THE IMPACT OF DYNAMIC NETWORK STRUCTURE AND HOMOGENEOUS EMBEDDEDNESS ON CULTURAL POLARIZATION

by

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ABSTRACT

YUNSUB LEE. The impact of dynamic network structure and homogeneous embeddedness on cultural polarization. (Under the direction of DR. JOSEPH M. WHITMEYER)

In this study, I use a computer simulation model to investigate one possible process of cultural polarization in modern society. Numerous studies have used computer simulation models based on the principle of homophily to explain the process of cultural or political polarization and convergence. Most of these assume (1) network structure is fixed and (2) an actor's ecology, in terms of possible interactions with others, is randomly decided. In contrast to (1), I assume network structure to be dynamic such that it consists in part of a non-trivial amount of non-structuralized, i.e., temporary, weak ties. I take this to be a reasonable assumption because the development of institutional certainty has improved levels of generalized trust, and technology, for example, through the development of online communities, has made it possible for actors to interact with unanticipated actors without the complicated process of building mutual trust. In contrast to (2), I assume that actors are initially embedded in homophily groups. This is because induced homophily (at the macro level) and repeated choice homophily processes (at the micro level) mean that an actor's close ties are likely to consist of similar actors. I investigate the effects of these two assumptions by modifying the simulation model developed by Flache and Macy (2011). The first simulation experiment shows that while structuralized weak ties, commonly used in previous studies, lead to cultural polarization, non-structuralized weak ties and homophily subnetworks tend to produce cultural convergence. The second experiment suggests why this is so. When weak ties are structuralized, the influence from dissimilar actors, which produces polarization, is always stronger than the influence from similar actors. When weak ties are non-structuralized, the early influence of similar actors tends to be stronger, which, coupled with the push toward convergence from the homophily subnetwork, tends to produce convergence. In the third experiment, I suggest two new models of cultural polarization, based on the findings from the second experiment: 1) a mixed model with non-structuralized and structuralized weak ties, and 2) a model with non-structuralized weak ties under a firmly polarized cultural value. The two new models exhibit polarization results and processes not seen in previous simulation studies. They constitute potential new theoretical models for cultural polarization in modern society.

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INTRODUCTION

Homophily is the principle that people tend to be more likely to make relationships among similar others than dissimilar others. Typically, the similarity is in terms of social characteristics such as race, gender, education and age (McPherson, Smith-Lovin and Cook 2001; McPherson and Smith-Lovin 2002). Homophily has been classified into choice homophily and induced homophily. Choice homophily is a psychological process: it posits that people prefer to interact with similar others more than dissimilar others. Induced homophily is a structural process: it posits that people are more likely to interact with similar others due to social structural factors (McPherson and Smith-Lovin 1987; Kossinets and Watts 2009).

Linking the homophily principle with the influence of network structure, many simulation studies have explained the emergence of divergence and convergence in social attitudes, political opinions and cultural preferences. Baldassarri and Bearman (2007) show how the choice homophily process operating in a dense network structure can lead to the polarization of political opinions. Axelrod (1997) argues that even with homophilous ties, network structures can produce cultural differences. Mark (1998) shows that homophilous network ties can result in the convergence of cultural preferences. Flache and Macy (2011) demonstrate that weak ties can polarize cultures characterized by homophilous and xenophobic ties, which change actors more similar or dissimilar to other actors.

The simulation studies cited above for the most part assume a fixed network structure or limited dynamic network structure, with the homogeneity vs. non-homogeneity of actors randomly assigned. I propose, however, two alternative assumptions based on what we know about contemporary developed societies. First, an actor's ties tend to be homogeneous. People are strongly embedded in homophily groups in numerous social spaces, such as neighborhood (Massey 1990; Massey and Denton 1988), school (Epstein 1985; Moody 2001; Orfield 2001), work places (Ruef, Aldrich and Carter 2003) and voluntary associations (Popielarz and McPherson 1995; McPherson and Rotolo 1996). In part, this is because the process of induced homophily has a macro structural effect on the likelihood of networks existing, such as in residential segregation, (Massey and Denton 1988) and because the process of choice homophily tends to create a microstructure that can produce selection bias, such as in resegregation (Moody 2001; Reskin 1993). All of this means that actors will not interact at random.

Second, in contemporary society, social network structure is dynamic, not fixed. That is, because many or most people do interact or exchange socially with unanticipated partners, the network structure changes frequently. At least three aspects of modern society have facilitated this dynamism. One is the development of institutions that have reduced the need for commitments to specific relationships in order to secure exchanges, for example, economic exchanges (Cook, Rice, and Gerbasi 2004; Guseva and Rona-Tas 2001). Another is a relatively high level of generalized trust, which allows people to interact and exchange with others without going through the complicated process of building mutual trust (Yamagishi, Cook and Watabe 1998). Third, social media and online communities provide numerous vehicles for interacting easily with others (Smith and Kollock 1999).

It is reasonable to conjecture that these two assumptions will affect cultural polarization. In homogeneous networks, actors easily gravitate to cultural niches in which they are all similar (Mark 2003). Here, weak ties (Granovetter 1973) are the only means through which the cultural similarity of group members can diminish. If weak ties tend to originate in the personal ties an actor already has (Granovetter 1983), for example, as second or third degree connections, then they will be biased, potentially limiting social change even through weak ties. As suggested above, however, in modern society new more-or-less random weak ties may be created more easily, which will affect the social network structures and the variability of those structures

The ultimate goal of this research is to develop a new theoretical model of cultural polarization in the modern society that embodies the above two assumptions. Computer simulation, as used in this research, is a tool for developing theory. Specifically, under a set of assumptions about process, it generates predictions for the effects of varying certain variables.

The simulation model used in this research is a modification of Flache and Macy's Monte Carlo model[1] (2011). Their model suggests an effect of weak ties on cultural polarization that differs from the effect proposed in Granovetter's 1983 theoretical study. Granovetter (1983) argues that weak ties can be a force for cultural integration in society, because weak ties make it possible for non-homogeneous actors to share their different cultures. The long-run consequence is that culture will be integrated. This argument is mainly based on the structural advantage that weak ties have and assumes that social actors generally have a positive attitude toward cultural influence from non-homogeneous actors (homophily process). Questioning this assumption, Flache and Macy (2011) show that if social actors have a negative rather than positive attitude toward different cultures (xenophobic process), the "long range" weak ties that increase the cluster coefficients can make cultures more polarized, not integrated.

[1] Monte Carlo refers to the fact that certain aspects of the process are probabilistic and therefore vary from run to run.

In Flache and Macy's model, an actor's cultural values are assigned at random, and the weak ties are structuralized, that is, made permanent. Our model changes these two conditions. First, actors are embedded in homophily groups; thus, an actor's cultural values are not random. Second, the network structure is dynamic, that is, the weak ties are not structuralized. All other assumptions are as in Flache and Macy's original model. This research examines whether these new assumptions produce cultural polarization effects that differ from those produced by Flache and Macy's original model.

EMPIRICAL STUDIES SUPPORTING THE TWO ASSUMPTIONS

Homogeneous Embeddedness

Numerous studies strongly support the empirical existence of homogeneous embeddedness. I mention here several prominent examples.

Neighborhood: Residential segregation means that people who are similar in important social characteristics such as class, race and age, are highly likely to live in the same space. Residential segregation affects an actor's likelihood of interacting with different kinds of people (Massey 1990; Massey and Danton 1988).

School: Research on resegregation points out that students in schools often segregate by race or economic status although they have the opportunity to interact more broadly (Epstein 1985; Moody 2001; Orfield 2001; Shrum, Cheek and MacD 1988).

Work places: Team selection in work place tends to be based on homophily. Research shows that, controlling for other possible causal factors, homophily has the strongest effect on team selection (Ruef, Aldrich and Carter 2003). In addition, many studies show evidence of gender resegregation in work places (Ibarra 1992; Reskin 1993; Ridgeway 1997).

Voluntary Associations: In voluntary associations as well it is easy to find homophily processes (Popielarz and McPherson 1995; McPherson and Rotolo 1996), including gender resegregation (Rotolo and Wharton 2003).

In sum, in numerous social spaces, actors are strongly embedded in homophily groups and are likely to interact with similar actors. This occurs due to both induced homophily from the macrostructure (e.g., children in school associate with others of the same age), and choice homophily from the microstructure that emerges from repeated choices (e.g., children in high school choosing at which table to eat lunch).

Dynamic Network Structure

Numerous studies show the possibility of weak ties with unanticipated actors in modern society.

Institutional certainty and weak ties: Guseva and Rona-Tas (2001) describe differences between Russian and American credit markets. The lack of a credit score company in Russia meant that banks could not calculate the risk of a loan impersonally. That is, due to uncertainty, financial decisions had to be based on a person's reputation. In the USA, however, since credit score companies provided credit scores as third parties, the risk was calculable, lowering the level of uncertainty, and a bank could base its financial decisions solely on credit scores. Thus, the tie between a banker and a customer could be non-structuralized. Similarly, Cook and her colleagues argued that Eastern European countries were becoming financially more similar to the United States and less to Russia due to the increase in institutional certainty (Cook, Rice, and Gerbasi 2004).

Generalized trust and weak ties: The empirical research of Yamagishi, Cook and Watabe (1998) shows that differences between Japan and the United States in generalized trust make the countries' patterns of social interactions different. In Japan, since the level of generalized trust is lower, people tend to be committed to closed networks. However, in the United States, due to a higher level of generalized trust, people form committed relations less frequently. That is, higher generalized trust makes actors more open to weak relationships.

The development of alternative communities: The number of online communities is increasing. This may facilitate collective action. Moreover, personal identities can be influenced by interactions within online communities (Smith and Kollock 1999). The development of internet reduces the limitation of physical spaces and expands the set of possible interaction partners (Wellman and Hampton 1999).

These studies support the two ideas that in modern society, network structure is dynamic and weak ties can have influence.

THE MODELING FRAMEWORK

Basic conditions (from Flache and Macy (2011))

The situation involves N actors each of whom has states on two values or opinions. The state of agent i on value k, ($k \in \{1,2\}$) is indicated by S_{ik}, which ranges between -1 and 1 ($-1 \leq S_{ik} \leq 1$). Each actor is embedded in a maximally connected subnetwork, i.e., one in which the clustering coefficient of each member is 1. In addition, sometimes some subnetworks may be linked by weak ties, that is, some actors may be able to interact with actors from other subnetworks.

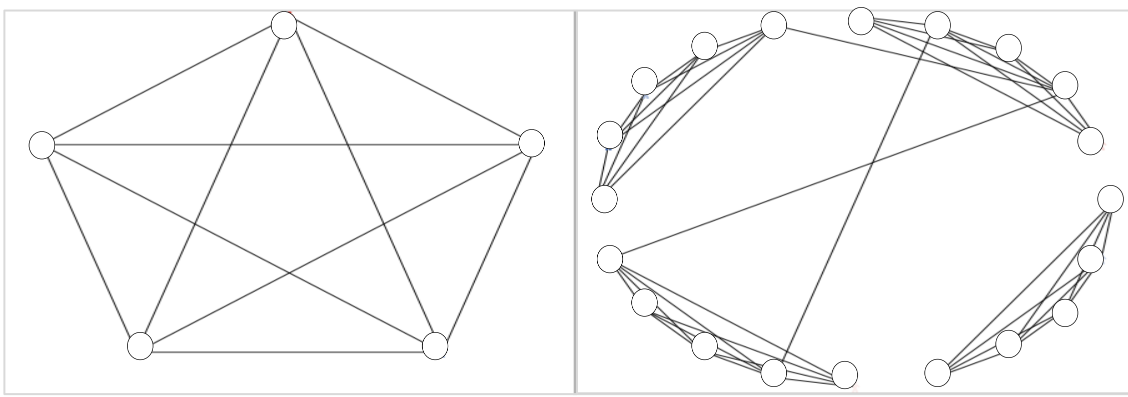


Figure 1: Pictures of closed subnetworks and weak ties

The first picture shows a closed subnetwork. All five actors in the subnetwork can interact with each other. The second picture shows weak ties between subnetworks. There are four closed subnetworks and between the subnetworks three weak ties involving five actors.

Homophily and Non-Homophily processes

The two processes of value change are taken directly from the Flache and Macy (2011) model. If actors A and B are linked and they have similar values (homophily), then their values will become even more similar. Conversely, if they have dissimilar values (xenophobia or non-homophily[2]), then their values will become less similar. The greater the homophily (respectively, non-homophily) is, the greater the change in values will be.

The specific equations, taken from Flache and Macy (2011), are as follows. Homophily or non-homophily in a relationship between actors i and j is indicated by the variable W_{ij}, $-1 \leq W_{ij} \leq 1$. $W_{ij} > 0$ means homophily, with homophily inceasing as W_{ij} approaches 1. $W_{ij} < 0$ means non-homophily, increasingly as W_{ij} approaches -1. $W_{ij} = 0$ neither homophily nor non-homophily characterizes the relationship between the actors. W_{ij} in essence is determined by how close actors i and j are in their values. The formula to calculate W_{ij} at time t is

$$W_{ij,t} = 1 - \frac{\sum_{k=1}^{2} \left| s_{jk,t} - s_{ik,t} \right|}{2}$$

Each value then changes from one time to the next as a weighted sum of positive influences from linked actors to which the focal actor is homophilous and negative influences from linked actors to which the focal actor is non-homophilous. For each value k separately, this is carried out by the following two equations

$$\Delta S_{ik,t} = \frac{1}{2N_{l,t}} \sum_{i \neq j} W_{ij,t} \left(s_{jk,t} - s_{ik,t} \right), \text{where } N_{l,t} \text{ is the number of linked actors}$$

$$S_{ik,t+1} = S_{ik,t} + \Delta S_{ik,t} \left(1 - \left| S_{ik,t} \right| \right)$$

[2] To conceptualize the opposite term of homophily, Flache and Macy (2011) name the term xenophobia. However, xenophobia is commonly used to define the phenomenon that people have extremely negative attitude toward immigrants or strangers (Wimmer 1997; Watts 1997). In order to reduce the possible conflict between two different terms, in this research, I use non-homophily as the opposite term of homophily instead of xenophobia.

The Two Values or Cultural Dimensions

As in the model of Flache and Macy (2011), the simulation model in the proposed research has two values or cultural dimensions; it is with respect to these that cultural convergence or divergence occurs. In Flache and Macy's model initially both values have a uniform distribution on the interval [-1, 1]. The model here retains a uniform distribution for value 1 (Si1), but, in order to operationalize homogeneous embeddedness, it treats value 2 (Si2) differently.

