicts might affect social structures in the long run.

In addition, the ongoing diversification of the media themselves should be noted here. A multichannel system of digital TV and the Internet are going to change our information environment. The function of the mass media is being transformed from broadcast to "narrowcast," from global information sharing to personalization and customization of the information environment. Under such circumstances, the domain of common knowledge might be reduced, although the fragmentation of information might be accelerated. The result of this ongoing trend, especially its influence on conflict and its resolution, should be examined in future research.

Of course, our models have their own assumptions and limitations. They were fundamentally based on Axelrod's (1997) ACM and its assumptions of the local convergence mechanism. The feedback of the plurality information was implemented in two ways as the fifth agent and the filter of local neighbor's influence. These local and feedback mechanisms can be modeled in many other ways, and there is a possibility that the results might be different under another mechanism. However, it seems reasonable to suppose that our implementation was one of the simplest and thus not relatively artificial. The validity of the results was also supported by another simulation—Ishiguro, Yasuno, and Shibanai (2000), where the same type of extension was conducted based on Latané, Nowak, and Liu's (1994) DSIT agent model. There, agents in a lattice network had only one binary issue position (pros and cons), and the distribution of this binary position was informed to them. The results were almost the same: more diverse issue groups emerged in the global information feedback conditions than in the original simulations.

There is also room for argument about plurality information feedback, which was regarded as a model of influence caused by the mass media in this article. It is not exaggerative to claim that one of the functions of the mass media is to broadcast information about opinion distribution in society, for example, which is the majority. Even if reporters in TV programs do not mention details in opinion polls, people can often tell which side is supported (cf. Noelle-Neumann 1993). Thus, it is important to examine the media effect from the point of the distribution information.

However, it is also clear that sources of information are multichanneled, especially in the late 1990s with the advancement of new media technologies like cable television and computer-mediated communication. Through these multichannels, information about minorities can be magnified by media coverage and broadly transmitted to a large audience. It is worth considering these phenomena in further research to examine the function of promoting diversity.

There are also several important ways other than those described above to extend our models. One possible extension is to take a cognitive bias mechanism into account, which enables agents to interpret distribution information in different ways depending on their internal traits and surrounded networks. The common tendency of overestimation of consensus is known as the "false consensus effect" (Ross, Greene, and House 1977) or "looking glass perception" (Fields and Schuman 1976), which is reported robustly in many studies (see Marks and Miller 1987 for a review). It can be said that people see what they want to see in the media, and whether this tendency would affect our result remains to be tested.

Most of the research on the mass media has been focused on short-term effects in some sense because long-term effects, such as how the media play a role to create social groups, can hardly be tested empirically. Surveys and experiments, which are usually employed to conduct media research, could not answer these questions. Computer simulations, including adaptive agent models, can be an important new tool to explore the role of the mass media in modern society.

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