

To What Extent does Persuadability of the Public Depend on their Culture?

- A Simulation by the Multi-Particle Model -

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Abstract

The modeling was made to estimate the extent of the change of public opinion in terms of culture of the society when the information is offered to the public with an intension of persuasion. To model the extent of the assimilation of public opinion to that of the persuader, the concept of a social psychology space is introduced, where the distance is assumed to mimic the social psychology distance between individuals. Each individual in the society is treated as a Brownian particle interacting with each other via a potential in this hypothesized space and is assumed to change probabilistically his or her view of values under the influence of a persuader who releases the information with an intention. As the first application of this model, an investigation was made, by introducing Hofstede's dimensions, on how the public's reaction differs with their cultures, namely how the effect of the persuasion activity differs from country to country. Here two cases were studied; the one is the case where the persuader's intension is the same as the values in the society (: called the positive persuasion), and the other is the case of the intension different from the social values (: negative persuasion). This simulation showed clearly that the public reaction to the persuasion can be categorized into several types from Greece type to Singapore type according to the national characteristics as the extent of collectivism and the

uncertainty avoidance traits. Moreover the efficiency of persuasion was found to vary depending on the culture; the Greece-type and the Singapore-type cultures are the most efficient in positive and negative persuasions, respectively, indicating that the so-called negative communication is promising as the method of persuasion in case of the culture similar to the Singapore type. As for the second example, applying this model to a small-scale community in Costa Rica, a simulation was made to what extent Costa Rican's collective consciousness changes depending on the strength and mode of the persuasion activity. From this simulation, the persuader was found to act as an attractor of public mind which, however, disperse to each other in case of the disappearance of persuader. It was also found that the substituter to the persuader, whose strength is much weaker than that of the persuader, acts as an essential role to make again a coagulation of the public mind thus dispersed to the right position. These simulations clarified the dynamical response of the public mind to the persuasion activity, which depends not only on the strength and mode of the activity but also on their own culture.

Keywords:

Persuasion; Campaign Effect; Social Psychology; Culture; Multi-Particle Model; Costa Rica

1. Introduction

The offer of some social information, such as the messages of election campaign, medical examination or some type of inoculation, to the public with the intension of persuasion has been made primarily by means of (1) the mass media or some other communication media, and/or (2) the oral communication via opinion leaders or facilitators such as medical doctors. We have seen many cases where the information, after its primary release by the mass media or the opinion leaders, further expands into the society by an

interpersonal communication, thus becoming a topic among the public so that it indirectly contributes to the persuasion of the public. More or less quantitative investigations to the present on the persuasiveness of the public are almost limited to the subjects on what extent the public *as a whole*, that is, the society or the community *on the whole* react macroscopically to the information. In this paper we investigate the persuadability of the individuals, each of which being a member of the society, by applying a microscopic approach of modeling. Although the persuadability depends on many factors including the issue of information, we treat it not to depend on those precise factors as a first approximation, but only on the values of information. In what follows, we briefly review the campaign activities made to the present and their effects regarding the persuasion of the public.

Hillygns (2005) pointed out by using the Markov model that the campaign at the time of president election in 2000 in the United States had a strong effect especially on the people who intended not to go to the poll before the election day, urging them to go to the vote, whereas it had various effects, depending on the type of campaign, on the people with the intension to go to the poll beforehand. According to the political campaigns made in 13 countries in Europe during 1960s-1990s (Stevenson and Vavreck, 2008), the threshold period for appearing the effect of campaign was about 6 months so that it only appeared a low voting rate to the political party in case of the campaign for less than this period, because the public did not sufficiently grasp its contents. Hobolt (2009) pointed out that, in the 18 referendums made in EU, the turnout became higher with the strength of campaign, namely the stronger was the campaign, the stronger became its driving force to make the public go to the vote. In this case the strength of campaign was measured by the sum of indicators corresponding to the partisan polarization, the closeness of the race and the

extent of news coverage. Hobolt (2009) found that the turnout increased by an order of 30 per cent when the strength was doubled.

By the multiethnic campaign using paid ads and Internet activities for one year to enhance the physical activity of children of the ages 9-13 (Huhman et al. 2005), the free-time physical activity of the children who were exposed to the campaign became enhanced by 34 per cent compared with the children without the exposure. The campaign of the vaccination against the rubella and measles for the adults in Costa Rica during 2 weeks in advance and 4 weeks during the period of vaccination resulted in the inoculation of 30, 61 and 81 per cent of the people at 1, 2 and 3 weeks of the vaccination period, respectively, and 98 per cent at the end (NMWR, 2001).

In the anti-smoking campaign of a long time duration (Siegel, 1998, Ibrahim and Glantz, 2007, Farrelly et al., 2008), the rate of smokers is reported apparently to decrease with the expense of the campaign ; it decreased from 37 to 22 per sent (Ibrahim and Glantz, 2007) and from 29.5 to 18.6 per sent (Farrelly et al., 2008) during 40 years in the past and during the period 1985-2003, respectively, for the adults older than 24. On the other hand, however, in the anti-drug and anti-marijuana campaign for the adolescent (Office of National Drug Control Policy, 2003, 2005, SSDP, 2008), the drug usage rate varied almost proportional to the expense of the campaign. When we interpret such behaviors of adolescent as a manifestation such that the media campaign excited the adolescent's interest in the drug and marijuana, and that the high sensitivity seekers strongly reacted to the media campaign (Donohew et al., 1994), these are an obvious appearance of anti-campaign effect.

Above cited studies of the mass media effect indicate the existence of the macroscopic cause-and-effect relation between the offered information and the reaction of the public as a whole. On the other hand, many studies have also been done regarding the change of

public attitude through the change of social norm, which is induced by the information of the campaign. In this case the persuasion is realized not only directly by the mass media and opinion leaders but indirectly via the interactive communication among the public. Examples of such an effect can be seen, for instance, in health campaigns.

Korhonen et al. (1998) show that, in the anti-smoking campaign in Finland using the advertisement by the mass media, the attitude change of the public was realized under the influence not only of that primary and direct effect from the mass media but also the indirect effect such as the social pressure enhanced by the interpersonal communication. The activity in the Philippines for offering information to mothers regarding the vaccination for their children (McDivitt et al., 1997), the national reproductive health program in Bolivia (Valente and Saba, 1998), and the HIV preventive campaign in Katmandu, Sao Paulo and Dakar (Geary et al., 2007) had all used the mass media during the campaign period, which induced the interpersonal communication about the issue among the public.

Those studies firmly indicate that the information released by the mass media acts not only directly but, at the same time, indirectly to the public, by becoming the news agenda or the topic among the public, and forming new values and a new recognition which lead a new social norm in the society. Such a mechanism is also reported by Slutkin et al. (2006) in case of the decreasing campaign of HIV epidemics in Uganda. Moreover those studies show that, for the campaign of a duration more than several months, it occurs the attitude change of the public of several to several tens per cent, depending on the strength and the issue of offered information.

Those studies are all the ones to macroscopically grasp the rate of the public who are persuaded by the information. On the contrary to this, the so-called opinion dynamics microscopically treats the feature of the change of individual's opinion, which takes place under the influence of mutual interaction between the individuals.

The change of opinion of individuals as a manifestation of persuasion, is one mode of the collective phenomena in the society. The application of the so-called multi agent model has become a major approach to this problem (Epstein and Axtell, 1996, Deffuant et al., 2002, and references therein). In this approach, the opinion by which each agent is characterized is expressed by a continuous value between zero and one. The model generally assumes that the opinions of an arbitrary pair of agents react to each other in a time-discrete space with attractive or repulsive forces depending on the states of opinions.

According to the bounded confidence model (Dittmer, 2001, Deffuant et al., 20002, Hegselmann and Krause, 2002, Amblard and Deffuant, 2004, Urbig et al., 2008, Weisbuch et al., 2008), the opinions of the randomly encountered two agents change respectively toward the direction of the opinion of the other agent when the difference of their opinions is less than a given value, whereas those opinions are unchanged otherwise. This mimics the selective exposure in psychology. On the other hand, an agent model including the repulsive effect by Jager and Amblard (2005) assumes that the opinion of an agents moves to the opposite direction to that of the other agent when the difference of those opinions exceeds a certain threshold. The opinion of each agent changes by repeating such processes with every encounter of the agents, so that the opinions of individuals in a collective group gradually converge to certain values. Although in such a model the evolutionary behavior of individual opinions considerably varies depending on the values of parameters, they finally converge to one opinion common to all individuals, or to several, polarized opinions.

In the fields of physics and engineering, simulation calculation has been made by the multi-particle model (Hockney and Eastwood, 1988, Greenspan, 1997). When we extend such a model into the field of mathematical sociology, the individual is treated as an active Brownian particle interacting to each other (Schimansky-Geier et al., 1995, Helbing and

Molnar, 1995, Helbing et al., 1997a, 1997b, Schweitzer et al., 1998). When we further characterize the particle by vesting a certain trait to each particle, such a multi-particle model directly becomes the multi-agent model. In this paper, a multi-particle model is developed to estimate to what extent each individual in the community changes his or her opinions by the persuasion via the mass media and opinion leaders and via the mutual interaction in the field of information environment.

In the next section some findings from the campaign in the past and an assumption based on them are given, which is used to estimate the values of constants in our model. In Section 3, a social psychology space is introduced to represent the extent of the variation of opinion, that is, the extent of the effect of persuasion for each individual. In Section 4, the modeling is made for the system of multi particles. Each particle in the social psychology space is treated as a Brownian particle which is soaked in an information environment, fluctuating under the field of force formed by the other particles. When we intend to apply such a model to the real society, we must determine the values of constants corresponding to the society. In Section 5 a method of determination of the model parameters is described. In section 6 some examples of the simulation are shown regarding to what extent the opinions of the public change in various countries under a given condition of persuasion, that is, the extent of persuadability of the public, which differs depending on the culture characteristic to each country. In Section 7, taking Costa Rica as a representative country, we investigate, by applying the multi-particle model, in what manner each individual in a small scale community in Costa Rica reacts social-psychologically to the activity of persuasion. In Section 8 concluding remarks are made.

2. Assumption on the effect of persuasion

There exist few reports which represent something regarding the quantitative relation between the amount of resources input in a certain campaign or some persuasion activities and the extent of those results. The analysis by Farrelly et al. (2008) for the anti-smoking campaign carried out in the United States during 1990s and 2000s is one of those reports. According to them, the adult smoking prevalence reduced from 29.5% to 18.6% in the United States during 1985 and 2003, which seems to be due to the success of the state tobacco control program. The annual amount of expenditure for this program was 200 million dollars in the early 1990s, and increased sharply after 1996 to become 900 million dollars in 2003. Assuming that the campaign effect in any arbitrary year is owed not only to the expenditure of that year but also to the expenditures of the preceding years with a reduced amount by a certain discount rate, which correspond to taking the delayed effect of the resources already input into account, Farrelly et al. (2008) pointed out from their multivariate analysis that the decrease of the smoking prevalence of the adult older than 23 has a negative correlation with the accumulated expenditure per capita.