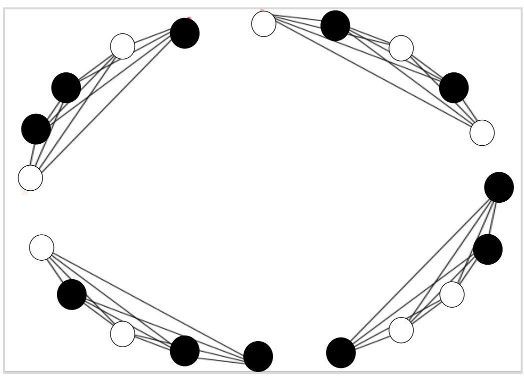


Figure 2: The Distribution of random-cultural value (value 1)

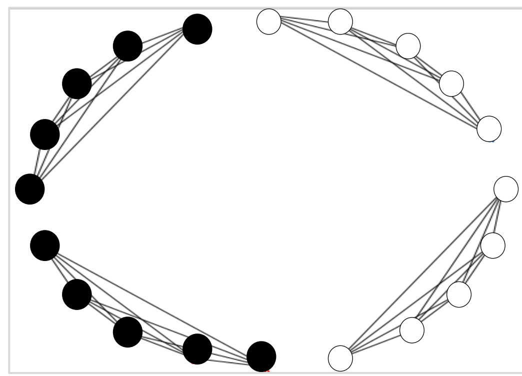


Figure 3: The distribution of non-random cultural value (value 2)

Specifically, for value 2 this model divides the population of actors in half. For one half the values for value 2 are drawn randomly from a normal distribution with mean -1 and standard deviation .3, but then truncated such that all values less than -1 are set to -1. The other half is treated symmetrically: the values for value 2 are drawn randomly from a normal distribution with mean 1 and standard deviation .3 and then truncated such that all values greater than 1 are set to 1. Note that, then, within a maximally connected subnetwork, value 2 will be strongly correlated whereas the values on value 1 will be independent. Figures 2 and 3 show this for a sample network.

The Network Structure

Flache and Macy (2011) create weak ties as part of their network conditions and fix these ties for the duration of a run. I call such ties "structuralized." In this research, in contrast I create a dynamic network structure by using non-structuralized weak ties—weak ties that change with each time unit. The two kinds of weak ties are shown in Figure 4 and Figure 5, structuralized weak ties on top and non-structuralized weak ties on bottom.

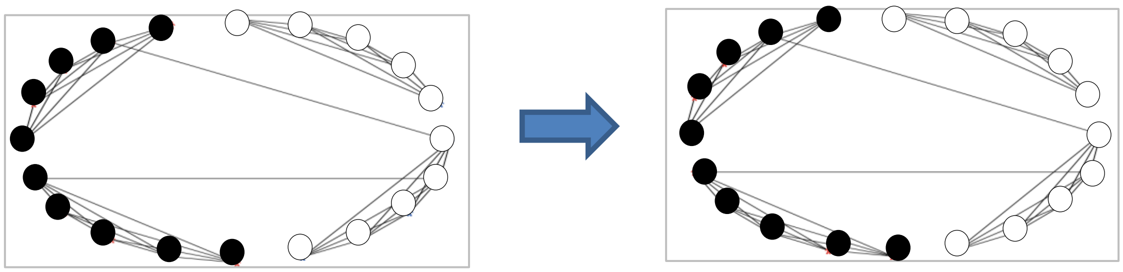


Figure 4: Structuralized weak ties changing from time t to time t+1

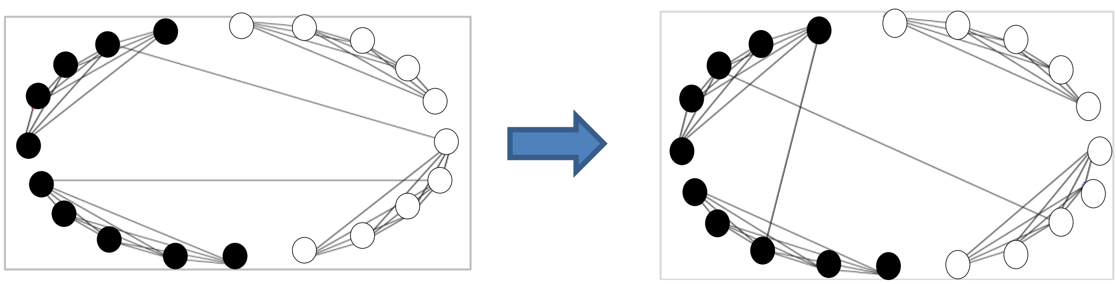


Figure 5: Non-structuralized weak ties changing from time t to time t+1

Measuring Polarization

To measure the level of polarization, Flache and Macy (2011) take each pair of actors, find the difference between their values on each cultural dimension, average these to get the distance between the two actors, then measure polarization as the variance of the distribution of this distance in the population. If the measured value is higher, it means actors are more polarized in terms of culture or opinions. Because our model treats values 1 and 2 differently, it is better to measure polarization for each value separately. Following Flache and Macy (2011), this will be as the variance of the distribution of the difference in values for a particular cultural dimension in the population of pairs of actors.

RESULTS: THREE EXPERIMENTS

I report the results of three experiments. The first investigates the effect of structuralized vs. non-structuralized weak ties on cultural polarization under the condition of homogeneous embeddedness. The second investigates the reasons why the two types of network structure have different effects on cultural polarization. The third suggests two new polarization models based on the findings of the first and second experiments.

Experiment 1

Experiment 1 involves 1000 actors divided into 200 maximally connected subnetworks of five actors each, and 200 weak ties. Recall that the condition of homogeneous embeddedness is created by giving value 2 an initially polarized distribution, close to -1 or +1, and assigning all actors in a given maximally connected subnetwork the same "polarity." In this experiment, there are 100 subnetworks of each polarity. Thus, each homophily group is present with proportion 0.5. Value 1 initially is uniformly distributed from -1 to 1. Figure 6 depicts the initial network structure and distributions of values 1 (top) and 2 (bottom).

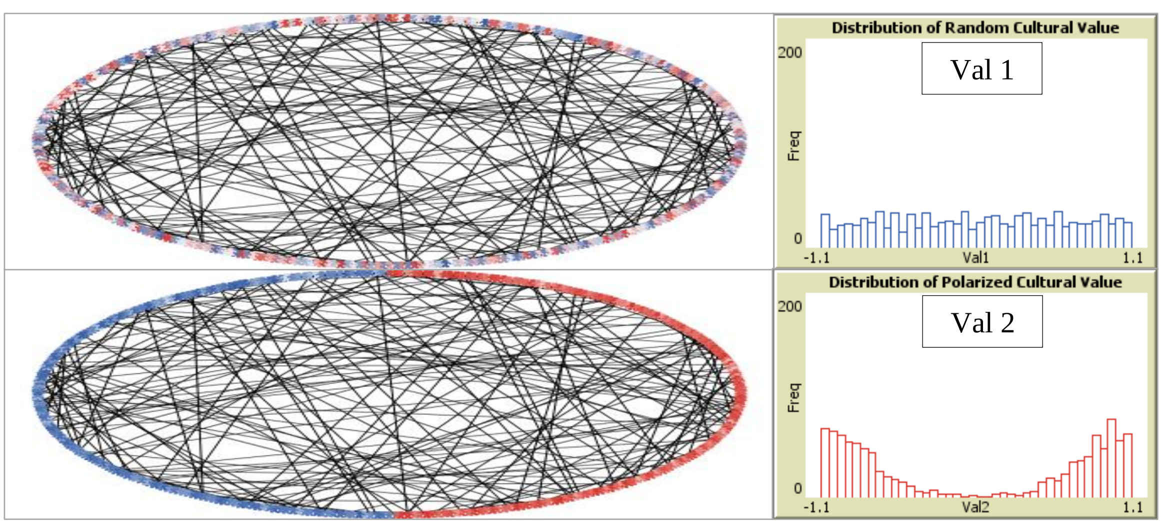


Figure 6: Basic setting of structuralized weak tie model (model 1-1)

In the first model, Model 1-1, weak ties are structuralized, that is, the initial network structure does not change during subsequent interactions. Figure 9 shows the changing distributions of value 1 (top) and value 2 (bottom) in time for a sample run. Note that all runs display the same pattern.

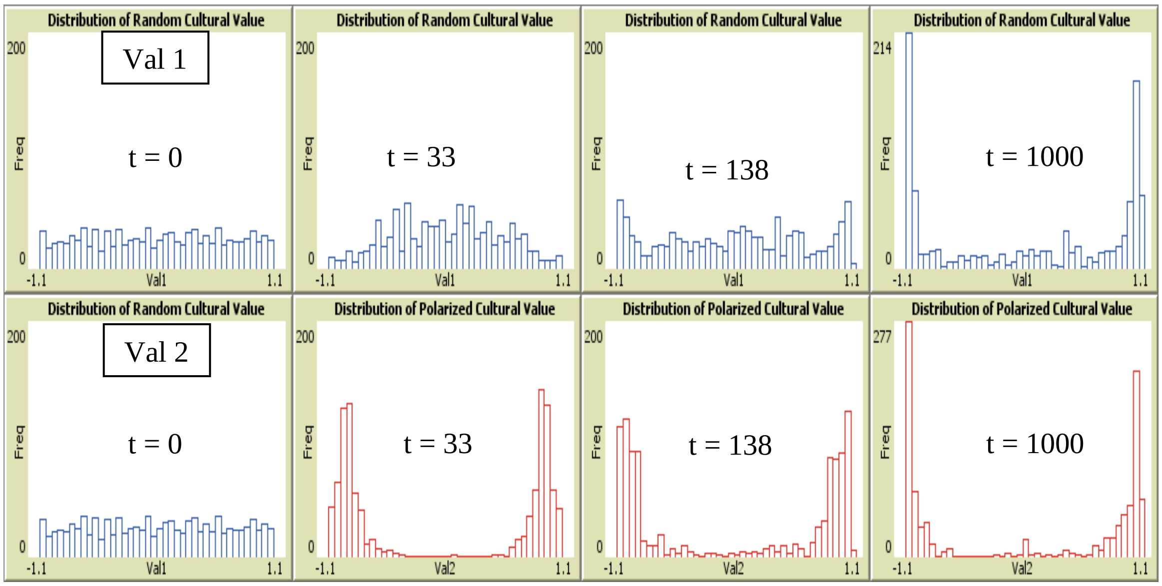


Figure 7: Changing distributions by time for model 1-1

The results present a contrast with those from Flache and Macy's original model. The initially polarized value 2 simply becomes more polarized. More interesting is the evolution of the distribution of random cultural value 1. Initially, value 1 is uniformly distributed and is not polarized, but after repeated interactions it appears to be converging to an intermediate value (slide 2). This convergence then reverses, however, and the distribution finally becomes completely polarized. This process contrasts with the original Flache and Macy model, which only produces a straightforward progression to polarization.

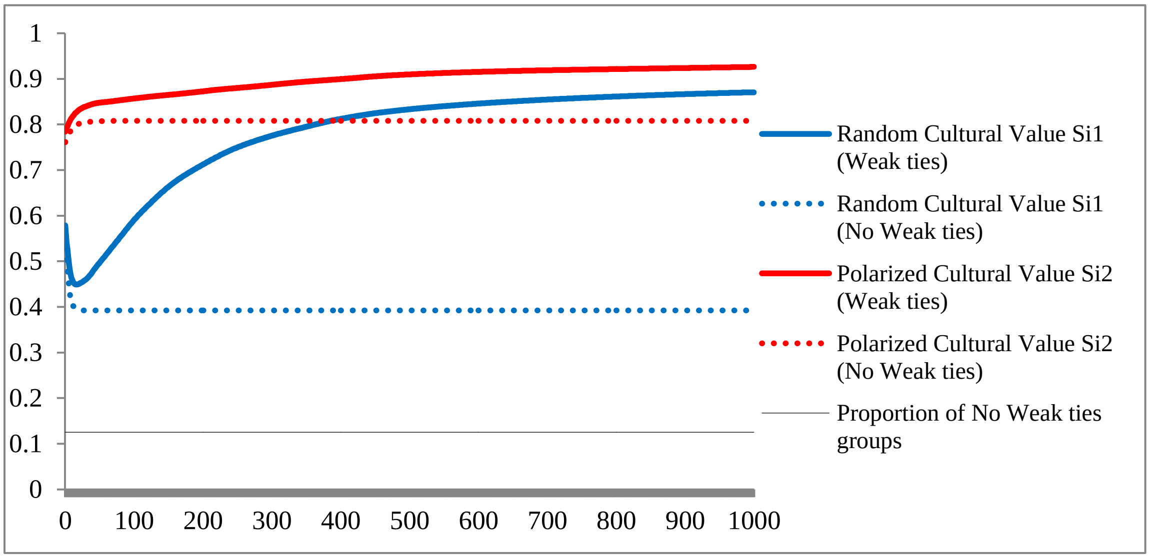


Figure 8: Changing standard deviations of each group in model 1-1

Figure 8 shows a different aspect of the polarization process. This graph contrasts the variation between actors with weak ties with the variation without weak ties, for each value separately. First, it shows that the polarization pattern in time occurs almost entirely within the set of actors with weak ties. Second, the changing pattern of the random-cultural value (value 1) shows that convergence occurs early on regardless of whether the actors have weak ties. Because homogeneous embeddedness is the only difference from the original model, we can see that homogeneous embeddedness has a positive effect on cultural convergence. However, the effect is clearly limited, because value 1 finishes by being polarized.

In the second model (Model 1-2), weak ties are non-structuralized, that is, the initial structure of weak ties is not maintained throughout a run but randomly changes each time unit. In this case, every actor has a chance to have weak ties, and this means that groups permanently without weak ties cannot exist under this condition. Thus, in order to compare the effect of non-structuralized weak ties to the effect of no weak ties, 20 groups (100 actors) are not allowed to have weak ties. The other settings remain the same as in condition 1 (see Figure 6). Figure 9 shows the changing distributions of value 1 (top) and value 2 (bottom) for a sample run.