Applying coefficients from this analysis, Farrelly et al (2008) estimated that the smoking prevalence for the person older than 17 could decrease from the initial 24.3% in 1992/3 finally to 17.7% in 2003 in the United States when the expenditure of the amount 9.19 \$/person/year had been continuously input in the society for the anti-smoking campaign. Here that amount 9.19 \$/person/year is the minimum expenditure for the tobacco control program recommended by the Center for Disease Control and Prevention (CDC). It could decrease, however, to 15.4% in 2003 when the optimum amount of 22.18 \$/person/year recommended by CDC had been continuously input during 8 years up to 2002.

From these estimations, under an appropriate amount of input resources as 22.18 \$/person/year in the United States around the year 2000, we might expect that the campaign

effect of about 10 per cent reduction of prevalence can be attained at the end of 10 year activity, and by linearly extending this, of about 20 per cent reduction at the end of 20 year activity, though its linear behavior has no firm reasons but only for simplicity. The value 10 per cent for the 10 year activity would be a maximum for the effect of campaign since it may include the contributions from the increase of cigarette price and also from other socio-economical factors. In this paper, we assume the persuasion activity such that it realize the effect of about 10 per cent and 20 per cent increase or decrease after respective 10 and 20 year continuous activities in the United States with the input resources of the amount 22.18 \$/person/year for media campaign irrespective of the difference of the issue of campaign, for simplicity.

3. Social psychology space

In what follows we discuss the feature of the public opinion by using the social psychology space which is an abstract and hypothetical one to give the relative positions of particles from which deduced is the social psychology distance. Such a concept of social psychology or psychological distances have been introduced and widely used in the field of psychology (Holl, 1966, Lewenstein et al., 1992, Latane et al., 1995, Latane and Liu, 1996, Guastello, 2001).

The social psychology distance between two persons regarding a certain issue is an indicator of the similarity (or non-similarity) of the psychological state or the attitude to the issue between the persons. For instance, the social psychology distance is small for two persons if they are psychologically resonant or similar to each other in a psychological state irrespective of the real, physical distance between the two. On the contrary to this, two persons, even if they are neighboring in the real space, are very far from each other in this space when there is a lack of mutual understanding between the two. An arbitrary point in

this space, therefore, corresponds to a specific state of psychology, thought or ideology of a certain issue.

Thus, although this space is utterly an abstract one without any correspondence to the real space, we dare, in this paper, to hypothesize the image of that space as to be analogous to our real space. Moreover we assume the dimension of that space as 2, though it may be of one-dimension or more than 2-dimension. In this case the 2-dimensional space hypothesized as such has no directions. It is the space where only the relative positions between particles, that is the distance between particles, becomes to be a significant variable, so that the radial coordinates from the origin is only the factor which characterizes each particle. There scarcely exist reasonable grounds for these assumptions. Nevertheless, with the introduction of these assumptions, we can grasp the movement of public mind as concrete, visual images and understand the phenomena relating to it more definitely.

When a particle characterizing a person approaches (or leaves from) a point in this space, it means that the psychology of the person gradually moves toward (or becomes apart from) the psychological state just corresponding to that point. Extending further this idea, when we intend to know the effect of some information released into a society regarding a certain thought, we can investigate it in the social psychology space by examining in what manner and to what extent with time the particles approach the position just corresponding to the thought. The distance at some instance between a particle and the position is, thus, an indicator of the influence of the information on the person, or in other words, the extent of persuasiveness by a *persuader*.

In the simulation by the multi-particle model carried out hitherto, the functional form of force exerted between particles is not explicitly given but is determined so as to fit the calculation most properly to the observation. By using the potential form thus determined the estimation has been made towards the unknown region. Although the potential form

widely used so far is the power-law type, the Lenard-Jones type and the exponential type (Hockney and Eastwood, 1988, Greenspan, 1997), we have no information on which of these forms is applicable to our hypothetical space, except for the phenomenological fact that the force becomes strong with the decrease of the distance between particles. Helbing and Molnar (1995) and Helbing et al. (2000) made the quantification of collective human behavior by introducing the force of psychological repulsion with an exponential function in terms of the physical distance between a pair of persons. On the other hand, although Latane et al. (1995) proposed that the psychological force acting between two individuals is inversely proportional to the second power of physical distance (hence the extent of social influence is inversely proportional to the physical distance), it is unclear the precise functional form of the force acting in the social psychology space. We proceed, therefore, by hypothesizing in this paper that the functional form of potential in the social psychology space is of an exponential type. The difference in the potential form would not essentially influence on the qualitative behavior of particle in so far as the force has a characteristic of growing strength with the decrease of distance.

In modeling the evolution of the society immersed in an environment of a specific problem (such as the problem of social psychology regarding the acceptance of nuclear energy, for instance), Ohnishi (2004) has introduced the social psychology space where each individual in the society is represented by a particle interactive with the surrounding particles. According to this model, the change of the individual's attitude to nuclear energy is subject both to the influence from the interaction with other individuals and to the sensitivity on how the individual accepts the thoughts around the problem. The movement of the individual in the social psychology space, that is, the time evolution of his or her attitude was found to be well given by a probabilistic differential equation corresponding to a randomly moving Brownian particle. Namely, the evolution of human mind can be given

by the so-called Langevin equation in the social psychology space. The effect of social education or the effect of persuasion expected when a certain information or thought is offered to the society can, therefore, be quantified and visualized by using such a type of multi-particle model.

4. Mathematical model

As described in the previous section, we assume that in our social psychology space only the relative relation of particles regarding their positions, that is, the distance between particles, is a meaningful quantity so that it is unnecessary to define the origin. In our case, however, for the necessity of formalization, we assume the position of a particle possessing a certain specific trait as our origin and invest the radial coordinates to each particle by taking the origin as a datum point. We can construct one space as such with every issue concerned, and hypothesize the social psychology strength of the specific particle at the origin as the standard of the strength with regard to the issue.

When an individual is characterized by a spherical particle without any structure within it, its motion can be described by the Langevin-type equation in the social psychology space as (Ohnishi 2002)

$$m_i \frac{d^2 \vec{r}_i}{dt^2} = C_1 \sum_k |-\text{grad } \phi_{ik}| H_{ik} + C_2 \Lambda_i \frac{d\vec{r}_i}{dt} + C_3 \left(\frac{T_i \Lambda_i}{\Delta t} \right)^{1/2} \exp(2\pi q \vec{j}) \quad (1)$$

where the suffix i refers to the i 'th particle, $C_1 \sim C_3$ are constants, \vec{r}_i is the position in the space, t the time, m_i the mass, ϕ_{ik} the potential acting between i and k , H_{ik} the attractive (or repulsive) factor whose value is determined depending on the characteristics of i and k , Λ_i the frictional coefficient, T_i the kinetic temperature, Δt the time span of an infinitely small value, q ($\in [0, 1]$) the random number and \vec{j} the unit vector of imaginary number. The summation is taken for all particles including the particle corresponding to the persuader.

Although we intend to simulate the change of human mind induced by a persuader, we leave out of consideration about the precise contents of the information by the persuader, but only consider the direction of the information environment. Each particle is vested the two-valued parity P_i which gives the social psychology state of yes (or approval) or no (or opposition) to the issue of attention, for instance, $P_i=1$ and -1 for the cases of approval and opposition to the information environment, respectively, so that the factor H_{ik} in Eq.(1) is given by $H_{ik}=P_i \cdot P_k$. The interactive potential between two particles, ϕ_{ik} , is assumed to be given by the exponential type as

$$\phi_{ik} = \phi_0 \exp\{(r_0 - r_{ik})/\rho\} \quad \text{when } r_{ik} \equiv |\mathbf{r}_{ik}| > r_0 \quad (2)$$

$$= -\phi_{00} \quad \text{otherwise} \quad (2')$$

where ϕ_0 , ϕ_{00} and ρ are positive constants, r_0 is the core radius of particle within which any particle can not invade, and $\mathbf{r}_{ik} \equiv \mathbf{r}_k - \mathbf{r}_i$. The assumption of non-zero value of r_0 is to mimic the self for every particle.

The persuader p with a parity P_p is also assumed to have an interactive potential with particles as

$$\Phi_{ip} = \Phi_0 \exp\{(r_0 - r_{ip})/\Xi\} \quad \text{when } r_{ip} \equiv |\mathbf{r}_{ip}| > r_0 \quad (3)$$

$$= -\Phi_{00} \quad \text{otherwise} \quad (3')$$

where Φ_0 , Φ_{00} , Ξ are positive constants.

The particle within an influence region ($r_{ip} < R_0$) of the persuader is assumed to flop for its social psychology state from approval to opposition or reverse to this, that is, $P_i = (+1 \rightarrow -1)$. The time variation of P_i is, in this case, given by

$$dP_i/dt = 2 \delta(r_{ip} < R_0) \delta(P_i \neq P_p) \delta(w < W_{i1} \cdot \Delta t) \{\delta(P_i = -1) - \delta(P_i = 1)\} / \Delta t \quad (4)$$

for the persuasion by the persuader, and

$$dP_i/dt = 2 \delta(r_{ip} < R_0) \delta(P_i = P_p) \delta(w < W_{i2} \cdot \Delta t) \{\delta(P_i = -1) - \delta(P_i = 1)\} / \Delta t \quad (4')$$

for the rebellion against the persuader. Here $\delta(x)$ is a function defined as $\delta(x)=1$ for $x=\text{true}$ and $\delta(x)=0$ otherwise, W_{i1} and W_{i2} are the probabilities per unit time for the particle i to change the state, and $w \in [0, 1]$ is a random number.

The quantities W_{i1} and W_{i2} are generally the functions of time; they may have a tendency to take small values in case of a small t or a large t and to take large values around a certain value of t . What functional form those quantities have is dependent on many factors such as the issue and the methodology of persuasion, and the cultural background of the target society. We simulate in this paper by assuming, for simplicity, that those quantities are constant without depending on time.

The first term on the right hand side of Eq.(1) represents the force coming from the interaction with the other particles, giving both an explicit effect from the direct communication among the public and an indirect, implicit effect by the social pressure which tacitly appears in the information environment. This, therefore, is the term which gives a social psychology force to a person who usually senses the state of atmosphere or the climate of the society made by his or her surrounding persons. With regard to the effect of social pressure, we can exemplify it as follows ; the person, who does not identify a sound attitude of his or her own, becomes to follow the decision of the community upon which he or she is based, whereas in the community where the social norm strongly restricts the individual's attitude, he or she is required to follow the collective will of the community, so that the individual scarcely acts with the independent attitude of his or her own. Thus the first term seems to relate to *the collectivity of the community* or the *identity of each individual* in Hofstede's dimension (Hofstede, 1997)..

The second term on the right hand side of Eq.(1) is a force term to resist the change and deny the fashion, sustaining the state of conventional thought so that it corresponds to the *conservation* and the *non-tolerance* (Hofstede, 1997) to a newly appeared matter. The third

term, on the other hand, is a fluctuation term originating from the environmental random forces, which makes the individual to change his or her thought via the matters not directly related to the issue concerned. The strength of this term is, therefore, an indicator to what extent the individual can easily fluctuate his or her opinion by the everyday information. The person, who usually decides his or her opinion based not only on the offered information regarding the issue in problem but the general information surrounding him or her self, would fluctuate his or her opinion depending on the general information. The person who can not establish and maintain a sound opinion of his or her own would also change his or her opinion in light of the everyday information, so that his or her opinion is always perplexed by the general information. Thus the opinion of such persons has usually a tendency to fluctuate. The third term is, therefore, related to the *tolerance of uncertainty* (Hofstede, 1997).

The W_{i1} and W_{i2} in Eqs.(4) and (4'), on the other hand, are the quantities which indicate the easiness and the difficultness, respectively, for the persuader to persuade the public. Namely, they are the indicators to give the easiness and difficultness with which the individual shifts his or her mind state to the opposite side under the influence of information environment, so that they have the meanings similar to the third term of Eq.(1).

5. Determination of constants and method of calculation

We consider hereafter the two dimensional space of social psychology within the square region of each side with $[-1, 1]$ for the sake of visual understanding. On this plane assumed are one persuader at the origin or at a certain point continuously releasing the information to persuade the public, and 1000 particles corresponding to 1000 peoples randomly distributed on the plane at an initial time. Our purpose is to follow the movement of such

particles on the plane, namely the evolution of the macroscopic society composed of 1000 microscopic individuals.

We assume for simplicity $\langle m_i \rangle = 1$, $\langle A_i \rangle = 1$, and $\langle T_i(t=0) \rangle = 1$, and normal distributions with standard deviations 0.3 for all these quantities m_i , A_i and $T_i(t=0)$, where $i=1\sim 1000$ and the carets $\langle x \rangle$ indicates the average of x . Eq.(1) is integrated by the Runge-Kutta method where the time step δt is determined by the condition $\delta t = 0.1 / \max_i(|d\mathbf{r}_i/dt|)$. Moreover adopted are the values $R_0=1.0$, $r_0=0.05$, $\rho=0.2$, $\Xi=1.0$, $\varphi_0=1.0$, $\varphi_{00}=10.0$, and $\Phi_{00}=10.0$, whose values being unessential for qualitative understanding of results.

When the values of constants C_1 , C_2 , C_3 , W ($\equiv W_{i1}=W_{i2}$), and Φ_0 are determined so that the model can approximately reproduce the effect of anti-smoking campaign made in the United States (the effect of an order of 10~20 per cent by the campaign of an order of 10~20 years long, as assumed in Section 2), we obtain the constants such as $C_1=1\times 10^{-5}\equiv C_1^0$, $C_2=5\times 10^{-2}\equiv C_2^0$, $C_3=1.0\equiv C_3^0$, $W=1\times 10^{-2}\equiv W_0$, and $\Phi_0=5\times 10^2$ which are rather arbitrary but can stand well qualitative discussion. In this case the time is in a unit of month.

For the example calculation by this model, we show in this paper to what extent the offer of a certain information to the society is effective for the change of public mind and with what feature the public psychologically react to the information depending on the culture of the society. To estimate the values of the quantities $C_1\sim C_3$ and W corresponding to an arbitrary culture, i.e. an arbitrary country, we introduce Hofstede's dimensions (Hofstede, 1997, 2001, Triandis, 2004, Peterson, 2008, itim International, 2008).

Hofstede (2001, itim International 2008) made a rating of the cultural extent in digital numbers from 0 to 100 (or 104, 110 and 112 according to itim International 2008) with respect to four types of cultural variables for 68 countries in the world. These variables are the power distance index, the individualism/the collectivism, the masculinity/the femininity, and the uncertainty avoidance index. In our model, the constant C_1 gives the extent of

influence from the social climate. This seems to relate to the characteristics of *collectivism* such that “*identity is based in the social network to which one belongs*”, “*children learn to think in terms of we*”, “*high-context communication*”, and “*harmony should always be maintained and direct confrontation avoided*” (Hofstede, 1997, Peterson, 2008).

The constant C_2 giving the extent of resistivity to the change almost directly corresponds to the variable *uncertainty avoidance* which means “*suppression of deviant idea and behavior, resistance of innovation*” (Hofstede, 1997, Peterson, 2008). On the other hand, the constant C_3 gives the extent of fluctuation of the influence from the information environment so that it relates to the extent of suppleness with regard to the acceptance of information. This seems to be considerably close to the characteristics of *weak uncertainty avoidance* such that “*uncertainty is a normal feature of life and each day is accepted as it comes*” (Hofstede, 1997, Peterson, 2008). Therefore in this paper those constants, along with the constant W are determined for an arbitrary country ω in terms of the constants for the United States as

$$C_1^\omega = C_1^0 I'_\omega / I'_0 \quad (5)$$

$$C_2^\omega = C_2^0 U_\omega / U_0 \quad (6)$$

$$C_3^\omega = C_3^0 U'_\omega / U'_0 \quad (7)$$

$$W^\omega = W^0 U'_\omega / U'_0 \quad (8)$$

where the suffixes and subscripts ω and 0 refer to the country ω and the United States, respectively, I is the Hofstede’s value for the individualism and U the uncertainty avoidance index. The prime indicates the supplement value to the maximum of the corresponding variable, for instance $I' \equiv 100 - I$.

In our model, the quantity $|\mathbf{x} - \mathbf{X}|$, that is, the distance for a particle at \mathbf{x} from the persuader at \mathbf{X} ($\equiv \mathbf{0}$), is an indicator of the individual for being persuaded. For the convenience of visual aid, however, we re-define the indicator ξ (called the persuasion

index hereafter) as $\xi \equiv |\mathbf{x}-\mathbf{1}|/(2 \cdot 2^{1/2})$ instead of $|\mathbf{x}-\mathbf{X}|$, where $\mathbf{1}$ is the coordinates corresponding to one of the apices of the social psychology plane considered here. Hence the value $\xi=0.5$ is the state for the individual's thought or attitude just to be identified to the persuader's ones, and the values $\xi=0, 1$ and $2^{1/2}/2(=0.707)$ all correspond to such a state as the particle is situated at one of the apices of the plane, that is, at the position furthest from the persuader's intention.

In the next section, by using those values of constants, we show the results of calculation in terms of various types of culture and discuss the efficiency of the information released by the media or some opinion leaders, namely by the persuader, with the intension to change the state of public mind.

6. Culture dependent persuadability

Simulation calculations are made here for two types of situation for the social environment such as (1) the positive persuasion, that is, the case where the values of the information released by the persuader is the same as the values prevailing in the society, and (2) the negative persuasion, that is, the case where their values are different from each other at an initial time.

6.1 Positive persuasion

Campaigns such as the environmental beatification or the environmental conservation might be the examples for the positive persuasion. In this case the parities of the particles are set equal to the parity of the persuader at the start; $P_p=P_i$ ($i=1\sim 1000$) $=+1$ at $t=0$. All particles are assumed to distribute randomly on the plane and to move in a random direction at first, making complete reflection on the boundaries.

The boundary condition as the complete reflection is owed to the two restrictions. The one is the tacit assumption that the public mind is always influenced by the persuader so

that any particle can not escape from the system considered. The second is the model assumption that the decrease of the psychological volatility, that is, the decrease of the thermal energy of the system, is due only to the second term on the right hand side of Eq.(1), which corresponds to the frictional loss of energy. Under these assumptions either of the cyclic or the completely reflective conditions is to be applied as for the boundary condition, which leads similar results as each other, only making unessential difference. Thus the complete reflection is not due to some requirement from the social psychology but due only to the physical requirement.

The time evolution of the particle system was followed with every set of parameters corresponding to 68 countries for which Hofstede's indexes are given. Table 1 gives the values of constants relating to Hofstede's indexes for some representative countries.

Table 1: Constants Relating to Hofstede's Dimension for Some Representative Countries

Country	Individualism	Uncertainty	C_1	C_2	C_3	W
ω	I_ω	avoidance index U_ω	$(\times 10^{-5})$	$(\times 10^{-2})$	$(\times 10^{-3})$	
Greece	35	112	7.2	12.2	0.0	0.0
Belgium	75	94	2.8	10.2	0.27	2.7
Japan	46	92	6.0	10.0	0.30	3.0
East Africa	27	52	8.1	5.7	0.91	9.1
the United States	91	46	1.0	5.0	1.0	10.0
Singapore	20	8	8.9	0.87	1.6	16.0
Costa Rica	15	86	9.4	9.3	0.39	3.9

Figure 1 shows the features of particle distribution on the plane at some discrete times for Greece, Japan, and Singapore. The Grecian public is promptly persuaded to result in the identification to the persuader. On the contrary to this, the public in Singapore are quite slow in changing their minds and in forming a unified consensus among the public. Moreover in Singapore the fraction of the public who oppose to the issue grows rather rapidly with time so that the social mind remains dispersed with an anti-issued color even at a later time. The evolution of the other countries, for instance the case of Japan is somewhere between those two extremes, where we can see the characteristic feature of particle coagulation; the one group is in the corners of the plane, which indicate the opposition party, and the other around the center which corresponds to the approval party to the persuader.

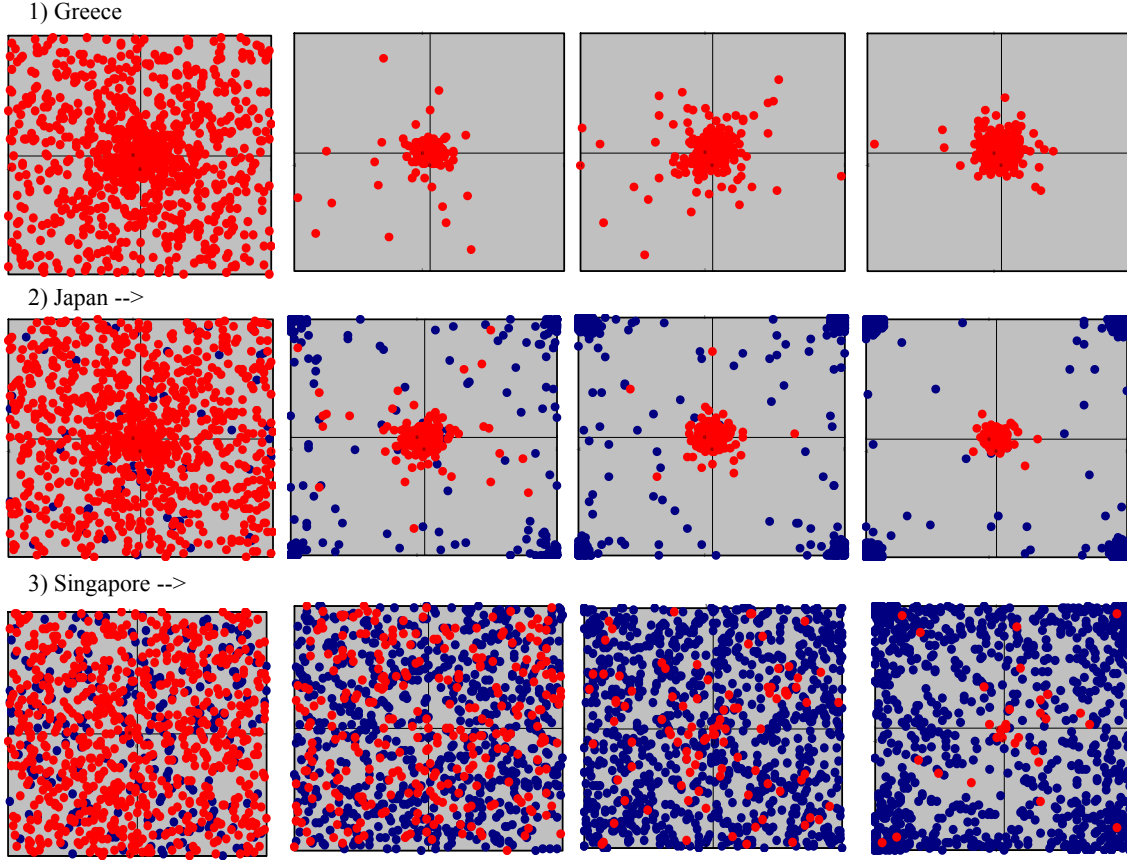


Figure 1: Evolutional features of particle system on the social psychology plane in case of the positive persuasion for Greece (upper line), Japan (middle line), and Singapore (lower line) at $t = 25, 100, 200$ and 350 from the left column to the right, respectively. The center of each figure is the origin where a positive persuader exists. Red dots represent the particles with positive parity, whereas blue dots the particles which changed their parities into negative ones because of the evasion of persuader.