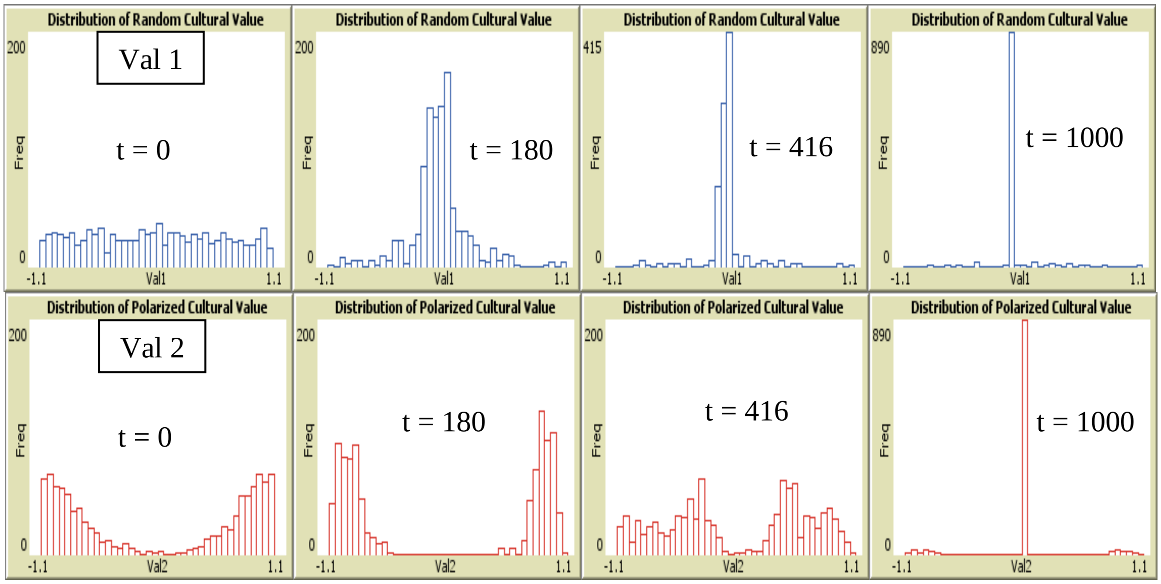


Figure 9: Changing distributions by time for model 1-2

The non-structuralized weak tie results in Figure 9 present a clear contrast with those under structuralized weak ties. With non-structuralized weak ties, the distribution of both values converges completely. The evolution of this convergence also is interesting, in that the initially polarized value 2 converges later. Value 1, uniformly distributed to begin with, converges first and appears then to compel or at least accelerate the convergence of value 2. It appears, therefore, that non-structuralized weak ties help even polarized values converge.

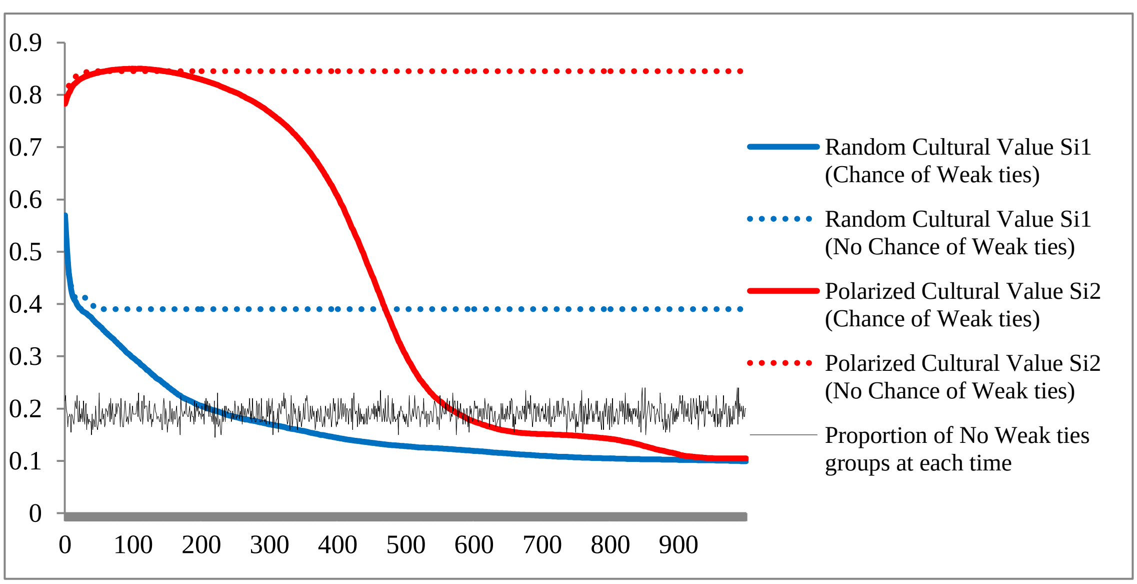


Figure 10: Changing Standard deviations of each group in Model 1-2

The graph in Figure 10 again contrasts the variation between actors having chances of weak ties and those having no chances of weak ties, for each value separately. This sheds more light on what is happening under both conditions. It is when actors experience weak ties that their values polarize (structuralized, Figure 8) or converge (non-structuralized, Figure 10). When actors have no weak ties throughout the experiment, their values neither converge nor polarize more, the same outcome as for Model 1-1. This means that whether weak ties are structuralized is an important factor for cultural change. Note that the line for the proportion of no weak tie groups is unstable because the weak tie structure changes each time unit.

To sum up, there are two principal findings from the first experiment. First, homogeneous embeddedness has a positive but also limited effect on cultural convergence when the cultural value is randomly distributed. The (temporary) convergence of random cultural value 1 (see Figure 8) is the evidence here. Second, non-structuralized weak ties have a positive effect on cultural convergence, while structuralized-weak ties have a negative effect. The two different patterns of changing distributions (See Figure 7 and 9) and the two different graphs for polarization (see Figure 8 and 10) support the argument. In the next experiment, I investigate the effect of homophily subnetworks (homogeneous embeddedness). Also, I further explore the effects of structuralized weak ties and non-structuralized weak ties to figure out why the different types of network structure produce different effects on polarization.

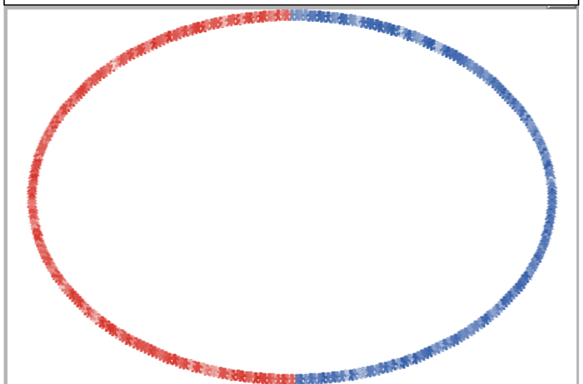
Experiment 2

The first experiment yielded two important findings. First, homophily subnetworks have a positive but limited impact on the convergence of the randomly distributed value (value 1). Second, non-structuralized weak ties can produce convergence in cultural values (value 1 and value 2). In the polarization graph shown, all cultural values finally converged as a result of interactions involving non-structuralized weak ties.

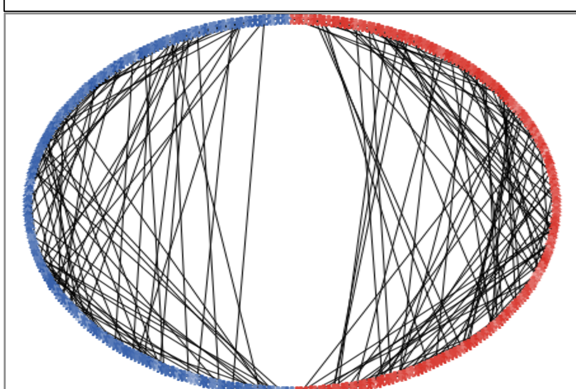
These two discoveries raise questions concerning why both factors have an impact on convergence while structuralized weak ties have an impact on polarization. These questions deserve further exploration because the results are so different from the most previous research on polarization. The state space examined in the first experiment was limited, which restricts our understanding of the results. Specifically, first, the effect of homophily subnetworks on convergence is still unclear when every actor has no weak ties. Second, it is unclear how the effect of non-structuralized weak ties may differ between ties to similar others and ties to dissimilar others. Third, the number of weak ties was fixed in the first experiment, but it is possible that effects may depend on the number of weak ties.

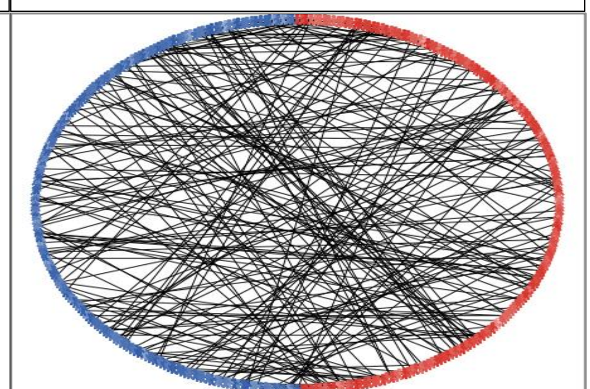
To explore the state space more fully and address these issues, I conducted a second experiment embodying three. First, either there are no weak ties (Model 2-1), all weak ties are to others similar in value 2 (non-random cultural value) (Model 2-2), or all weak ties are to others dissimilar in value 2 (Model 2-3). In Model 2-2 and Model 2-3, all weak ties emerge after 100 interactions with no weak ties in order to figure out the only effect of weak ties. Second, all weak ties are non-structuralized or all are structuralized. Third, the number of weak ties is set to 100, 200, or 400. In combination, these three factors create a total of 13 conditions. Figure 11 shows the conditions and graphs of each model.

Model 2-1 Only Subnetwork Interaction



Model 2-2 Only Homophily Process	Model 2-3 Only Non-Homophily Process





Model 2-2-St Only homophily process with Structuralized			Model 2-2-NonSt Only homophily process with Non-Structuralized			Model 2-3-St Only Non-homophily process with Structuralized			Model 2-3-NonSt Only Non-homophily with Non-Structuralized		
100 Weak Ties (2)	200 Weak Ties (3)	400 Weak Ties (4)	100 Weak Ties (5)	200 Weak Ties (6)	400 Weak Ties (7)	100 Weak Ties (8)	200 Weak Ties (9)	400 Weak Ties (10)	100 Weak Ties (11)	200 Weak Ties (12)	400 Weak Ties (13)

Figure 11: Graphs of each model for experiment 2

The first graph shows Model 2-1, with no weak ties. The second graph depicts Model 2-2, in which weak ties connect only actors whose non-random cultural values (value 2) are the same, symbolized by red connected only to red, blue only to blue. The third graph shows Model 2-3, in which weak ties connect only actors whose non-random cultural values are different, symbolized by colors only connected to the other color.

In model 2-1, which has no weak ties, because each actor can only interact with similar actors in homophily subnetworks, it is expected that actors are likely to become more similar after repeated interactions. Figure 12 shows the expected effect of homophily subnetworks on convergence.

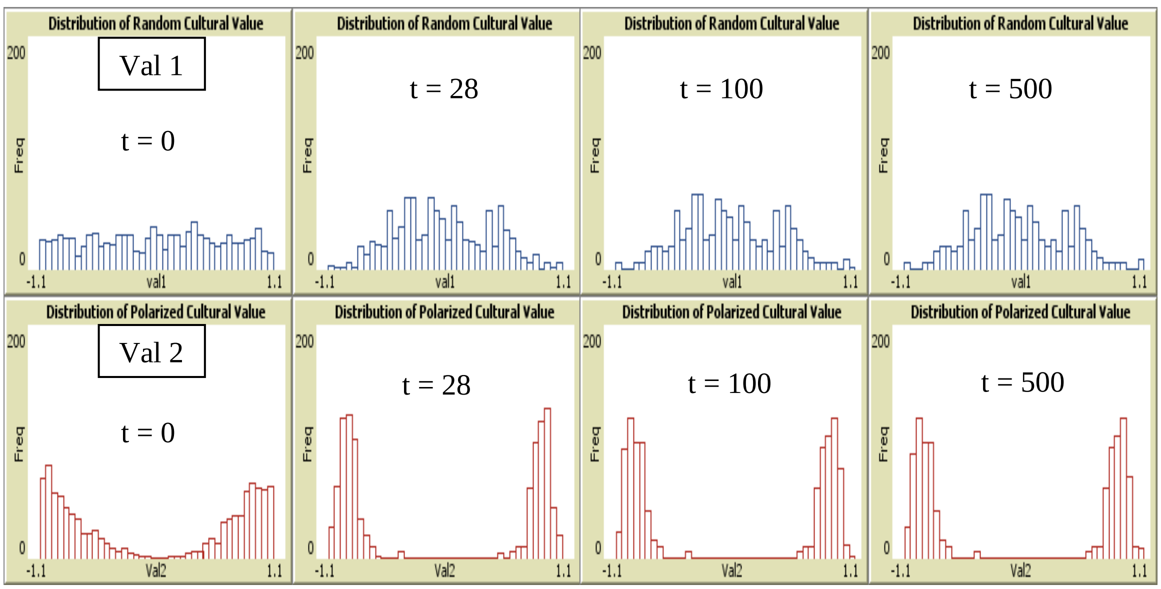


Figure 12: Changing distributions for model 2-1

During the interactions, the distribution pattern shows that the non-random cultural value (Value 2) does not converge to the center value 0, but partially converges to the two center values of each polarized group. In contrast, the random cultural value (Value 1) converges to the center value 0. However, the amount of convergence is limited because the process stops after 100 interactions (Slide 3).

Model 2-2 is similar to Model 2-1 in that actors can only interact with similar actors. In Model 2-2, however, actors have more chance to interact with similar actors because they also may have weak ties, which are only to similar actors. Thus, it is expected that convergence will be greater than in the first model. The chief feature of Model 2-2, however, is the contrast between non-structuralized weak ties in three conditions and structuralized weak ties in three conditions.

Figure 13 displays the outcome of model 2-2 under structuralized weak ties and Figure 14 the result under non-structuralized weak ties, for 100 weak ties in each situation.