Figures 2 and 3 show the time evolution of the opinion of some specified individuals in representative countries, where 30 curves for the persuasion index ξ (denoted by x_i in the figures) corresponding to 30 persons randomly selected from the system are depicted altogether in each figure. The feature of these figures should be noted to resemble the

feature of the opinion dynamics (for instance Deffuant et al. 2002) at least for the case of Greece. Our feature, however, is much complex and much dynamical as compared with that of opinion dynamics because of the change of parity randomly with time, that is, the effect of the capricious change of mind, and of the introduction of particle-specified values of the traits such as m_i and λ_i which vary from particle to particle. We should note that the case for the United State shown in Fig.3 just corresponds to the anti-smoking campaign in that country because we use the constants derived from that campaign.

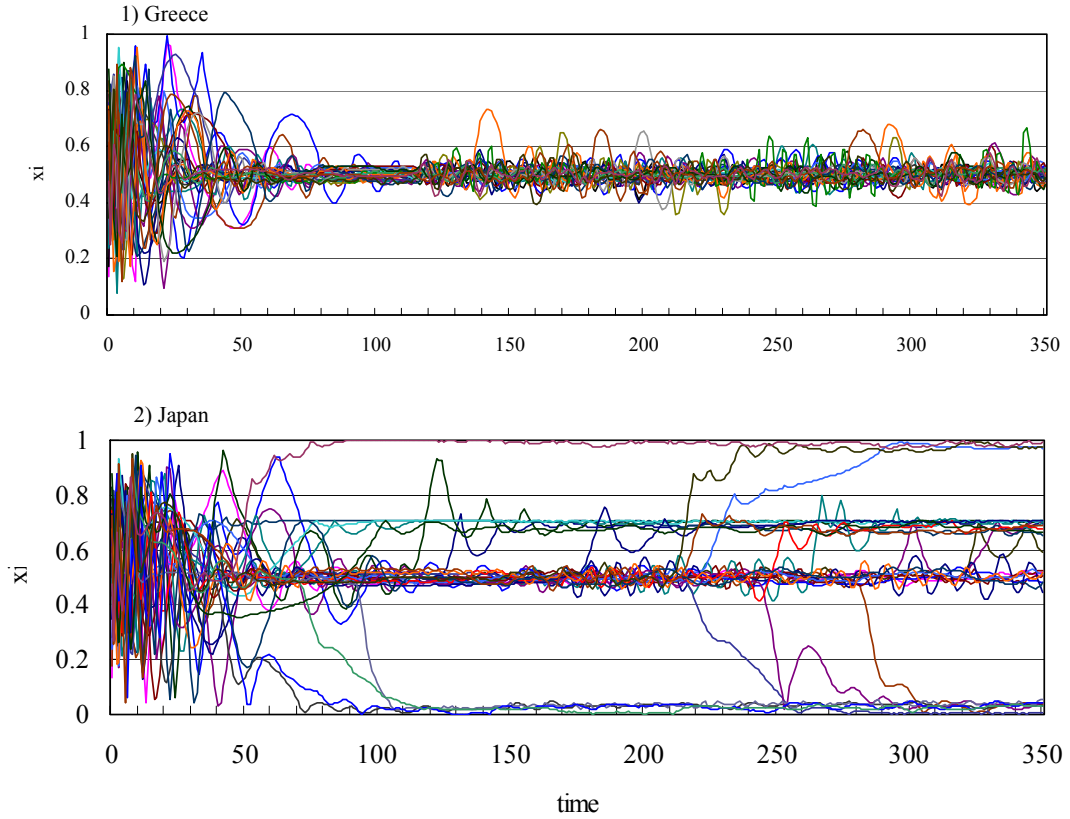


Figure 2: Time variation of the attitude ξ (denoted as xi) for the representative 30 particles in case of the positive persuasion for Greece (upper figure) and Japan (lower figure). The cohesion at $xi=0.5$ corresponds to the coagulation of particles on the positive persuader at the origin, whereas the cohesion at other values of xi to the coagulation of negative particles on the apices of social psychology plane.

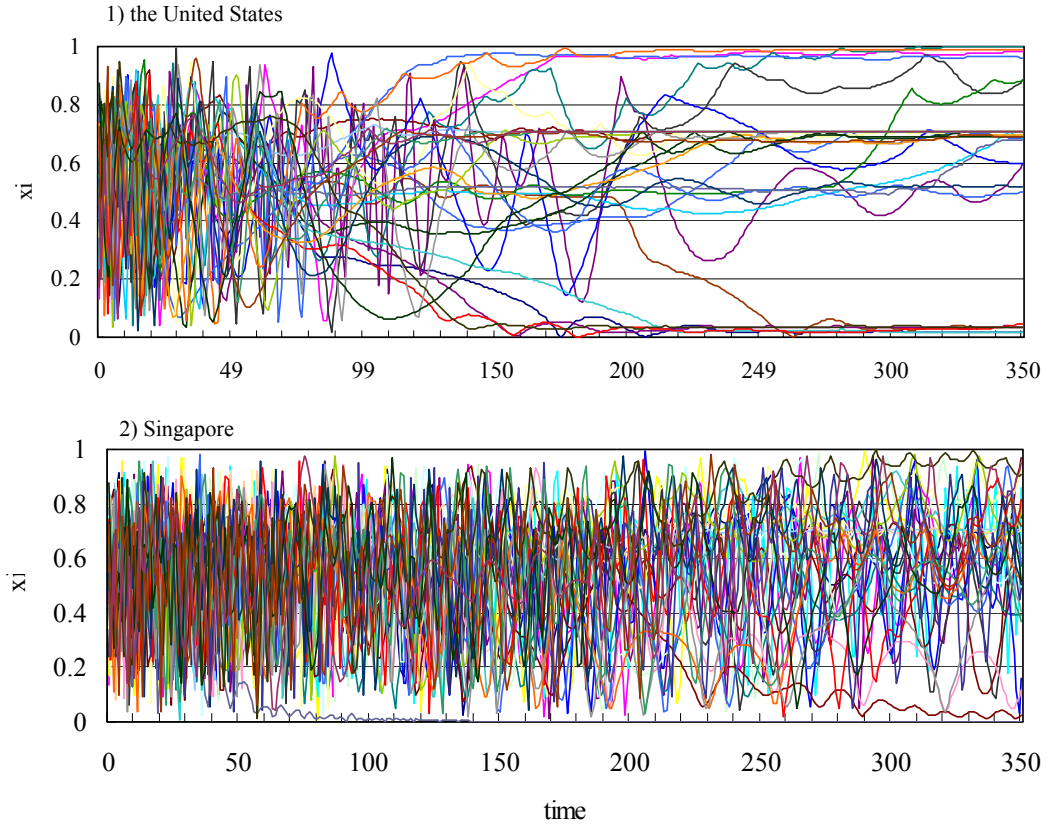


Figure 3: Time variation of the attitude ξ (denoted as xi) for the representative 30 particles in case of the positive persuasion for the United States (upper figure) and Singapore (lower figure).

Culture dependent patterns in Figs.2 and 3 indicate that there exist national characteristics for the persuadability which can be classified into some categories as follows.

1.Greece type: Almost all people are promptly persuaded in less than $t \approx 50$. The psychological fluctuation of the opinion, however, is not neglected after that. The strong collectivism and the extremely strong trend of uncertainty avoidance are the characteristics of this type. The former trait means that, for instance, *collective interests prevails over*

individual interest, or that *opinions are predetermined by group membership*, whereas the latter trait indicates the *strong resistance to innovation*, *the strong conservatism* or the proverb “*time is money*” (Hofstede, 1997) Portugal is also the country classified as this type.

2. Belgian type: Although many people are persuaded up to an early time $t \approx 50$, the number of the people who become repelled against the issue grows non-negligibly in a later time. The people who are persuaded and not repelled are considerably gentle so that they hardly waver psychologically. The strong individualism and the strong trend of uncertainty avoidance are the common characteristics to this type. Here the strong individualism means that, for instance, *everyone is expected to have a private opinion* (Hofstede, 1997). Ecuador, Estonia, France, Hungary, Italy and so on are classified as this type.

3. Japanese type: The persuasion can be almost completed up to an early time $t \approx 50$ although the public who opposed to the issue are not neglected. The psychological fluctuation of the public is not necessarily so large but modest. The strong collectivism and the strong trend of uncertainty avoidance are the characteristics of this type. Many countries in the Central and South America as Costa Rica and Colombia, Czech Republic, Israel, Morocco, Russia, Korea and so on are of this type.

4. East African type: The persuasion of the public is considerably difficult. Once they are persuaded, however, they hardly fluctuate their opinions. The strong collectivism and the weak trend of uncertainty avoidance are the common traits of this type. Here the weak uncertainty avoidance corresponds to, for instance, *the comfortable feeling when lazy, hard working only when needed*, *citizens positive towards political process*, *regionalism* or *internationalism* (Hofstede, 1997). Iran, Ireland, Luxembourg, Malaysia, South Africa and so on are of this type.

5. The United States type: The public move violently on the social psychology plane even after $t \approx 100$, only a bit amount of people gathering to $\xi = 0.5$ in $t > 100$. This indicates the persuasion to be quite difficult. The strong individualism and the weak trend of uncertainty avoidance are the traits common to this type. Australia, Canada, United Kingdom, and so on are of this type.

6. Singapore type: The violent movement of the public continues over $t = 350$ on the plane. There appears a greater number of people who oppose to the issue than who are persuaded in $t > 100$. The persuasion can not be succeeded even when the time elapsed. The strong collectivism and the extremely weak trend of uncertainty avoidance are the common characteristics to this type. Viet Nam, Sweden, Hong Kong, China, India and so on are of this type.

The temperature T_i in our model is of the social psychology, i.e. an indicator of the psychological volatility. This relate to the velocity V_i on the social psychology plane as $V_i = (2kT_i/m_i)^{1/2} = (2T_i/m_i)^{1/2}$, setting a constant corresponding to the Boltzmann constant k as 1.0 for simplicity. The initial condition for the velocity, $\langle V_i(t=0) \rangle = 0$, corresponds to the state that each person lives stationary with a firm opinion of his or her own regarding the issue considered, while in case of $\langle V_i(t=0) \rangle \neq 0$, each person's consciousness varies with time without having a firm opinion. Since in our calculation the particle system is assumed to have an initial temperature $\langle T_i(t=0) \rangle = 1.0$ with $\langle \sigma_T \rangle = 0.3$, it corresponds to a random velocity distribution as $\langle V_i(t=0) \rangle = 2^{1/2}$ at an initial time. In case of the condition $\langle T_i(t=0) \rangle = 0$ (not shown here with figures), the random motions of particles are induced at first in the system, and then the system evolves with a similar feature as in the case of $\langle T_i(t=0) \rangle \neq 0$.

In the case of $\langle T_i(t=0) \rangle \neq 0$, the system is initially in a quite chaotic state irrespective to the difference of culture. To reach a state for the system where the persuader becomes to

grasp the public's mind, it seems to require a finite time, namely, a relaxation time τ_{rlx} for all cultures. For our values of parameters such a time τ_{rlx} has a value around 50~100, which can be guessed from the cases of Greece, Japan, and the United States in Figs.2 and 3.

6.2 Negative persuasion

In this case the parity of the persuader is opposite to the public's one at $t=0$. The society does not consent to the offered information at first so that all the people in the society take a repulsive reaction. The case is an example for such a situation where some authorized power prohibits the public the use of the natural resources because of its conservation, which, however, the public have used for a long time as their own right.

Figure 4 shows the distributions of particles at some discrete times for Japan, the United States, and Singapore. As before, the particles coagulated at the corners of the plane correspond to the public who oppose to the information released from the origin. Moreover, Fig.5 depicts the features of the evolution of the public opinions for Japan, the United States, and Singapore.

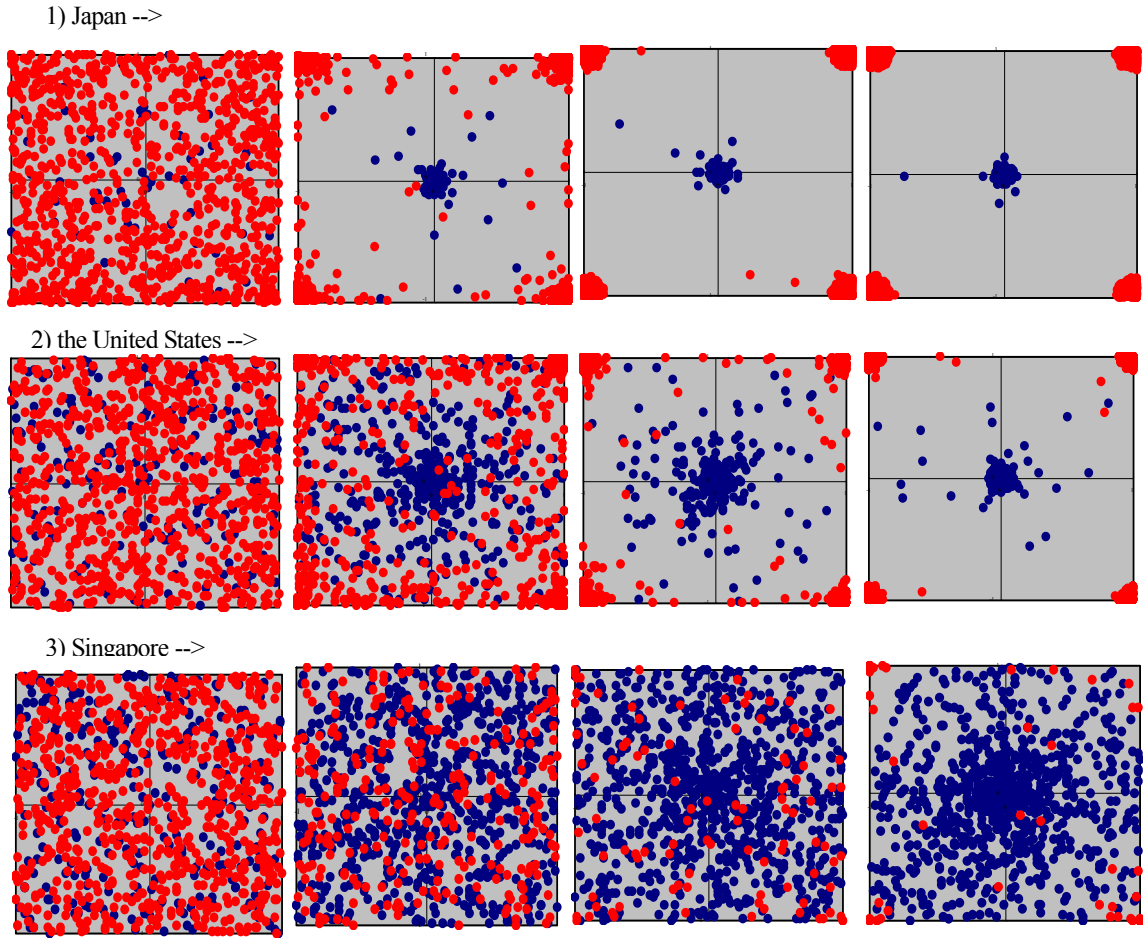


Figure 4: Evolutional feature of particle system on the social psychology plane in case of the negative persuasion for Japan (upper), the United States (middle), and Singapore (lower) at the time $t = 25, 100, 200$ and 350 from the left column to the right, respectively. The red dots represent the particles with positive parity, whereas the blue dots the particles which changed their parities into negative ones under the influence of persuasion by the persuader.

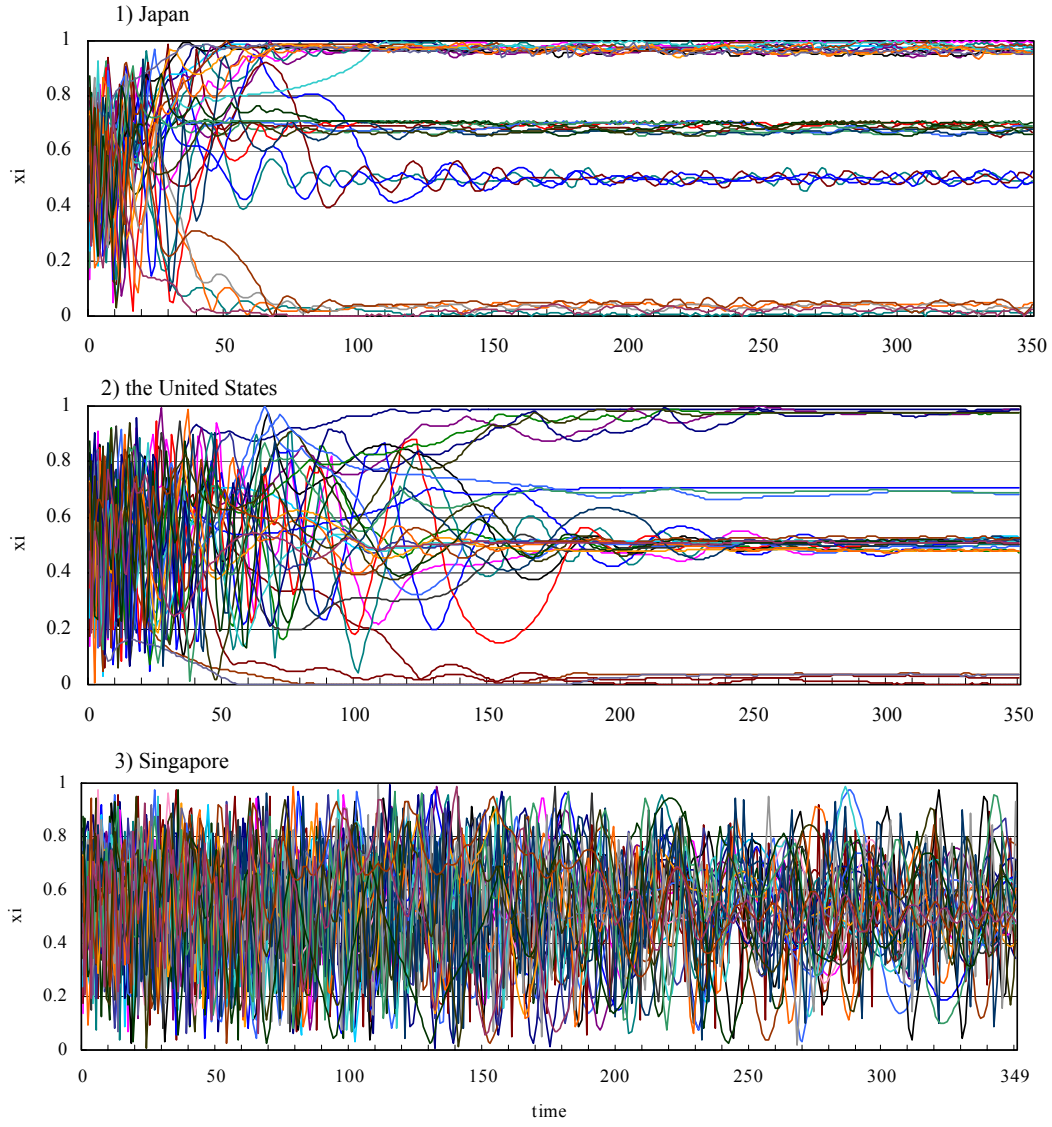


Figure 5: Time variation of the attitude ξ (denoted as xi) for the representative 30 particles in case of the negative persuasion for Japan (upper), the United States (middle), and Singapore (lower). The meaning of the value of xi is the same as in Figure 2.

To make the results further quantified, we define the efficiencies of persuasion $\eta_+(t)$ and $\eta_-(t)$ for the positive and negative persuasions, respectively, which are the fraction of particles coagulated within the radius 0.05 of the origin. For the case of positive persuasion, the quantity $\eta_+(t)$ gradually increases with t , becomes maximum at some time τ , and then decreases with time due to the estrangement of the public mind. On the other hand for the case of negative persuasion, the quantity $\eta_-(t)$ decreases at first, becomes minimum and then increases with time to asymptotically approach to a final value $\eta_-(\infty)$, after it passes the point $0.9\eta_-(\infty)$ at a certain time τ . Such a behavior of $\eta_-(t)$ as it becomes minimum once a time is due to the time-delayed appearance of persuasion effect.

We show in Fig.6 the features of $\eta_+(\tau)$ and $\eta_-(\tau)$ which are made of 68 cultures. Each data point on these figures is the average of only two trials made with different random number series so that the points scatter rather considerably. Nevertheless there appears a clear trend such that the different group of categorization occupies different regions from each other on those diagrams. Moreover there seem to obey a power law or an exponential relation between $\eta_{\pm}(\tau)$ and τ , although they are within the limited ranges of η_{\pm} . The further situates the nation on the leftward side on the η - τ diagram, the easier becomes the persuasion in the positive atmosphere, but on the contrary, the harder in the negative atmosphere. This, however, does not necessarily mean that the persuasion in a positive atmosphere is more effective than a negative atmosphere for every country.