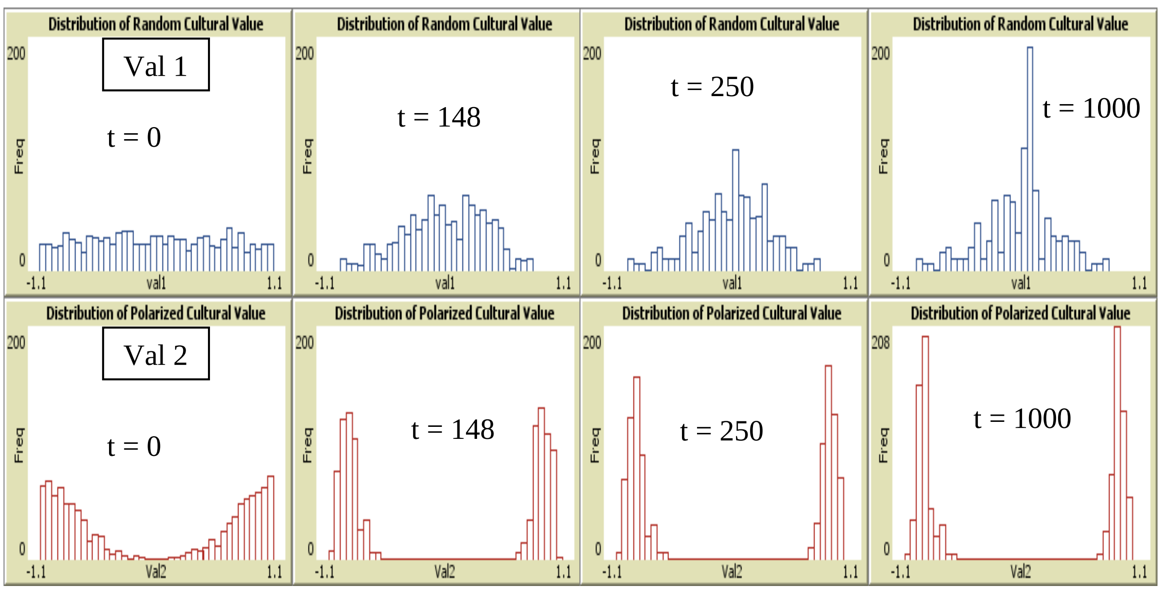


Figure 13: Changing distributions for model 2-2 with 100 structuralized weak ties

As expected, Figure 13 also shows the convergence process of cultural value 1 and value 2 (partially) and the results show more convergence than in Model 1-1. After 100 interactions with no weak ties (Slide 2), structuralized weak ties emerge and both values begin to converge. This is presumably because adding the weak ties to similar others increases the effect of homophily.

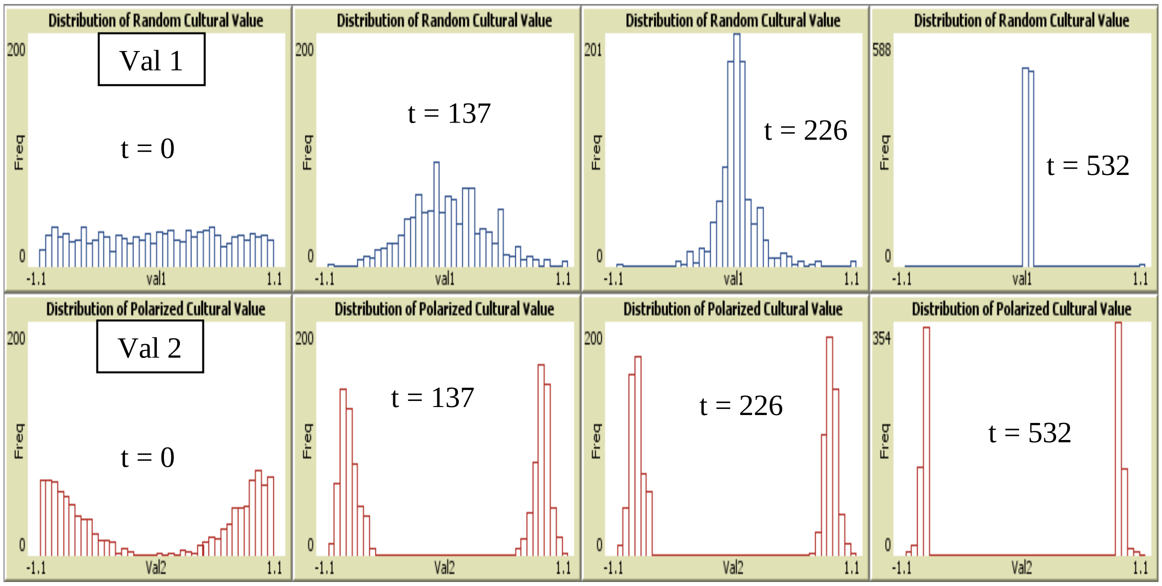


Figure 14: Changing distributions for model 2-2 with 100 non-structuralized weak ties

Non-structuralized weak ties, shown for model 2-2 with 100 weak ties, produce a noticeably stronger effect. The same convergence pattern is present in all three models, but convergence of random cultural value (value 1) is much greater with non-structuralized weak ties. Because the number of non-structuralized weak ties is also 100, the connectivity of the non-structuralized weak ties model—measure, for example, with the clustering coefficient—is similar through time to that of the structuralized weak tie model. This means that the connectivity cannot be responsible for the difference in convergence.

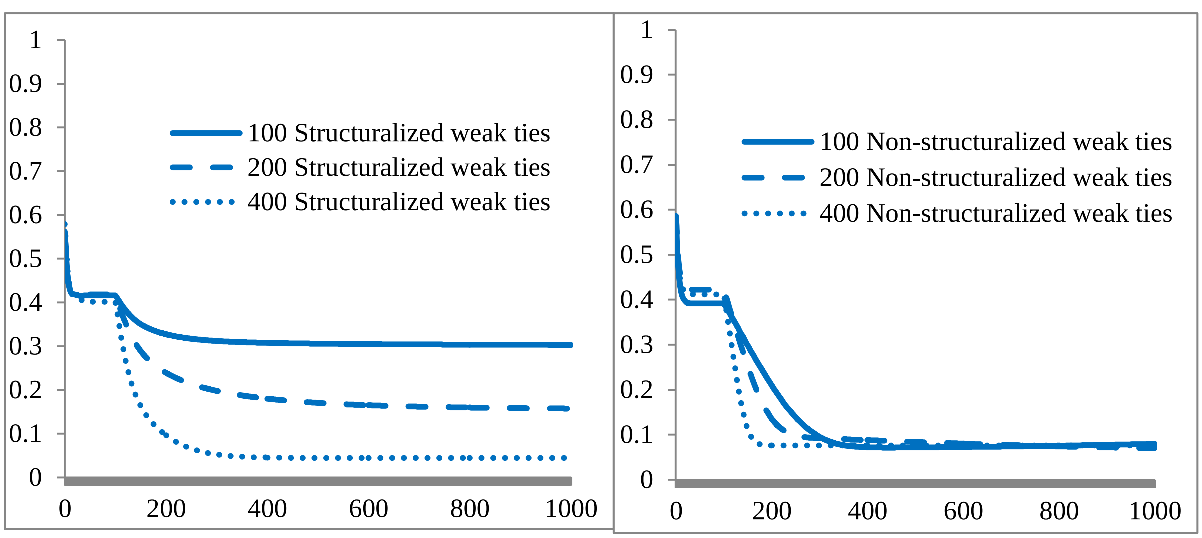


Figure 15: Changing standard deviations of each group for value 1 for model 2-2

The graphs in Figure 15 showing the effects of varying the number of weak ties show further differences between the effects of structuralized and non-structuralized weak ties and again demonstrate that network connectivity is not the reason for the differences. When weak ties are structuralized, the amount of polarization of the random cultural value (value1) is strongly affected by the number of weak ties. Namely, polarization is less, i.e, convergence is greater, for larger numbers of weak ties. When weak ties are not structuralized, however, the number of weak ties has no effect on the amount of polarization or convergence. It only affects the time to reach a stable level. Note, also that this stable level is complete convergence, that is, a polarization value of around 0.

We can anticipate different results from Model 2-3, in which weak ties link actors only to dissimilar actors. This is because actors' weak tie interactions are likely to make them more dissimilar. Specifically, it is expected for random cultural value (value 1) to become polarized and non-random cultural value (value 2) to become more polarized.

Figure 16 displays results from model 2-3 under 100 structuralized weak ties and Figure 17 results under 100 non-structuralized weak ties.

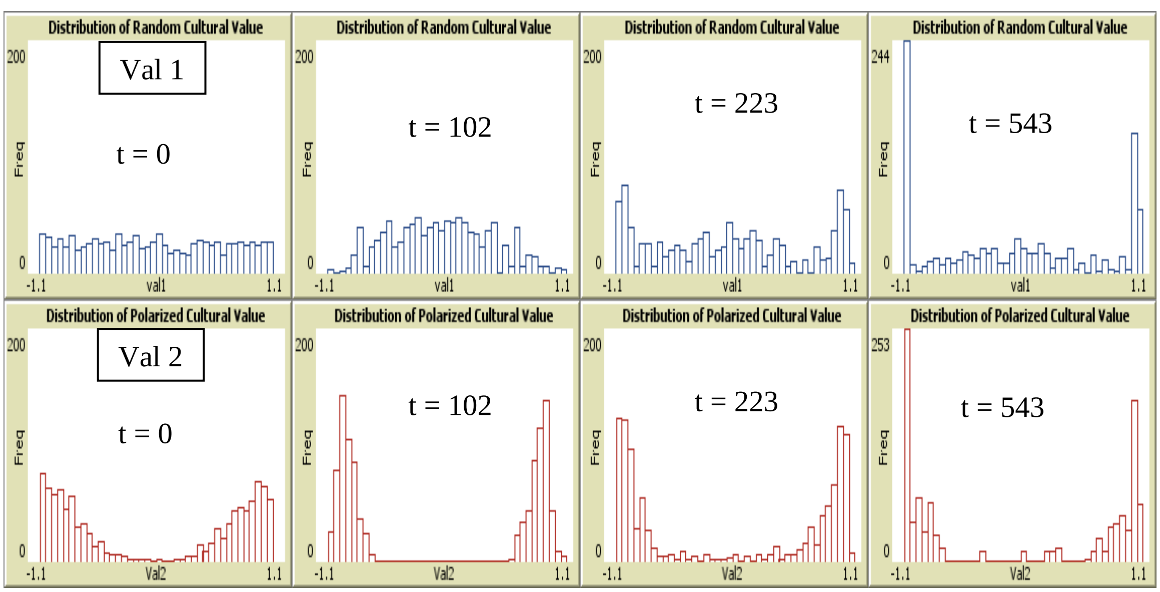


Figure 16: Changing distributions for model 2-3 with 100 structuralized weak ties

As expected, both distributions undergo polarization. Note, however, that although the random cultural value (value 2) becomes more polarized, some cases remain in the center of the distribution. In other words, value 1 does not completely polarize under the condition of 100 structuralized weak ties.

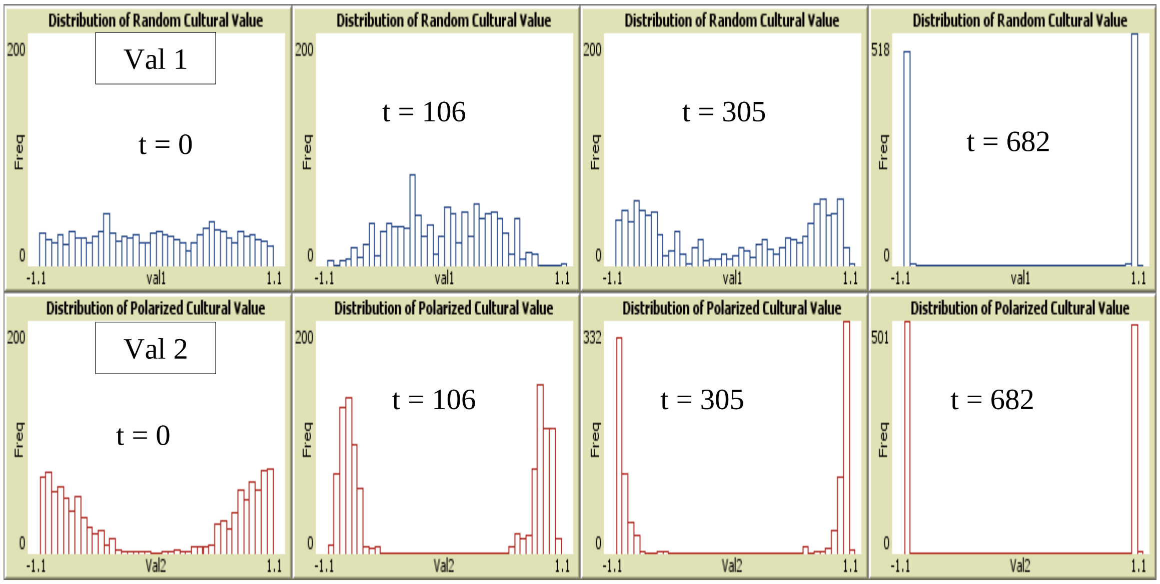


Figure 17: Changing distributions for model 2-3 with 100 non-structuralized weak ties

Polarization occurs also when weak ties are not structuralized. As for Model 2-2, for Model 2-3 non-structuralized weak ties have a stronger effect than structuralized weak ties. Here, where the weak ties are to non-similar actors, they produce stronger, almost complete polarization.

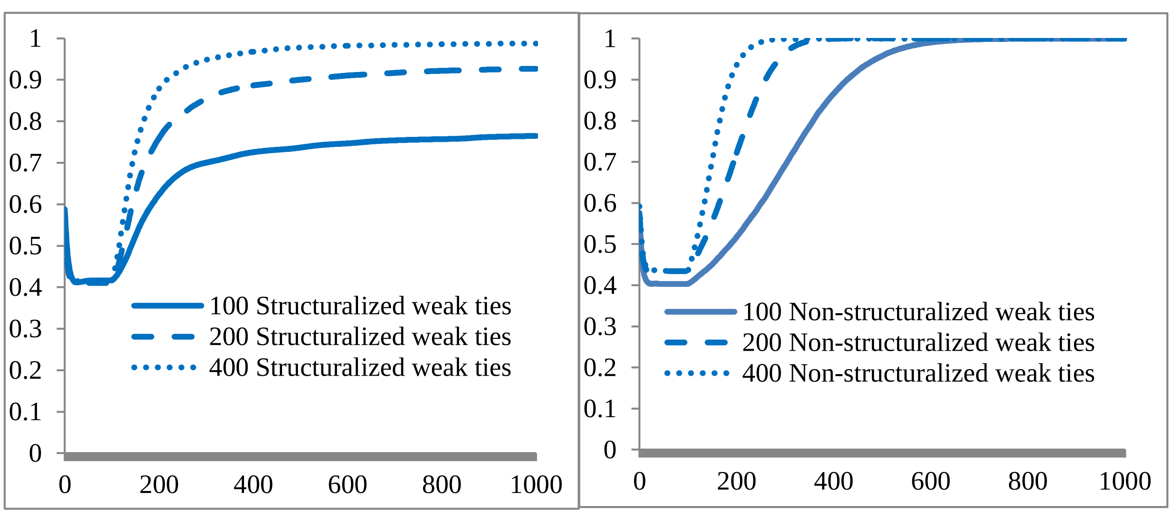


Figure 18: Changing standard deviations of each group for value 1 for model 2-3

Figure 18 shows the effect of the number of weak ties on the amount of polarization. These results are similar to those for Model 2-2. When weak ties are structuralized, the polarization of the random cultural value (value 1) varies—here, increases—with the number of weak ties. When weak ties are non-structuralized, polarization is almost complete regardless of the number of weak ties.