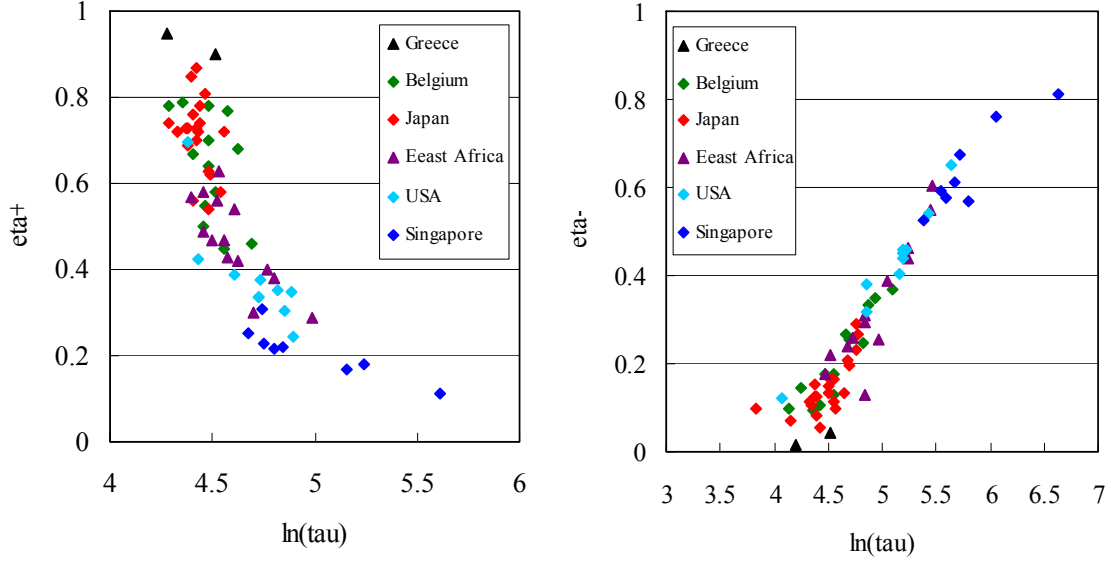


Figure 6: Relation between the efficiency of persuasion η and the time for its realization with cultural categories for positive (left) and negative (right) persuasions.

As one of the techniques of risk communication (Lundgren and McMakin, 1998), the negative communication has been applied when one wants to propagate a certain type of products or technologies in the society, where the persuader positively announces the risk to use the products or the technologies together with the necessity of them in the society and the persuader's endeavor paid to reduce the risk. Such a situation almost corresponds to the negative persuasion in our case. Our results indicate, therefore, that which of the methods of negative or positive communications is more effective depends not only on the issue concerned but also on the culture of the society, that is, the national characteristics. Namely, the positive communication is more effective than the negative method for the nations of the types of Greece, Belgium, Japan, and East Africa, whereas the negative one is more effective for the countries belonging to the types of the United States and Singapore.

7. Simulation of the persuasion in a small-scale community in Costa Rica

7.1 Present situation of persuasion in Costa Rica : case studies

The following examples for persuasion activities in Costa Rica are for the cases by the Japanese dispatched during 2 years to Costa Rica to make technological transfer in the fields of (1) car maintenance and (2) occupational therapy under the social environment of quite different ways of thinking and values from those of Japan. These can be modeled as the negative persuasion by the persuaders with a different culture, therefore with a different parity from those of the surrounding communities.

A car engineer Kato had taught about 20 Costa Ricans the car maintenance technology at a service station in Costa Rica every day (Kato, 2006). In the beginning he was surprised by their deficiency of fundamental knowledge on the car mechanism, the lack of safety conception, the badness of working environment and the disorders of working place, together with the incompleteness of management so that he had insisted every day the importance of the safety in the maintenance work to the surrounding Costa Ricans. Although there existed no such concepts originally in the Costa Rican society (Biesanz et al., 1999), persons surrounding him became gradually to recognize the importance of safety so far as he had guided it. Kato had activated so as to make a new culture such that the engineers should continuously keep the safety concept in the work of car maintenance even when he left that service station. In this case Kato's persuasion activity can lead the Costa Ricans not only the new knowledge and technologies on the car maintenance but also the utterly new concept as the safety in the working place which never originally exist in the Costa Rican's society. This can be interpreted as that the Costa Ricans coagulated at the safety concept of Kato.

An occupational therapist Yoshikawa had contacted during 2 years about 10 therapists at a school for handicapped children in Costa Rica and taught them the methodology, the ideal method along with the knowledge and technology for the occupational therapy (Yoshikawa, 2007). From the beginning she had endeavored to share the recognition common to all members of therapists by continuously talking and discussing with them, and holding training courses repeatedly so as to get the members more fundamental understanding. Through those processes the members became to recognize anew the meaning and necessity of their own work, which had been vague before. The members gradually recognized that Yoshikawa was an important and indispensable person for their school. At the end of her 2 year activity, the members became to be able to move actively and independently with a common object of their own along the methodology which Yoshikawa intended in the beginning. In this case the member sympathized and resonated with the thought of Yoshikawa and coagulated psychologically at the position of Yoshikawa. After the leave of Kato and Yoshikawa from their working places, however, there exists no information on what state appeared on the staffs and the members.

In what follows investigation is made by using the parameters of Costa Rica on how each member of a small-scale community reacts social-psychologically when the persuader with a different sense of values from that of the community makes a persuasion activity on a certain issue.

7.2 Model assumption

Studies are made here (1) in what manner each member of a community reacts when the persuader releases the information to the community, (2) what measure is required for the community to sustain the member's new attitude after the member changed his or her

attitude according to the persuasion, and (3) what extent of the persuasion effect is expected in terms of the strength of persuader and the period of persuasion.

The values of constants used in the previous section are for the system with $n=1000$. When the quantity n takes an arbitrarily small value corresponding to a local community or a social group, the scale lengths of the potential are to be modified as a function of n , in order to make the strength of force acted on each particle independent on n . Namely

$$\exp\{(r_0 - r_{ij,n})/\Xi_n\} = \exp\{(r_0 - r_{ij})/\Xi\} \quad (9)$$

where $r_{ij,n}=(1000/n)^{1/2} r_{ij}$, and the factor $(1000/n)^{1/2}$ is a scaling factor. In the case of $r_0 \ll 1$, therefore,

$$\Xi_n = (1000/n)^{1/2} \Xi \quad (10)$$

and, also for the scale length ρ , we have

$$\rho_n = (1000/n)^{1/2} \rho \quad (11)$$

Here the suffix n refers to the n -particle system and letters without any suffix to the 1000-particle system. In this case the unit of time Δt_n^U becomes to

$$\Delta t_n^U = (n/1000)^{1/2} \Delta t^U \quad (12)$$

In what follows, investigation is made with the system $n=30$ under the condition of negative persuasion. Since, in a previous section, the unit of time Δt^U is month, the unit time becomes to $(30/1000)^{1/2}$ month ≈ 5 days in this system. The 30 particles are initially distributed randomly on the social psychology plane with the same parity $P_i=+1$ to each other, so that the coordinates of their average consciousness is very close to the origin. The persuader with the parity $P_p=-1$ is assumed to situate at the position (0.5, 0.5) at this time, not at the origin, so that the intension of the persuader is different from the social consciousness at first. Here (0.5, 0.5) expresses the position apart from the origin by 0.5 both in the vertical and horizontal directions when a rectangular coordinates are assumed for convenience in our social psychology space as seen in Figs. 1 and 4.

In this section we differentiate *opinion* from *attitude*. The change of opinion is defined here as the state of change of the consciousness, accepting the persuader's values quite different from one's original view of values, whereas the change of attitude is defined as the change of the way of practical behavior according to the different view of values. The change of parity in our model corresponds to the change of opinion and the coagulation of the particle to a certain point indicates the change of attitude. As an example regarding the environmental problem in a local community, the public had not a custom to separate rubbish from the family by type. According to the persuasion by a persuader, however, they understood the necessity and importance of the separation of rubbish. In such a situation, when they do not take any action for separating rubbish, their change is only of the state of opinion change. While on the other hand, when they take action in a real life, their attitudes are said to be changed, which is the final intension of the persuader.

Although the strength of persuasion, that is, the magnitude of the pre-factor Φ_0 of the potential given by Eq.(3), was determined in a previous section so as to reproduce the effect of the anti-smoking campaign carried out in the United States, it is unclear to what amount of resources and information it concretely corresponds. Notwithstanding its non-quantifiability, we define the strength of that case as 500 as before, as a standard also in our case study:

$$\begin{aligned} & \text{Average extent of the maximum exposure of persuasion on one person per year in} \\ & \text{the long term anti-smoking campaign in the United States} \equiv 500 \end{aligned} \quad (13)$$

In our simulation, the strength of persuasion Φ_0 , rewritten as Φ_n for the n -particle system, is assumed as

$$\Phi_n = \Phi_{n1} \quad \text{when } t \leq t_0 \quad (14)$$

$$= \Phi_{n2} \quad \text{when } t_0 < t \quad (15)$$

where Φ_{n1} , Φ_{n2} ($<\Phi_{n1}$) and t_0 are constant parameters so that the persuasion is made in a step function-like manner, abruptly changing its strength at a time t_0 . Such a form of strength mimics the situation of the persuader who continues the persuasion up to the time t_0 with the mode 1, changing its mode after that, or after the time t_0 ceasing to make the persuasion if $\Phi_{n2}=0$. Moreover assumed is the probability for the particle to change its parity under the influence of the persuader, W_n , which varies depending on the strength of the persuasion, as

$$W_n = (\Phi_n / \Phi_0) W. \quad (16)$$

The constants C_1 , C_2 , and C_3 , on the other hand, are set the values corresponding to Costa Rica according to Eqs.(5)~(7).

7.3 Simulation results

Figure 7 shows the evolutionary feature of the opinions for all members of the community in case of the absence of the persuader; $\Phi_{n1} = \Phi_{n2}=0.0$, together with the distributions of particles on the social psychology plane at some discrete times. The parity is +1 for all particles, which is unchanged with time. The system is quite chaotic in $t<100$. Although there remain some particles with high volatilities after the elapse of the relaxation time τ_{rlx} (≈ 80), a consensus is gradually formed in this community. With the values of parameters used here, a completely unified attitude is formed in this community at around the origin in $t>250$, which is the average of the public opinion at $t=0$.

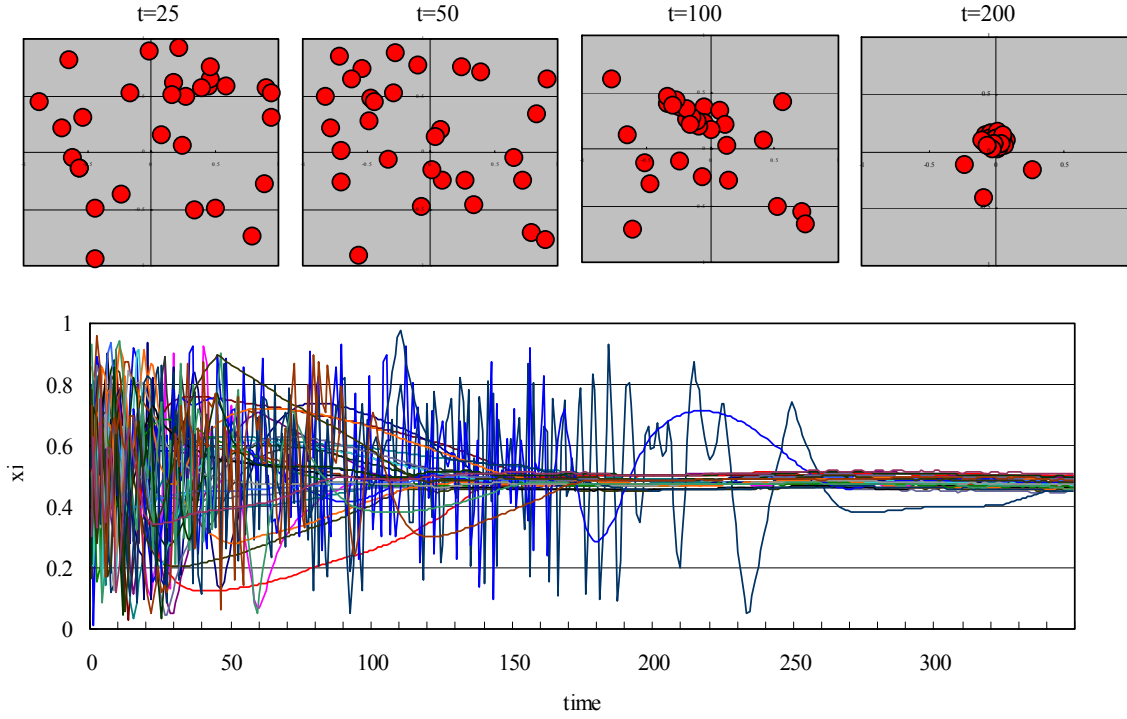


Figure 7: Evolution of the Costa Rican's community when there exist no persuaders ($\Phi_1=\Phi_2=0.0$). The upper part is the particle distribution on the social psychology plane at four discrete times, whereas the lower part is the evolution of opinions of the community member, where the cohesion at ξ (denoted as xi) =0.5 corresponds to the coagulation on the origin of the plane.

Figure 8 shows the evolution of public opinion, along with the particle distribution at some discrete times under the condition of $\Phi_{nl}=500$, $t_0=\infty$, which is the same condition as used in the previous section. Since the persuader situates at (0.5, 0.5) at this time, the coagulation of attitude to $\xi=0.25$ corresponds to the success of persuasion, whereas the people not to be persuaded locate at the positions far from the persuader in a psychological sense.

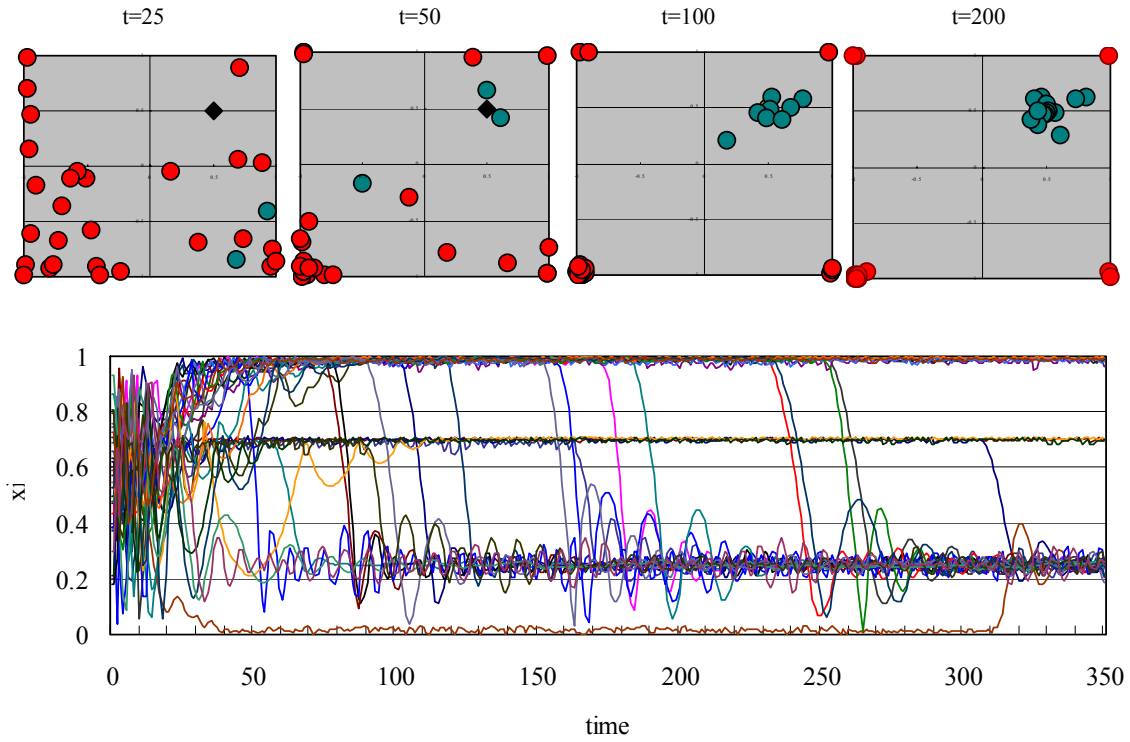


Figure 8: Evolution of the Costa Rican's community when there exists a negative persuader (shown by a black rhombus) at the position $(0.5, 0.5)$ with the strength $\Phi_1=500$ at all times up to $t=350$. Red circles represent the particles with positive attitude and green circles are the ones whose parities were changed by the persuasion. The cohesion at ξ (denoted as ξ_i) $=0.25$ corresponds to the coagulation on the negative persuader, whereas the cohesions at other values of ξ to the coagulation on the apices of the social psychology plane.

Figure 9 shows the case of $\Phi_{n1}=500$, $\Phi_{n2}=0.0$, and $t_0=100$, where the persuader disappears at $t=100$, and no information is offered after that. As seen in this figure, the particles coagulate up to $t=100$ at the position of the persuader, suddenly cease to coagulate with the disappearance of the persuader, resulting in the psychological dispersion in $100 < t < 250$. Although these particles become to coagulate self-organically again in $t > 270$, the position of the coagulation is different from its previous position, that is the position of the persuader in $t \leq 100$. This indicates that the existence of the persuader in the community is

necessary for the public in order not only to change their opinions but also to sustain their changed attitudes as they are. In the community where the persuader disappear halfway, the state of the unified consensus, which is re-formed within the people who have changed their opinions is determined depending on the position of another consensus formed in the group whose member did not change their opinions. Namely, it is subjected to the relative strength of forces between the particles with changed and unchanged parities.

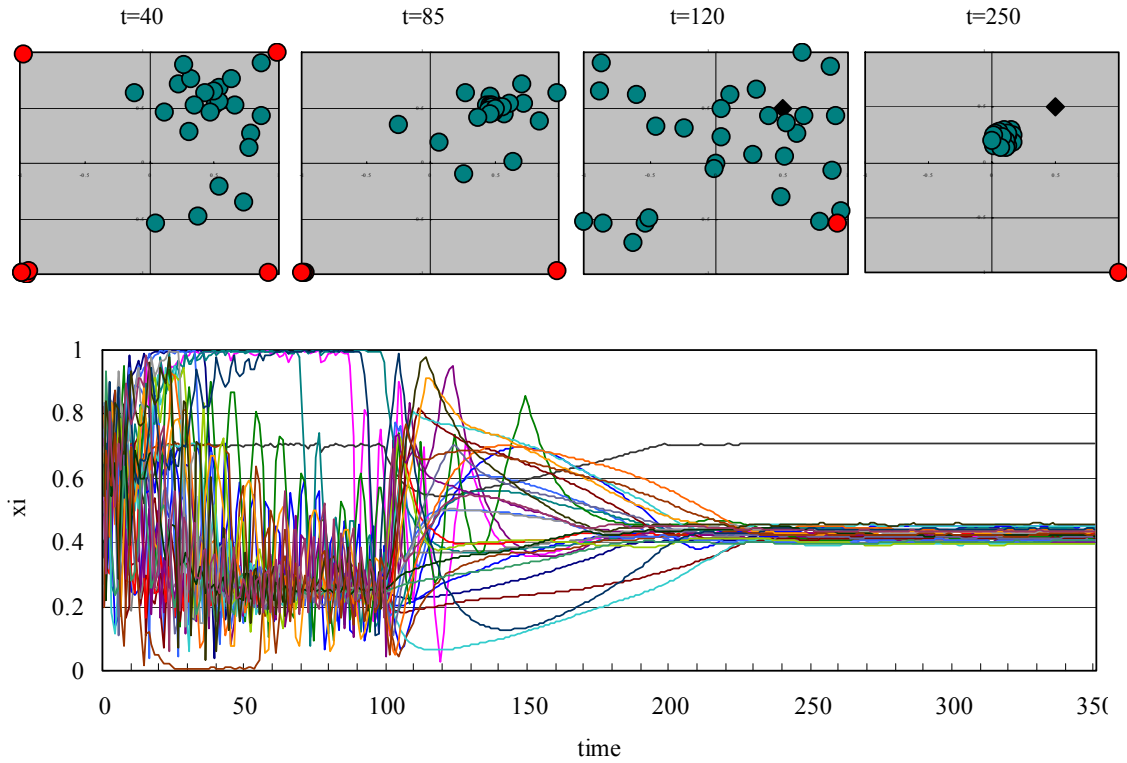


Figure 9: Evolution of the Costa Rican's community when there exists a negative persuader at $(0.5, 0.5)$ on the social psychology plane with the strength $\Phi_1=5000$ only in $t \leq 100$, which disappears in $t > 100$.

After the disappearance of the persuader, in order to sustain the public's attitude at the position where the persuader intended at the beginning, it is sufficient only to put a

certain substitute to the persuader, called a substituter hereafter, at the persuader's position, which continuously attracts the public's attention. The strength of the substituter never need to be strong as the persuader. Figure 10 shows the evolution of the community, together with the states of particle distribution under the condition of $\Phi_{n1}=5000$, $\Phi_{n2}=5$, and $t_0=100$. We can see in these figures that, after $t=100$, coagulated particles once rapidly disperse over the plane, gradually coagulate again to form a firm coagulation around the substituter who situates the same position as the persuader.