According to Model 2-2 and Model 2-3, when weak ties are not structuralized, the only difference the number of weak ties makes is that the fewer weak ties the longer it takes until complete polarization or convergence is attained.

However, this is important because the speed of convergence is faster than the speed of polarization. Under100 non-structuralized weak ties, while convergence of value 1 is complete around 354 interactions (see figure 15), polarization of value 1 is complete around 616 interactions (see Figure 18). Thus, at the early part of interactions, non-structuralized weak ties make cultural value converged. This is the reason why the first experiment shows the converged result of cultural values.

On the other hand, when weak ties are structuralized, the number of weak ties makes the level of polarization or convergence different. The most important thing is, polarization is always stronger than convergence. For example, under 100 structuralized weak ties, while convergence of value 1 change from 0.4 to 0.3 (-0.1; see Figure 15), convergence of value 1 change from 0.4 to 0.76 (+ 0.34; see figure 15). Thus, when weak ties are structuralized, random cultural value is always polarized.

Experiment 3

In the first experiment, homogeneous embeddedness and non-structuralized weak ties had a positive effect on cultural convergence, and structuralized weak ties had a positive effect on cultural polarization. The convergence process is that after the random cultural value converged, the converged value became a value shared by all actors, which apparently compelled the convergence of the non-random cultural value. However, this experiment did not reveal the mechanism. The second experiment showed more of why this occurred, namely, different effects on cultural polarization and convergence. In the second experiment, structuralized weak ties had an impact on polarization, while non-structuralized weak ties had a positive impact on the convergence of the random cultural value during the early part of interaction. Based on the results of the second experiment, the third experiment will try two possible polarization process models.

1) 100/100 Model (Model 3-1): Under the conditions of the first experiment, the number of structuralized weak ties and non-structuralized weak ties is set to 100 each.

2) More polarized Model (Model 3-2): Under the conditions of the first experimental model for non-structuralized weak ties, the initial settings of the non-random cultural value are more polarized than for the original model.

Based on the outcomes of the first and second experiments, I expect the 100/100 Model to produce mixed effects of both types of weak ties, structuralized and non-structuralized, and thus to show complicated and dynamic results concerning cultural polarization or convergence. Recall that the first and second experiments demonstrated that structuralized and non-structuralized weak ties have opposite effects on cultural change.

In the second model of this experiment, the more polarized Model, by initially polarizing the non-random cultural value of each actor strongly, I expect it to resist convergence through interactions from weak ties. This means that every actor's non-random cultural value is highly likely to be maintained throughout its interaction, and the result will be different from Model 1-2 for non-structuralized weak ties in experiment 1, which shows the convergence of both cultural values.

The ties of the 100/100 model are shown below. Most conditions of Model 3-1 are identical to experiment 1. The main difference is that there are both 100 non-structuralized weak ties, shown in grey, and 100 structuralized weak ties, shown in black. In addition, the standard deviation for value 2 has been changed from 0.3 to 0.5 because, otherwise, when the number of weak ties is 100, the speed of convergence due to non-structuralized weak ties is too slow to compensate for the impact of structuralized weak ties on polarization.

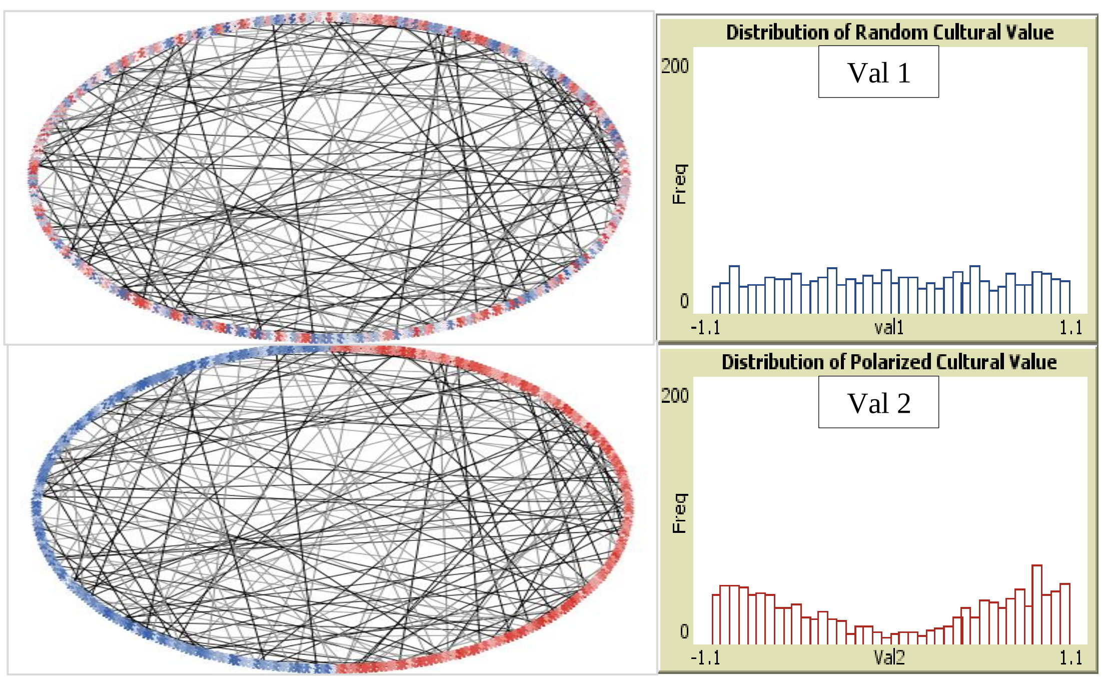


Figure 19: Basic setting of structuralized 100/100 model (model 3-1)

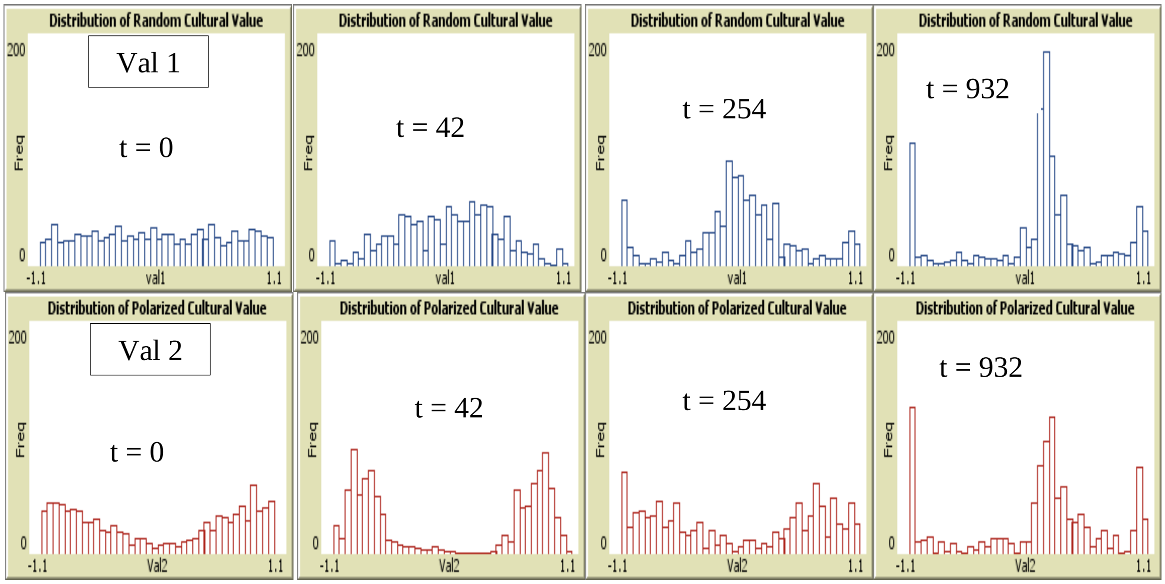


Figure 20: Changing distributions for 100/100 model (model 3-1)

Figure 20 shows results from Model 3-1. These results differ from those of experiment 1 as follows. In experiment 1, the model for structuralized weak ties, Model 1-1, produces polarization in both cultural values while the model for non-structuralized weak ties, Model 1-2, produces convergence in both cultural values. The 100/100 model, Model 3-1, however, produces convergence and polarization. Initially, the random cultural value converges toward the center. After some interaction, however, although the amount of convergence to the center is higher than before, some actors are more polarized. In other words, the random cultural value (value 1) of many actors is near 1 or -1. A similar complicated process is seen in non-random cultural value (value 2). Even though many actors remain polarized in this value, many other actors converge. Thus, the final distributions of the two cultural values show the similar distributions.

The changing graphs from the basic setting to final result is helpful to figure out the detailed information about this change,

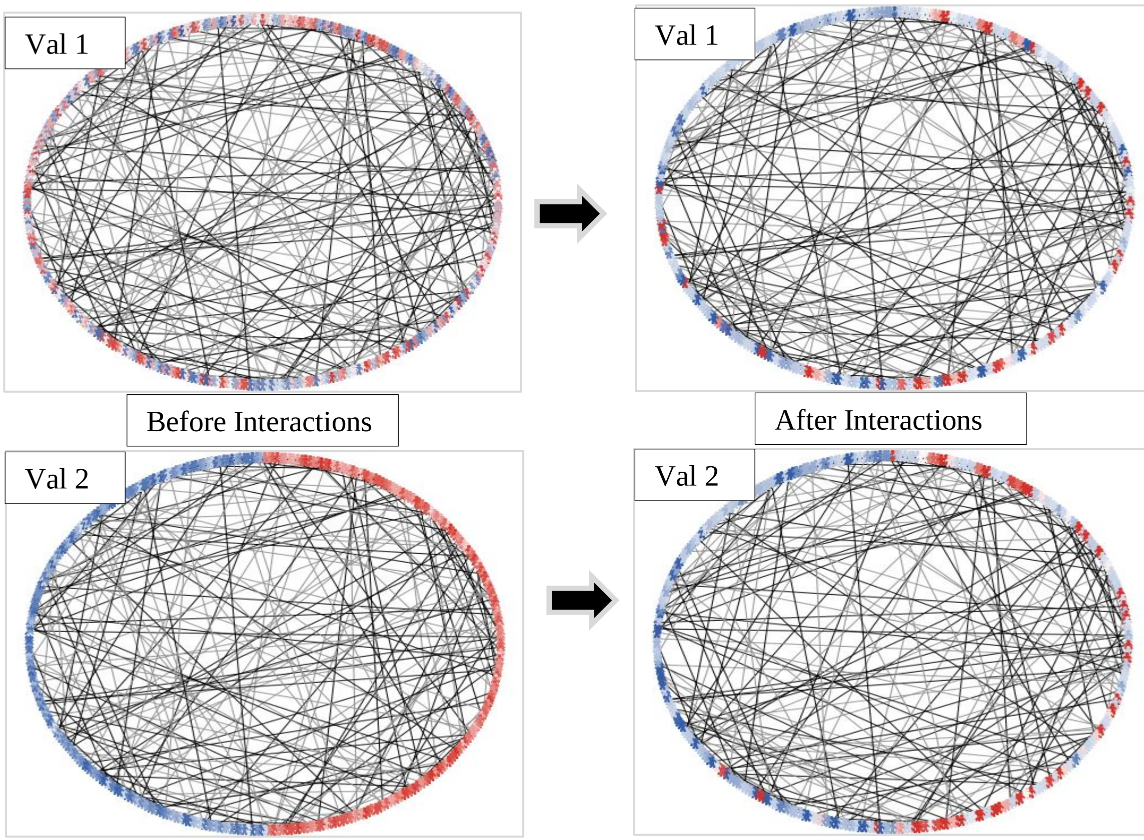


Figure 21: Changed graphs for two cultural values (model 3-1)

The above two changed network graphs show the similarity and dissimilarities in the final outcomes for the two values. The similarity is that in many cases, the color of each cultural value has become almost completely white, which means the value is near 0, and the other colors are similar to red or blue, which means the value is near 1 and -1. However, while there is no color pattern in the random cultural value (value 1), the non-random cultural value (value 2) still maintains the polarized pattern of red and blue colors. This result shows that the change in the random cultural value is dynamic, but the change in the non-random cultural value is limited seen from a macro perspective.

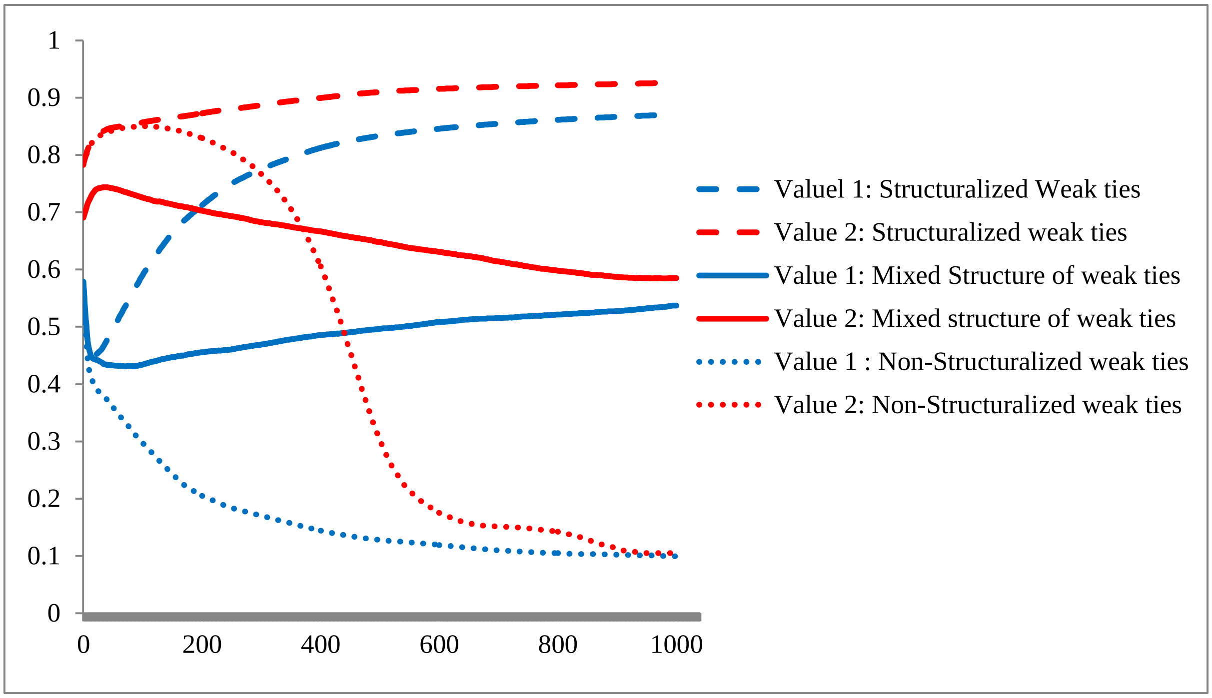


Figure 22: Standard deviation graphs for model 1-1, model 1-2 and model 3-1

The above graph shows the effect of each network structure on cultural polarization. As shown in first experiment, non-structuralized weak ties have a positive impact on cultural convergence, and structuralized weak ties have a positive impact on cultural polarization under the conditions of the experiment. However, when the two types of weak ties are mixed, the effect is unclear. In other words, the level of polarization or convergence does not increase or decrease during interactions. This is because both weak tie structures evenly affect the cultural polarization or convergence, and thus, although it produces a complicated process of polarization and convergence, the level of polarization seems to be roughly the same in aggregate.

Turning to the more polarized Model, the basic settings are similar to those of the model for non-structuralized weak ties in the first experiment. There are two cultural values – random and non-random – and 200 non-structuralized weak ties. The only different condition is that the non-random cultural value is extremely polarized, such that we do not expect convergence in the non-random value through interaction. In other words, no matter how much convergence there is in the random cultural value, we still expect non-homophilic rather than hemophilic interaction between two polarized actors.

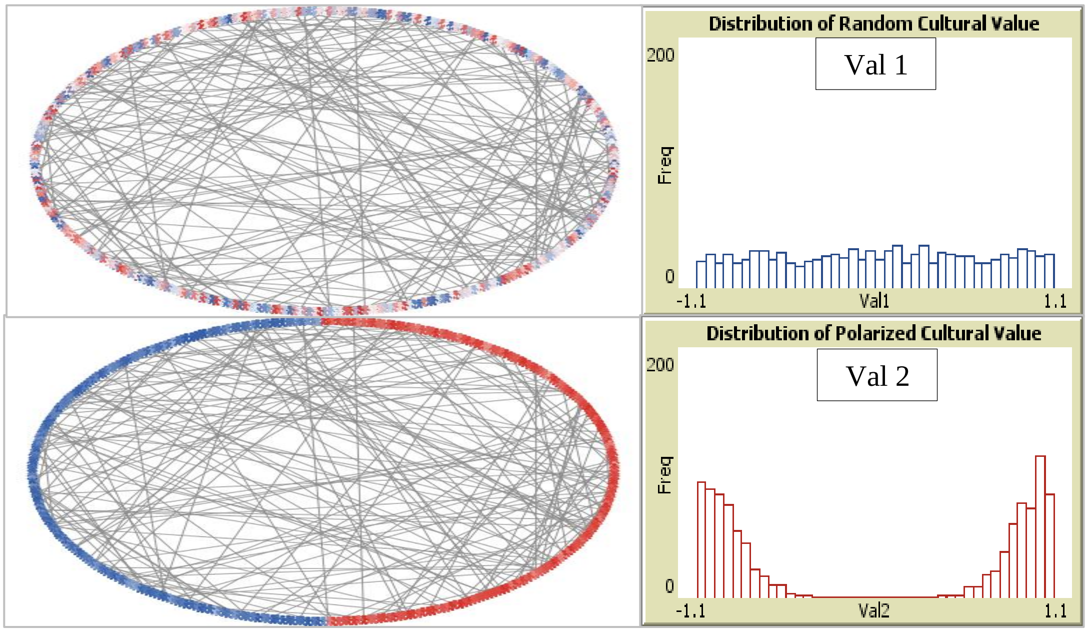


Figure 23: Basic settings for the more polarized model (model 3-2)

This model produces a number of unexpected and interesting results. Figure 24 and 25 show the two. First, there is convergence in random cultural value (value 1) by time 101. By time 227, however, there is divergence into two groups, and by time 350 there is complete polarization. This is similar to a pattern seen in the first experiment. The similar result in that experiment, however, was produced in the structuralized weak tie condition. In the non-structuralized weak tie condition, the outcome was not polarization, but convergence. Because this more polarized model is based on non-structuralized weak ties, the polarization result in fact contrasts with the results of the first experiment models.

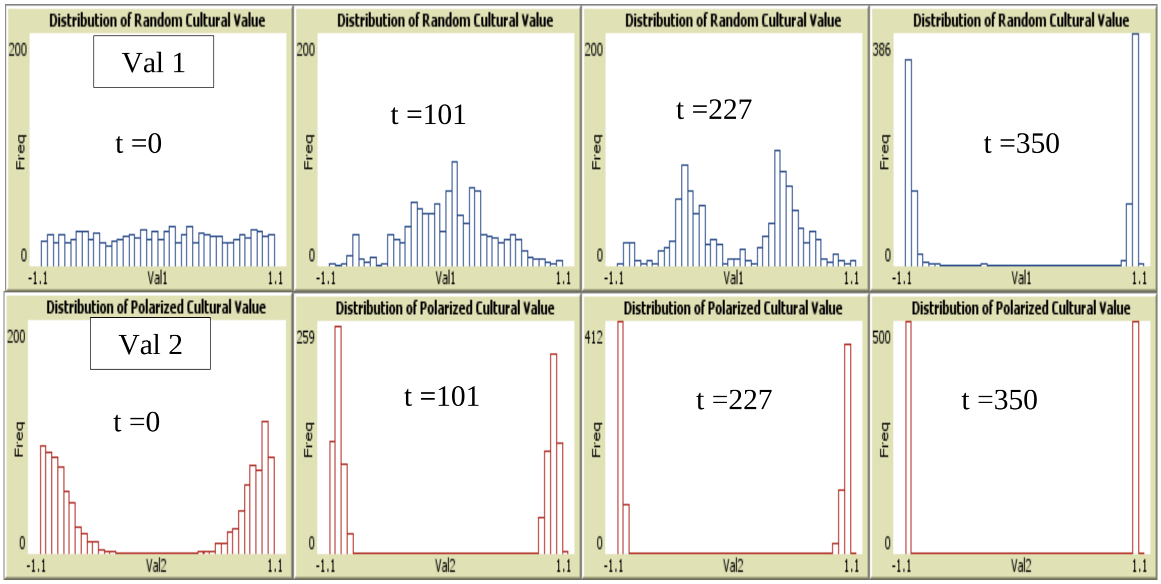


Figure 24: Changing distributions for more polarized model (model 3-2)

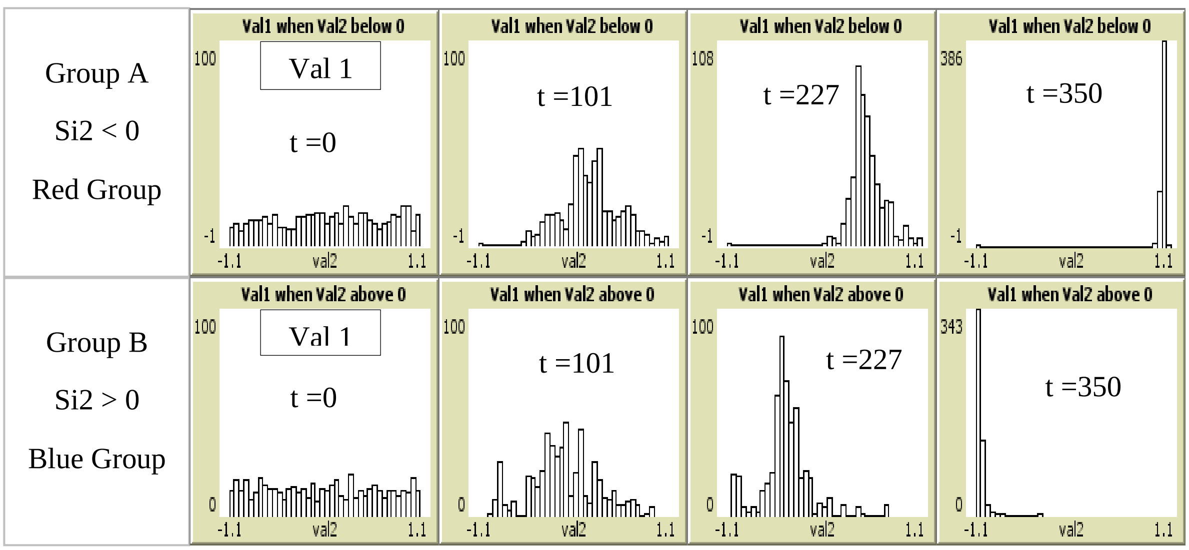


Figure 25: Changing distributions of group A and B (model 3-2)

Perhaps the most interesting result is that the polarization of the random cultural (value 1) is brought on by the polarized non-random cultural value (value 2). As shown in Figure 25, even though all actors have a random value of value 1 initially, the distribution of this value converges corresponding to each polarized group until finally all actors whose non-random value 2 is less than 0 (Group A) have the 1 value for value 1 and other actors whose non-random value 2 is more than 0 (Group B) have the - 1 value for value 1.

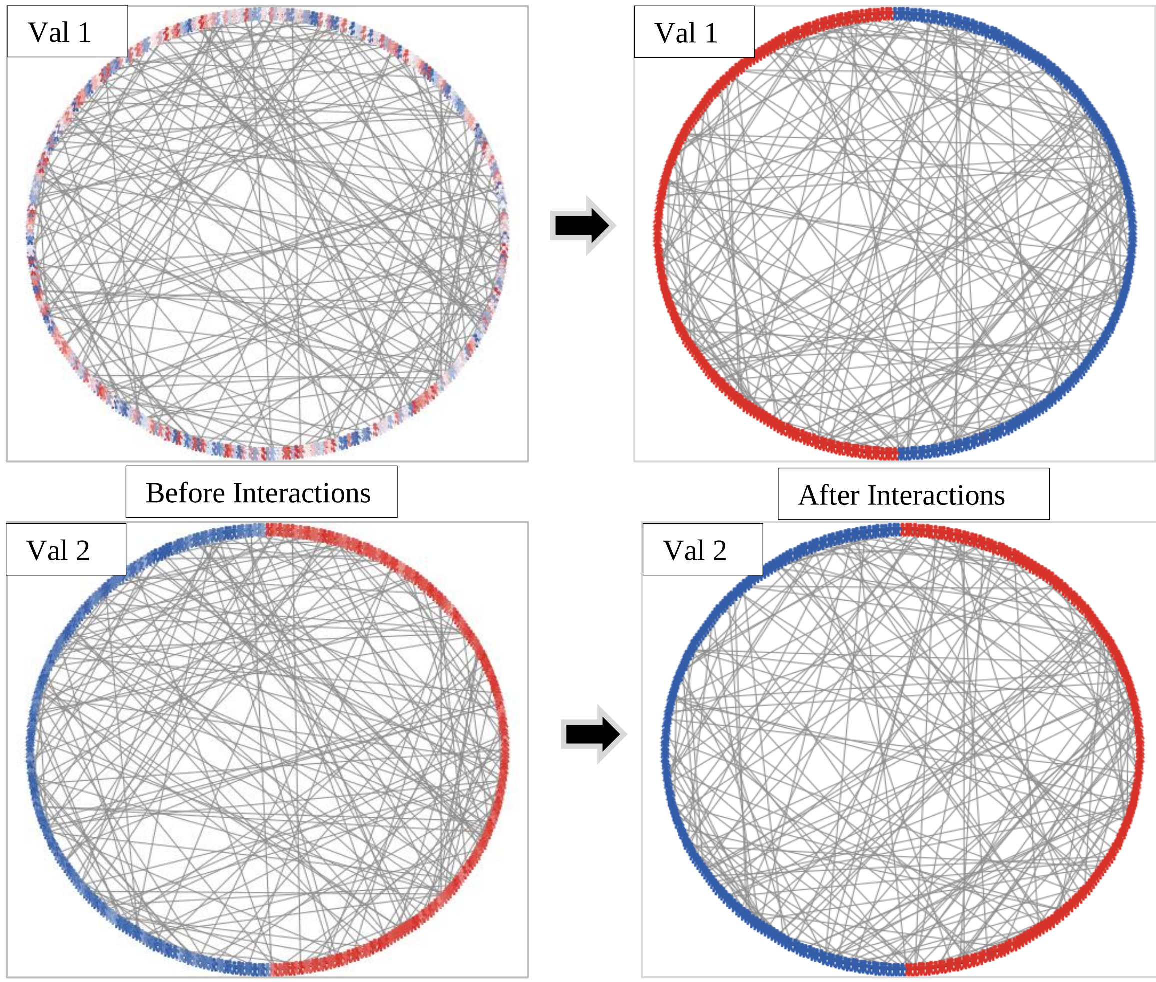


Figure 26: Changed graphs for two cultural values (model 3-2)

Figure 26 shows changing pattern of network graphs and this clearly shows the result of this process. In the first two graphs before interactions, Red actors, whose non-random value 2 is less than 0 (Group A), and Blue actors, whose non-random value 2 is more than 0, have no shared random cultural value. In other words, the random value does not have the tendency following the pattern of two groups in non-random value (value 2). However, after the interactions, every Blue polarized actors share the similar random cultural value, which is colored as red, and Red polarized actors also share the similar random cultural value, which is colored as blue.