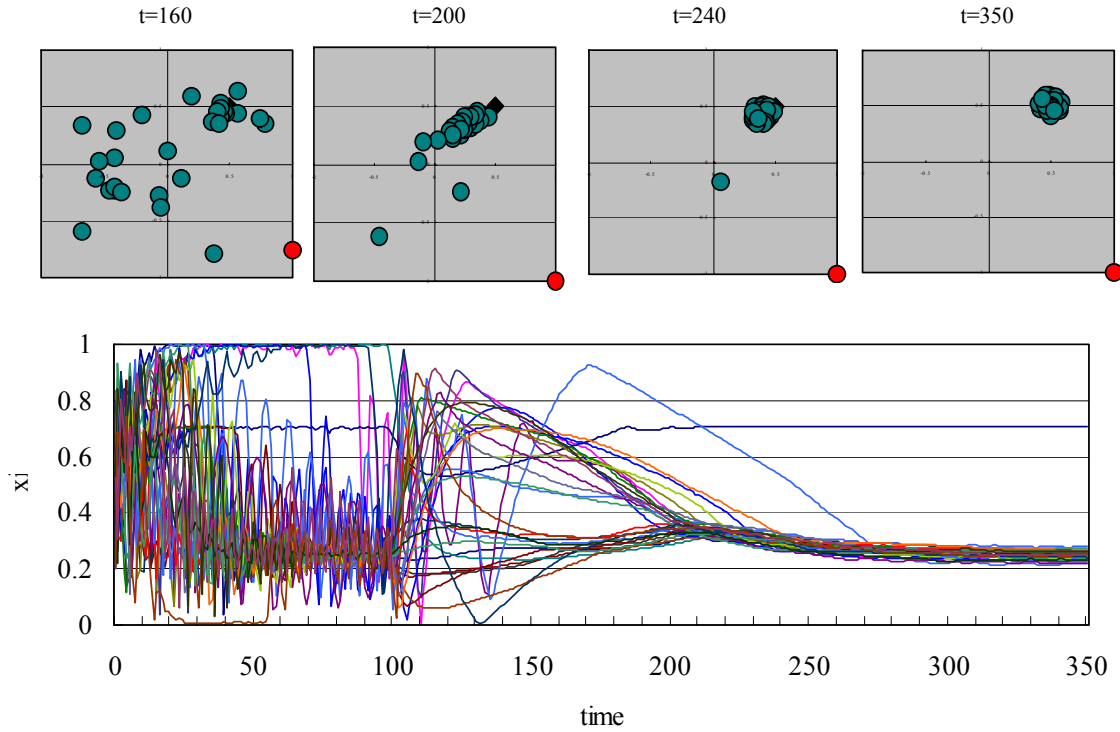


Figure 10: Evolution of the Costa Rican's community when there exists a negative persuader with the strength $\Phi_1=5000$ in $t \leq 100$, and a negative substituter with $\Phi_2=100$ in $t > 100$ both at the position $(0.5, 0.5)$.

From these calculations, the followings become clear.

(1) The persuader has a function to change not only the public's opinion, but also their attitude after a finite time.

(2) In the case where the persuader disappears from the community or ceases to persuade, the public consensus rapidly disperses in a psychological sense. The public attitude cultivated up to that time, therefore, also disappears.

(3) The public consciousness becomes to coagulate again after a finite time to result in a unified consensus or a unified attitude. These are, however, not the same as the original ones any more.

(4) To make coagulate again the public consciousness to the intended point of the persuader, it is required to put a substitute to the persuader at that point.

(5) A substituter even with a sufficiently weak strength as compared to that of persuader can act as an attractor of the public consciousness. After the disappearance of the persuader, therefore, it is necessary only to offer continuously the weak messages with that intension to the community via the various types of the mass media and/or the opinion leaders.

Under the existence of the substituter only with a negligibly weak strength, we have seen heretofore that a finite fraction of the public in the community sustains the attitude as the persuader intended at the beginning. That fraction realized after a sufficiently long time, that is the efficiency of the persuasion, ε , depends, in our model, on both the strength Φ_{nI} and the duration of the persuasion t_0 , scarcely depending on the strength of substituter so far as it is negligibly weak. Figure 11 shows the relation between Φ_{nI} and t_0 for given values of ε , where plotted are the values averaged over the results of two trials, for simplicity, by selecting different set of random numbers. From this figure, we can deduce the following experimental relation about the input quantities Φ_{nI} and t_0 and their resultant efficiency ε as

$$\varepsilon = \text{MAX}[\text{MIN}\{0.317 \ln(3.16 \times 10^{-5} \Phi_{nI} t_0^{1.1}), 1.0\}, 0.0] \quad (17)$$

$$= \text{MAX}[\text{MIN}\{0.317 \ln(0.109 \Phi'_{nI} (t'_0)^{1.1}), 1.0\}, 0.0] \quad (18)$$

where $\Phi'_{nl} \equiv \Phi_{nl}/500$ and t_0' is the time in month. In the case where the system is sufficiently large ($n \gg 30$), the probability for an arbitrary person to change his or her opinion is, in our model, approximately proportional to the product $\Phi_{nl} \cdot t_0$ so that the relation $\varepsilon \propto \Phi_{nl} \cdot t_0$ holds so far as the ε is not so large. The reason why the above equation does not show such a simple relation is only due to the small, finite system as $n=30$ in our case.

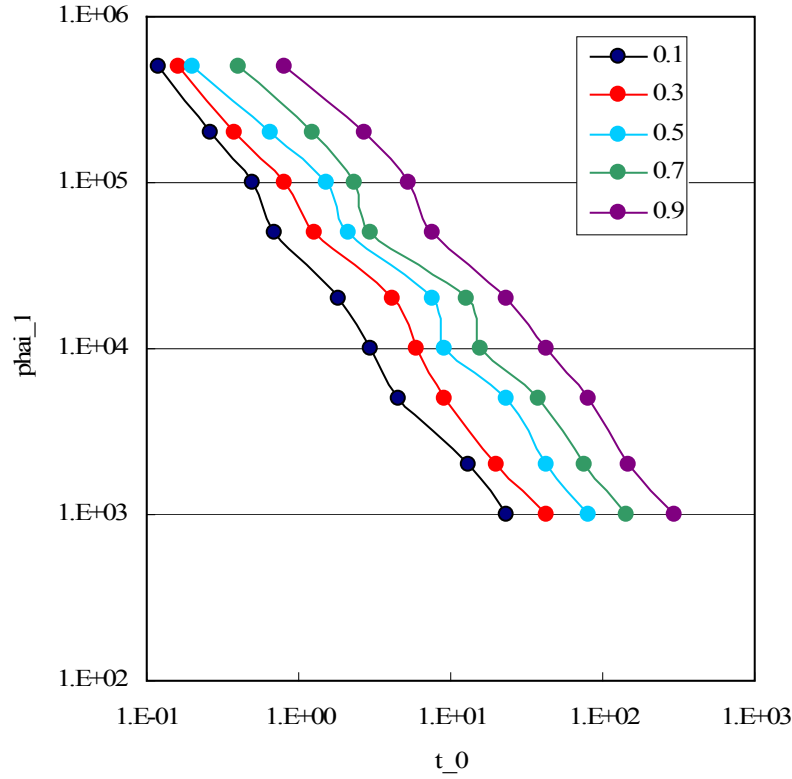


Figure 11: Relation between the strength of persuader Φ_1 and the duration of the persuasion t_0 to attain the efficiency ε ($=0.1, 0.3, \dots, 0.9$) in the Costa Rican's community.

8. Concluding remarks

In our model the origin of the social psychology space is an abstract point where a certain subject situates, intending to propagate a certain thought or spirit in the society. Hence our model is applicable to estimate the effects not only of some types of social educations or the commercial advertisements but also of the activations for propagating some specific thought in politics. In the latter case we can derive the time varying approval rating of that political thought. When we talk about such approval ratings for the form of government or for some sort of Zeitgeist, their maximum values attainable during a long time unquestionably depend on the national characteristics as seen in Fig.6. Namely the political thought supported by the nation, whenever it is sustained stationarily, resonates just with the national characteristics, so that there exists one stable form of government for each nation at a time. In this case when the national characteristics change with time, the form of government or some thought or spirit must also change their standpoints with the public so far as they intend to survival. When they intend to obtain an approval rating which exceeds its maximum allowable value, there appear strains and conflicts in the society which may bring the instability of the society. We have seen so many examples of this case such as the rise of the Nazism in Europe or the socialism and the fall of them when they isolated from the public mind. In connection with this, we further notice that the disintegration of Yugoslavia after the death of the President Tito, who had played a roll of attractive persuader, is also another example for the appearance of instability which can be understood with our model.

According to our calculation, the relaxation time τ_{rlx} for the persuasion is almost constant, of around 80 with scarcely depending on the culture. This indicates the existence of a threshold time for the public to establish their opinions to an issue when they are immersed in an information environment of a new issue. Stevenson and Vavreck (2008) pointed out that the effect of political campaigns appears in European countries only in the

cases of duration longer than about 6 months, indicating the relaxation time is about 6 months in this case. Although the time $\tau_{rx} \approx 80$ in our case corresponds to 80 months, the unit of time Δt^U varies depending on the strength of the persuader, that is, the quantity Φ_0 in our model. In the case when the social psychology force from the persuader is much stronger than the interpersonal force and the contribution from the first term on the right hand side of Eq.(1) exceeds that from the second and the third terms, the quantity Δt^U is approximately proportional to $\Phi_0^{-1/2}$ according to Eq.(1). The strength of the persuader in the political campaign in Europe, Φ_0^E , therefore, is estimated as $\Phi_0^E = (80/6)^2 \Phi_0 \approx 180 \Phi_0$ in so far as we assume the necessity of relaxation time for the public acceptance for any arbitrary issue and the public reaction of that sort is commonly expressed by Eq.(1). Such a strength Φ_0^E corresponds to the monetary amount S as $S = 180 \times 22.18 \text{ \$}/\text{person}/\text{year} \approx 4000 \text{ \$}/\text{person}/\text{year}$ with the standard of price of the year around 2000, because the strength Φ_0 for the anti-smoking campaign corresponds to the expense 22.18 $\text{ \$}/\text{person}/\text{year}$. The amount 4000 $\text{ \$}/\text{person}/\text{year}$ seems to be too large even when we consider the possibility of the concentrated input of resources into the target society in a limited period of time in case of the political campaign. We should note, however, that this is the case where the public are exposed only by the direct effect of campaign.

During the relaxation time, each individual makes communication with surrounding persons to determine his or her own opinion. In the case when the effect of such indirect, mutual communication is q times the direct campaign effect in establishing the public opinion, the monetary amount expended for the political campaign in Europe is estimated as $S = \{4000/(1+q)\} \text{ \$}/\text{person}/\text{year}$. By giving the amount of resources S really input in the campaign in the past, we can obtain the extent of the indirect campaign effect, that is, the amplification factor q of the persuasion by the mutual communication, which is expected as $q \gg 1$. The situation is the same as each other both for the persuasion activity and the

political campaign. The success or failure of persuasion, therefore, depends on how effectively the limited amount of resources is used in the target society, or in other words, on how efficiently the persuader make the concerned issue a current topic which enables the factor q to increase. We can find valuable indication for this problem in the successful examples of health campaign described in Section 1 where the interpersonal communication played a significant role in enhancing the q .

With our value of Φ_0 (=500), the effect of about 10 per cent reduction of prevalence is attainable by the 10 year continuous anti-smoking activity in the United States. To make our estimation more quantitative, we need quantitative information on the relations between Φ_0 and the expense, between the expense and the effect, and between the effect and the campaign length in cases of the issues other than the anti-smoking activity in various cultures. The quantity Φ_0 relates to the quantity of matters which the persuader inputs to the society, for instance, the labor of the persuader including his or her enthusiasm, the resources input to the paid advertisements, the expense for preparing materials and so on. We need to estimate the total amount of those resources in terms of money, some of which, such as the labor and enthusiasm, are difficult to estimate. We can not make quantitative estimation of the effect of persuasion even by using a simple mathematical model like ours without clarifying such relations which hold in a target society. To make verification of the calculation regarding the long-term effect of persuasion, we are now planning to investigate the actual situation for several cases in Costa Rica including the ones shown in Subsection 7.1.

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