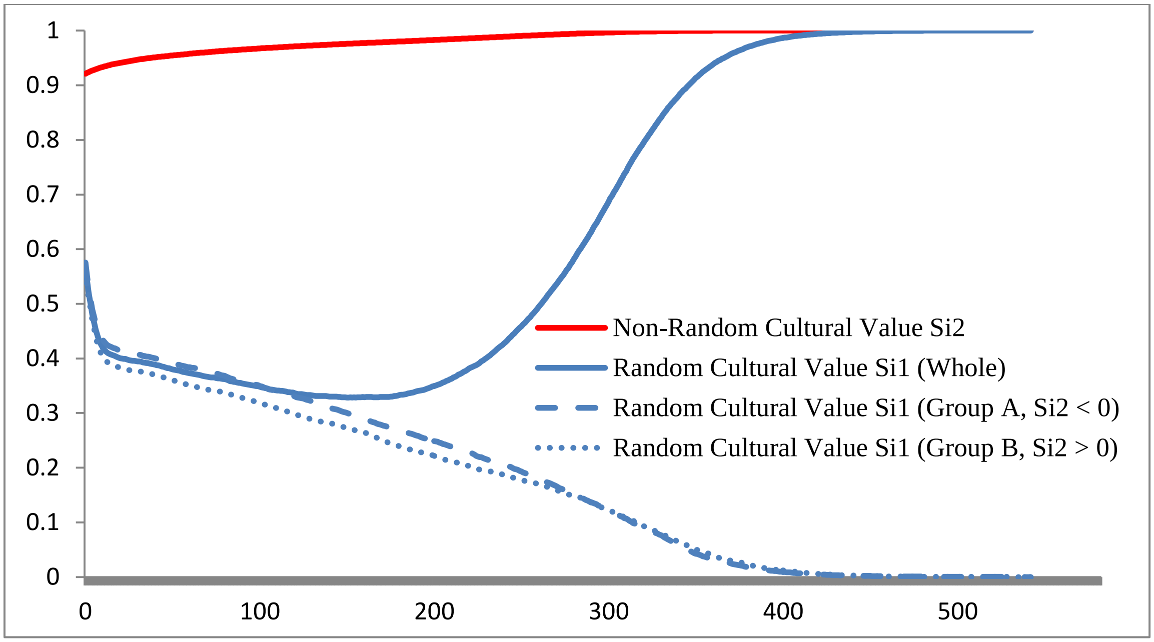


Figure 27 Changing standard deviations of each group (model 3-2)

The changing pattern of the random cultural value's (value 1) standard deviation is dramatic in the more polarized Model (Model 3-2). It begins by converging, but then it polarizes until, finally, it is perfectly polarized and its value (value 1) is close to 1 and -1. When the population is grouped according to its final non-random cultural value (value 2), within each group I find convergence of in the random cultural value (value 1). The model suggested in the first experiment does not show this dynamic. As shown in Figure 27, when population is grouped according to the polarized value, in the other cultural value (value 1), the amount of polarization is higher for the whole group, but is lower for each group separately. This means that while structuralized week ties can lead to polarization in a cultural value, which nevertheless does follow the polarization in the other value, non-structuralized weak ties can extend the polarization between two groups into a new cultural value, which is polarized in the same way as the original polarization.

CONCLUSION

From the perspective of network theory, Granovetter (1983) suggests a theoretical process how cultures can be converged by weak ties under the assumption of homophily interaction. Still, Flach and Macy (2011) shows the another process how cultures can be polarized by weak ties under the both assumptions of homophily and xenophobic (non-homophily) interactions. Although the two processes yield opposite results, they are similar in that in each process cultural change proceeds toward an extreme –integration or polarization.

Here, I argue that two structural conditions of modern society, non-structuralized weak ties and homogeneous embeddedness, may make the process of cultural change more dynamic. In other words, social interaction in a diverse environment may not lead in a straightforward fashion to polarization or integration but rather the outcome may be more complex. The two models in experiment 3, building on the findings in experiments 1 and 2, demonstrate this possibility. Under Flache and Macy's (2003) assumption that actors can have a negative reaction to dissimilar others, the simulation results reveal the possibility of the coexistence of both polarization and convergence (model 3-1). They also demonstrate and how the process of cultural integration could be reversed to produce polarization in the long run (model 3-2). This simulation cannot establish that these mechanisms are responsible for the naturally occurring cultural convergence and polarization that we see. Nevertheless, it does show that they are theoretically plausible as mechanisms and suggests they should be considered in constructing theories of cultural convergence, polarization, and change.

For example, according to Baldassarri and Bearman (2007)'s summary, many empirical studies about political polarization show that political opinions are extremely polarized for some people, but in other hand, most of social actors share the converged political opinion. In other words, the processes of political polarization and convergence are emerging at the same time. In this case, model 3-1 might explain this phenomenon because the mixed effect of non-structuralized and structuralized weak ties in the model makes cultures (or political opinions) converged and polarized at the same time. In addition, model 3-2 also could be an explanation model for subcultural change in urban society. For example, although potential weak ties exist in urban society, subcultures, such as youth culture, are not converged to other cultures, but reproduce their new cultural value or attitude (Fischer 1975; Bennett 1999). Since model 3-2 shows the changing process how random cultural value can represent two polarized groups, the mechanism of subcultural change may be explained by the model.

This study, however, has limitations; future research will be directed at overcoming these limitations. First, in all simulations, the number of cultural dimensions was limited to two. Because there are numerous dimensions of culture in the society, the number of cultural values needs to be extended, for adding additional cultural dimensions is likely to add to the complexity and interest of the dynamics of cultural convergence and polarization. Second, initial heterogeneity in the simulated networks is balanced in terms of numbers of actors. This, however, is unlikely in the real world, in which a cultural characteristic is almost always majority or minority. Thus, future research must investigate how the proportions adhering to different cultural values affects the results found here. Finally, this simulation assigned non-structuralized weak ties randomly, but this is unrealistic. It is likely that people form even non-structuralized weak ties in some biased fashion. Therefore, future research should investigate the extent to which bias in non-structuralized weak tie formation affects the convergence and polarization results found here.

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APPENDIX A: SYNTAX FOR NETLOGO 5.05

```
turtles-own [  own-number val02 val01  w11 w12 w21 w22 w31 w32 w41 w42 w51 w52 w61
w62 w71 w72 w81 w82 w1 w2 w3 w4 w5 w6 w7 w8 s-df1 s-df2 weak1 weak2 weak3 weak0]
globals [ weak-tie-number number2 turtle-number turtle-number2 turtle-number-weak-1 turtle-
number-weak-2]

to check-color
   if opinion-dimension = "Random-Cultural-Value" [variable-color1]
   if opinion-dimension = "Polarized-Cultural-Value" [variable-color2]
end

to setup
  if auto-setting? = 1 [auto-setting]
  clear-all
   set-default-shape turtles "person"
   set-default-shape links "default"
     crt number
     own-numbering
   layout-circle (sort turtles ) max-pxcor - 1
   random_normal
   random_Polarization_A
   random_Polarization_B
   random_number_val01
     node
     if opinion-dimension = "Random-Cultural-Value" [variable-color1]
     if opinion-dimension = "Polarized-Cultural-Value" [variable-color2]
     ask links [set color black]
     ask patches [set pcolor white]
     reset-ticks
end

to auto-setting
if experiment = "First Experiment - St Weak-Ties" [set Weak-interaction 0]
if experiment = "First Experiment - St Weak-Ties" [set Non-St-Weak-Ties 0]
if experiment = "First Experiment - St Weak-Ties" [set St-Weak-Ties 200]
if experiment = "First Experiment - St Weak-Ties" [set Std_A 0.3]
if experiment = "First Experiment - St Weak-Ties" [set Std_B 0.3]
if experiment = "First Experiment - St Weak-Ties" [set only-subnetwork 0]

if experiment = "First Experiment - Non-St Weak-Ties" [set Weak-interaction 1]
if experiment = "First Experiment - Non-St Weak-Ties" [set Non-St-Weak-Ties 200]
if experiment = "First Experiment - Non-St Weak-Ties" [set St-Weak-Ties 0]
if experiment = "First Experiment - Non-St Weak-Ties" [set Std_A 0.3]
if experiment = "First Experiment - Non-St Weak-Ties" [set Std_B 0.3]
```

```
if experiment = "First Experiment - Non-St Weak-Ties" [set only-subnetwork 0]

if experiment = "Second Experiment - Only Subnetwork" [set Non-St-Weak-Ties 0]
if experiment = "Second Experiment - Only Subnetwork" [set Weak-interaction 0]
if experiment = "Second Experiment - Only Subnetwork" [set St-Weak-Ties 0]
if experiment = "Second Experiment - Only Subnetwork" [set Std_A 0.3]
if experiment = "Second Experiment - Only Subnetwork" [set Std_B 0.3]

if experiment = "Second Experiment - Only Homophily" and Weak-interaction = 0 [set St-
Weak-Ties 0]
if experiment = "Second Experiment - Only Homophily" and Weak-interaction = 0 [set Non-
St-Weak-Ties 0]
if experiment = "Second Experiment - Only Homophily" and Weak-interaction = 1 [set St-
Weak-Ties 0]
if experiment = "Second Experiment - Only Homophily" and Weak-interaction = 1 [set Non-
St-Weak-Ties 0]
if experiment = "Second Experiment - Only Homophily" [set Std_A 0.3]
if experiment = "Second Experiment - Only Homophily" [set Std_B 0.3]
if experiment = "Second Experiment - Only Homophily" [set only-subnetwork 1]

if experiment = "Second Experiment - Only Xenophobia" and Weak-interaction = 0 [set St-
Weak-Ties 0]
if experiment = "Second Experiment - Only Xenophobia" and Weak-interaction = 0 [set Non-
St-Weak-Ties 0]
if experiment = "Second Experiment - Only Xenophobia" and Weak-interaction = 1 [set St-
Weak-Ties 0]
if experiment = "Second Experiment - Only Xenophobia" and Weak-interaction = 1 [set Non-
St-Weak-Ties 0]
if experiment = "Second Experiment - Only Xenophobia" [set Std_A 0.3]
if experiment = "Second Experiment - Only Xenophobia" [set Std_B 0.3]
if experiment = "Second Experiment - Only Xenophobia" [set only-subnetwork 1]

if experiment = "Third Experiment - 100/100 model" [set Weak-interaction 1]
if experiment = "Third Experiment - 100/100 model" [set St-Weak-Ties 100]
if experiment = "Third Experiment - 100/100 model" [set Non-St-Weak-Ties 100]
if experiment = "Third Experiment - 100/100 model" [set Std_A 0.5]
if experiment = "Third Experiment - 100/100 model" [set Std_B 0.5]
if experiment = "Third Experiment - 100/100 model" [set only-subnetwork 0]

if experiment = "Third Experiment - More Polarized Model" [set Weak-interaction 1]
if experiment = "Third Experiment - More Polarized Model" [set St-Weak-Ties 0]
if experiment = "Third Experiment - More Polarized Model" [set Non-St-Weak-Ties 200]
if experiment = "Third Experiment - More Polarized Model" [set Std_A 0.2]
if experiment = "Third Experiment - More Polarized Model" [set Std_B 0.2]
if experiment = "Third Experiment - More Polarized Model" [set only-subnetwork 0]
end
```

```
to own-numbering
 set number2 (number - 1)
 own-numbering2
end

to own-numbering2
 ask turtle number2 [set own-number number2 ]
 if number2 != -1 [set number2 (number2 - 1) ]
 if number2 != -1 [own-numbering2]
 if number2 = -1 [stop]
end


to random_normal
  ask turtles with [own-number < number * (Polarized-Percentage / 100)]
     [set val02 (  ((random-normal Polarized-Cultural-Value-A Std_A)  )  ) ]
  ask turtles with [own-number >= number * (Polarized-Percentage / 100)]
     [set val02 ((  random-normal Polarized-Cultural-Value-B Std_B ) )  ]
  ask turtles [set val01 ( (random-normal Random-Cultural-Value Std_Random-Cultural-
Value)    ) ]
end

to random_Polarization_A
  ask turtles with [own-number < number * (Polarized-Percentage / 100) and (val02 < -1 or
val02 > 1)]  [set val02 (  (random-normal Polarized-Cultural-Value-A Std_A)   ) ]
  ask turtles with [own-number < number * (Polarized-Percentage / 100) and ((val02 <
(Polarized-Cultural-Value-A - Range_A / 2) or val02 > (Polarized-Cultural-Value-A +
Range_A / 2)))]
[set val02 (  (random-normal Polarized-Cultural-Value-A Std_A)   ) ]
  if any? turtles with [own-number < number * (Polarized-Percentage / 100) and (val02 < -1 or
val02 > 1)] [random_Polarization_A]
  if any? turtles with [own-number < number * (Polarized-Percentage / 100) and (val02 <
(Polarized-Cultural-Value-A - Range_A / 2) or val02 > (Polarized-Cultural-Value-A +
Range_A / 2))] [random_Polarization_A]
end

to random_Polarization_B
  ask turtles with [own-number >= number * (Polarized-Percentage / 100) and (val02 < -1 or
val02 > 1)] [set val02 (  (random-normal Polarized-Cultural-Value-B std_B ) ) ]
  ask turtles with [own-number >= number * (Polarized-Percentage / 100) and (val02 <
(Polarized-Cultural-Value-B - Range_B / 2) or val02 > (Polarized-Cultural-Value-B +
Range_B / 2))]
[set val02 (  (random-normal Polarized-Cultural-Value-B std_B ) ) ]
  if any? turtles with [own-number >= number * (Polarized-Percentage / 100) and (val02 < -1
or val02 > 1)] [random_Polarization_B]
```

```
  if any? turtles with [own-number >= number * (Polarized-Percentage / 100) and (val02 <
(Polarized-Cultural-Value-B - Range_B / 2) or val02 > (Polarized-Cultural-Value-B +
Range_B / 2))] [random_Polarization_B]
end

to random_number_val01
  ask turtles with [val01 > 1 or val01 < -1 ] [set val01 ( (random-normal Random-Cultural-
Value  Std_Random-Cultural-Value)  ) ]
  ask turtles with [val01 > (Random-Cultural-Value + Range_Random-Cultural-Value / 2) or
val01 < (Random-Cultural-Value - Range_Random-Cultural-Value / 2)] [set val01 ( (random-
normal Random-Cultural-Value  Std_Random-Cultural-Value)  ) ]
  if any? turtles with [val01 > 1 or val01 < -1] [random_number_val01 ]
  if any? turtles with [val01 > (Random-Cultural-Value + Range_Random-Cultural-Value / 2)
or val01 < (Random-Cultural-Value - Range_Random-Cultural-Value / 2)]
[random_number_val01 ]
end


to node
   set turtle-number  (number - 5)
   process1
   ask links [set color blue]
   ask turtles [set weak1 -1]
   ask turtles [set weak2 -1]
   set weak-tie-number St-Weak-Ties
   if St-Weak-Ties != 0 [process-weak-tie]
end


to  process1
   ask turtle turtle-number [create-link-with turtle (turtle-number + 1)]
   ask turtle turtle-number [create-link-with turtle (turtle-number + 2)]
   ask turtle turtle-number [create-link-with turtle (turtle-number + 3)]
   ask turtle turtle-number [create-link-with turtle (turtle-number + 4)]

   ask turtle (turtle-number + 1) [create-link-with turtle (turtle-number + 2)]
   ask turtle (turtle-number + 1) [create-link-with turtle (turtle-number + 3)]
   ask turtle (turtle-number + 1) [create-link-with turtle (turtle-number + 4)]

   ask turtle (turtle-number + 2) [create-link-with turtle (turtle-number + 3)]
   ask turtle (turtle-number + 2) [create-link-with turtle (turtle-number + 4)]

   ask turtle (turtle-number + 3) [create-link-with turtle (turtle-number + 4)]

   process2
end
```

```
to process2
set turtle-number (turtle-number - 5)
   if turtle-number != -5 [process1]
   if turtle-number = -5 [stop]
end


to process-weak-tie
  numbering
 end

to numbering
  set turtle-number-weak-1 random number
  set turtle-number-weak-2 random number
  if [weak1] of turtle turtle-number-weak-1 = turtle-number-weak-1 or [weak1] of turtle turtle-
number-weak-1 = turtle-number-weak-2 [numbering]
  if [weak1] of turtle turtle-number-weak-2 = turtle-number-weak-1 or [weak1] of turtle turtle-
number-weak-1 = turtle-number-weak-2 [numbering]
  if [weak2] of turtle turtle-number-weak-1 != -1 [numbering]
  if [weak2] of turtle turtle-number-weak-2 != -1 [numbering]
 numbering2
end


to numbering2
  if (int (turtle-number-weak-1 / 5)) = (int (turtle-number-weak-2  / 5)) [numbering]
  if turtle-number-weak-1 >= 500 and turtle-number-weak-2 < 500 and experiment = "Second
Experiment - Only Homophily" [numbering]
  if turtle-number-weak-1 < 500 and turtle-number-weak-2 >= 500 and experiment = "Second
Experiment - Only Homophily" [numbering]
  if turtle-number-weak-1 >= 500 and turtle-number-weak-2 >= 500 and experiment = "Second
Experiment - Only Xenophobia" [numbering]
  if turtle-number-weak-1 < 500 and turtle-number-weak-2 < 500 and experiment = "Second
Experiment - Only Xenophobia" [numbering]
  if turtle-number-weak-1 < 50 and experiment = "First Experiment - Non-St Weak-Ties"
[numbering]
  if turtle-number-weak-1 >= 950 and experiment = "First Experiment - Non-St Weak-Ties"
[numbering]
  if turtle-number-weak-2 < 50 and experiment = "First Experiment - Non-St Weak-Ties"
[numbering]
  if turtle-number-weak-2 >= 950 and experiment = "First Experiment - Non-St Weak-Ties"
[numbering]
  if (int (turtle-number-weak-1 / 5)) != (int (turtle-number-weak-2 / 5)) [processgogo]
end
```

```
to processgogo
  ask turtle turtle-number-weak-1 [create-link-with turtle turtle-number-weak-2 ]
  ask turtle turtle-number-weak-2 [if weak1 != -1 [set weak2 turtle-number-weak-1]]
  ask turtle turtle-number-weak-1 [if weak1 != -1 [set weak2 turtle-number-weak-2]]
  ask turtle turtle-number-weak-2 [if weak1 = -1 [set weak1 turtle-number-weak-1]]
  ask turtle turtle-number-weak-1 [if weak1 = -1 [set weak1 turtle-number-weak-2]]
  weak-weak
end


to weak-weak
 if (count links with [color = grey]) != weak-tie-number  [process-weak-tie]
 if (count links with [color = grey]) = weak-tie-number   [stop]
end

to variable-color1
  ask turtles with [val01 > 0] [set color ((val01 * (-4.9) + 9.9) + 100 + change-color) ]
  ask turtles with [val01 = 0] [set color white ]
  ask turtles with [val01 < 0] [set color ((val01 * (4.9) + 9.9) + 10 + change-color) ]
end

to variable-color2
  ask turtles with [val02 > 0] [set color ((val02 * (-4.9) + 9.9) + 100 + change-color) ]
  ask turtles with [val02 = 0] [set color white ]
  ask turtles with [val02 < 0] [set color ((val02 * (4.9) + 9.9) + 10 + change-color) ]
end

to go
 if opinion-dimension = "Polarized-Cultural-Value" [variable-color2]
 if opinion-dimension = "Random-Cultural-Value" [variable-color1]
 if St-Weak-Ties > 0 and Weak-interaction = 1 and Non-St-Weak-Ties = 0 [stop]
 if Weak-interaction = 1 and (Experiment !="Second Experiment - Only Homophily" and
Experiment !="Second Experiment - Only Xenophobia") [weak-interaction-process]
 variable23
 if any? turtles with [val02 > 1 or val02 < -1]  [errors]
 tick
 if ticks = 100 and Non-Structuralized? = 0 and only-subnetwork = 1 [set St-Weak-Ties #of-
Weak-Ties-for-2nd-Exp]
 if ticks = 100 and Non-Structuralized? = 0 and only-subnetwork = 1 [node]
 if ticks = 100 and Non-Structuralized? = 1 and only-subnetwork = 1 [set Non-St-Weak-Ties
#of-Weak-Ties-for-2nd-Exp]
 if ticks >= 100 and Non-Structuralized? = 1 and only-subnetwork = 1 and (Experiment
="Second Experiment - Only Homophily" or Experiment ="Second Experiment - Only
Xenophobia")[weak-interaction-process]
 if ticks = Stop-Time [stop]
 end
```

```
to weak-interaction-process
 ask links with [color = grey] [die]
 ask turtles with [count link-neighbors = 4] [set weak1 -1]
 ask turtles with [count link-neighbors = 4] [set weak2 -1]
 ask turtles with [count link-neighbors = 5] [set weak2 -1]
 process-weak-weak-tie
end


to process-weak-weak-tie
  numbering11
 end

to numbering11
  set turtle-number-weak-1 random number
  set turtle-number-weak-2 random number
  if [weak1] of turtle turtle-number-weak-1 = turtle-number-weak-1 or [weak1] of turtle turtle-
number-weak-1 = turtle-number-weak-2 [numbering11]
  if [weak1] of turtle turtle-number-weak-2 = turtle-number-weak-1 or [weak1] of turtle turtle-
number-weak-1 = turtle-number-weak-2 [numbering11]
  if [weak2] of turtle turtle-number-weak-1 != -1 [numbering11]
  if [weak2] of turtle turtle-number-weak-2 != -1 [numbering11]
 numbering22
end


to numbering22
  if turtle-number-weak-1 >= 500 and turtle-number-weak-2 < 500 and experiment = "Second
Experiment - Only Homophily" [numbering11]
  if turtle-number-weak-1 < 500 and turtle-number-weak-2 >= 500 and experiment = "Second
Experiment - Only Homophily" [numbering11]
  if turtle-number-weak-1 >= 500 and turtle-number-weak-2 >= 500 and experiment = "Second
Experiment - Only Xenophobia" [numbering11]
  if turtle-number-weak-1 < 500 and turtle-number-weak-2 < 500 and experiment = "Second
Experiment - Only Xenophobia" [numbering11]
  if turtle-number-weak-1 < 50 and experiment = "First Experiment - Non-St Weak-Ties"
[numbering11]
  if turtle-number-weak-1 >= 950 and experiment = "First Experiment - Non-St Weak-Ties"
[numbering11]
  if turtle-number-weak-2 < 50 and experiment = "First Experiment - Non-St Weak-Ties"
[numbering11]
  if turtle-number-weak-2 >= 950 and experiment = "First Experiment - Non-St Weak-Ties"
[numbering11]
  if (int (turtle-number-weak-1 / 5)) != (int (turtle-number-weak-2 / 5)) [processgogo11]
  if (int (turtle-number-weak-1 / 5)) = (int (turtle-number-weak-2  / 5)) [numbering11]
end
```

```
to processgogo11
   ask turtle turtle-number-weak-1 [create-link-with turtle turtle-number-weak-2 ]
   ask turtle turtle-number-weak-2 [if weak1 != -1 [set weak2 turtle-number-weak-1]]
   ask turtle turtle-number-weak-1 [if weak1 != -1 [set weak2 turtle-number-weak-2]]
   ask turtle turtle-number-weak-2 [if weak1 = -1 [set weak1 turtle-number-weak-1]]
   ask turtle turtle-number-weak-1 [if weak1 = -1 [set weak1 turtle-number-weak-2]]
   weak-weak11
end


to weak-weak11
  if (count links with [color = grey]) != Non-St-Weak-Ties  [process-weak-weak-tie]
  if (count links with [color = grey]) = Non-St-Weak-Ties   [stop]
end


to errors
  ask turtles with [val02 > 1 or val02 < -1] [show own-number]
  ask turtles with [val01 > 1 or val01 < -1] [show own-number]
end

to variable23
 variable2
 variable3
end


to variable2
  ask turtles [set w11 (sum [val01] of link-neighbors with [own-number mod 5 = 1 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ) ]
  ask turtles [set w12 (sum [val02] of link-neighbors with [own-number mod 5 = 1 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ) ]
  ask turtles with [ own-number mod 5 != 1] [set w1  (1 - (abs (w11 - val01 ) + abs (w12 -
val02) ) / (2 + 2 * Homophily)) ]


  ask turtles [set w21 (sum [val01] of link-neighbors with [own-number mod 5 = 2 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ) ]
  ask turtles [set w22 (sum [val02] of link-neighbors with [own-number mod 5 = 2 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ) ]
  ask turtles with [ own-number mod 5 != 2] [set w2  (1 - (abs (w21 - val01 ) + abs (w22 -
val02)) / (2 + 2 * Homophily)) ]


  ask turtles [set w31 (sum [val01] of link-neighbors with [own-number mod 5 = 3 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ) ]
```

```
  ask turtles [set w32 (sum [val02] of link-neighbors with [own-number mod 5 = 3 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ) ]
  ask turtles with [  own-number mod 5 != 3] [set w3  (1 - (abs (w31 - val01 ) + abs (w32 -
val02)) / (2 + 2 * Homophily)) ]


  ask turtles  [set w41 (sum [val01] of link-neighbors with [own-number mod 5 = 4 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ) ]
  ask turtles  [set w42 (sum [val02] of link-neighbors with [own-number mod 5 = 4 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ) ]
  ask turtles with [ own-number mod 5 != 4] [set w4  (1 - (abs (w41 - val01 ) + abs (w42 -
val02)) / (2 + 2 * Homophily)) ]


  ask turtles  [set w51 (sum [val01] of link-neighbors with [own-number mod 5 = 0 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ) ]
  ask turtles  [set w52 (sum [val02] of link-neighbors with [own-number mod 5 = 0 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ) ]
  ask turtles with [ own-number mod 5 != 0] [set w5  (1 - (abs (w51 - val01 ) + abs (w52 -
val02)) / (2 + 2 * Homophily)) ]


  ask turtles [set w61 (sum [val01] of link-neighbors with [ int (own-number / 5) != int ([own-
number] of myself / 5) and [weak1] of myself = own-number  ] ) ]
  ask turtles [set w62 (sum [val02] of link-neighbors with [ int (own-number / 5) != int ([own-
number] of myself / 5) and [weak1] of myself = own-number ] ) ]
  ask turtles with [ weak1 != -1] [set w6  (1 - (abs (w61 - val01 ) + abs (w62 - val02)) / (2 + 2 *
Homophily)) ]
  ask turtles with [ weak1 = -1] [set w6 0]


  ask turtles [set w71 (sum [val01] of link-neighbors with [int (own-number / 5) != int ([own-
number] of myself / 5) and [weak2] of myself = own-number ] ) ]
  ask turtles [set w72 (sum [val02] of link-neighbors with [int (own-number / 5) != int ([own-
number] of myself / 5) and [weak2] of myself = own-number ] ) ]
  ask turtles with [ weak2 != -1] [set w7  (1 - (abs (w71 - val01 ) + abs (w72 - val02)) / (2 + 2 *
Homophily)) ]
  ask turtles with [ weak2 = -1] [set w7 0]
end
```

```
to variable3
   ask turtles [set s-df1 ( (-1 / (2 * (count link-neighbors )) ) * (
         (w1 * (val01 - sum [val01] of link-neighbors with [own-number mod 5 = 1 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ))
        + (w2 * (val01 - sum [val01] of link-neighbors with [own-number mod 5 = 2 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ))
        + (w3 * (val01 - sum [val01] of link-neighbors with [own-number mod 5 = 3 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ))
        + (w4 * (val01 - sum [val01] of link-neighbors with [own-number mod 5 = 4 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ))
        + (w5 * (val01 - sum [val01] of link-neighbors with [own-number mod 5 = 0 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ))
        + (w6 * (val01 - sum [val01] of link-neighbors with [int (own-number / 5) != int ([own-
number] of myself / 5) and [weak1] of myself = own-number  ] ))
        + (w7 * (val01 - sum [val01] of link-neighbors with [int (own-number / 5) != int ([own-
number] of myself / 5) and [weak2] of myself = own-number ] ))
           ) )  ]


   ask turtles [set s-df2 ( (-1 / (2 * (count link-neighbors )) ) * (
         (w1 * (val02 - sum [val02] of link-neighbors with [own-number mod 5 = 1 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ))
        + (w2 * (val02 - sum [val02] of link-neighbors with [own-number mod 5 = 2 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ))
        + (w3 * (val02 - sum [val02] of link-neighbors with [own-number mod 5 = 3 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ))
        + (w4 * (val02 - sum [val02] of link-neighbors with [own-number mod 5 = 4 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ))
        + (w5 * (val02 - sum [val02] of link-neighbors with [own-number mod 5 = 0 and int
(own-number / 5) = int ([own-number] of myself / 5) ] ))
        + (w6 * (val02 - sum [val02] of link-neighbors with [int (own-number / 5) != int ([own-
number] of myself / 5) and [weak1] of myself = own-number  ] ))
        + (w7 * (val02 - sum [val02] of link-neighbors with [int (own-number / 5) != int ([own-
number] of myself / 5) and [weak2] of myself = own-number  ] ))
           ) )  ]

  ask turtles  [set val01 val01 + s-df1 * (1 - abs (val01) ) ]
  ask turtles  [set val02 val02 + s-df2 * (1 - abs (val02) ) ]
end
```

APENDIX B. SIMULATION INTERFACE FOR NETLOGO 5.05