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Do the micro cognitive and communicative processes constrain group formation? Simulating Eastern and Western social cognition and group formation

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Abstract: How macro-level social structures such as groups emerge and transform over time through the combined effects of micro-level individual cognition and communication is an open and intriguing question. This micro-macro dynamics lies at the heart of social psychology. Simulation provides a helpful tool to explore this issue. Recent cross-cultural research suggests that how people construe their social relationships is critical to the size of social groups. It has been suggested that those who construe social relationships in terms of a social category defined by its prototype (Western style) are more likely to form larger social groups than those who construe their social relations in terms of connections (Eastern style). An agent-based simulation framework has been created to explore under what circumstances this empirical relationship between social cognition and group formation can be reproduced. The results suggest that this may hold under most empirically plausible circumstances: when there are more than or equal to three groups to begin with and when the agents are capable of communicating with each other about their common enemies. There were some surprising results to be discussed in the paper, including the finding that the agents' ability to communicate about common friends did not have a large impact on group formation.

Keywords: *Computer simulation, social group formation, agency, structure, culture*

1. INTRODUCTION

The micro-macro relationship is one of the master questions in social sciences. We have used agent-based computer simulation as a method to explore this relationship. Micro-level processes include an agent's cognition and communication; macro-level processes include the formation and transformation of culture and social structure. Culture can be defined as a collection of information that is (a) non-genetically transmitted between agents, (b) more or less shared within a population of agents, and (c) maintained across generations of agents over a period of time. One important cultural property is the distribution of different types of information across an agent population. One of the basic aspects of social structure is how these agents interact with each other, and the social groups the agents form. Cultures and social groups are conceptually distinct but interdependent. A group is a collection of agents who self-consciously regard themselves as members of the group (i.e., self-reflectively defined), and as an entity with an existence independent from specific members. The culture of a group is the totality of non-genetic information more or less shared among members of that group. The culture of a group is a property of the group.

Our aim was to manipulate culture to see the effect on social structure, i.e. the properties and dynamics of groups. We did this by manipulating two aspects of culture. These were different agent cognitive processes and communication styles. These aspects were examined under different initial conditions to test the robustness of any findings.

2. RESEARCH QUESTION

In cross-cultural psychology, Yuki (2003) has suggested the existence of two types of cultures. These are a category-based collectivism and a network-based collectivism. He suggested the existence of a predominant category-based intergroup orientation in the West, and a network-based intragroup orientation in East Asia. East Asian collectivism is characterized by an attention to intragroup relations, a cognitive representation of the ingroup as a network of interpersonal ties, and a self-concept connected with, but also distinguished from, other ingroup members. The self is regarded as a "node" in a social network. East Asian collectivism is concerned about relationships among ingroup members. Group members are motivated to maintain reciprocal and cooperative relations within an ingroup. People in this culture predominantly see the group as an interpersonal network among individual members. We call this a *linking* conception of a social group. In contrast, North American collectivism is generally concerned about intergroup comparison. In this culture people are motivated to attain a superior standing of the ingroup relative to outgroups. People in this culture predominantly see a group as a relatively "depersonalized" entity. We call this a *typing* conception of a group. Yuki's suggestion of two types of collectivism was supported by empirical studies of depersonalized trust (trust toward a relatively unknown target person) across cultures (Yuki et al., 2005).

We examined the implications of individual micro-level cognitive processes (typing or linking conceptions of groups) and communication about social relationships on macro-level social structure, in particular, the size of people's ingroups. Wheeler, Reis, and Bond (1989) found that North Americans (category-based collectivists) tended to interact with more people than East Asians, whereas East Asians (network-based collectivists) tended to have a smaller group of friends with whom they had longer contacts. Although it is intuitively possible a category-based view of the world would generate larger groups than a network-based view, a more principled theoretical reasoning needs to be provided. As well, it is unclear how communication may moderate the effect of these cognitive mechanisms. The communication we studied took the form of talking about friends (friendship communication) (Adams & Plaut, 2003), enemies (enemyship communication) (Adams, 2005) and a combination of both in comparison to no communication. We explored the conditions under which each type of communication impacted on social structure. We used agent-based computer simulation as a theory deduction tool to explore the consequences of different cognition and communication assumptions on social structure.

3. SIMULATION METHODOLOGY

An agent-based discrete time simulation framework called *ABCSocNet* was created to explore the effects of micro-level culturally-based cognitive and communicative processes on group formation. The logic of the simulation is depicted in **Figure 1**. It consisted of a population of interacting social agents. Agents were equipped with cognition (the ability to dynamically categorize their social world into ingroups and outgroups), as well as communication (the ability to determine common ingroup and outgroup members through grounding). Each agent perceived their own social network. This perception was updated by local interactions. Agents also had two-dimensional attitudes composed of approach and avoid potentials (Cacioppo & Berntson, 2004), and memory of social interaction (Kashima et al., 2000). Over time these agents interacted in dyads. Partner choice was determined via the attitudes. Each time a pair of agents interacted they communicated their perceived ingroup and outgroups to each other. They adjusted their attitudes towards each other and towards those agents whose group membership they agreed on in their communication. This logic was repeated for a set number of time steps.

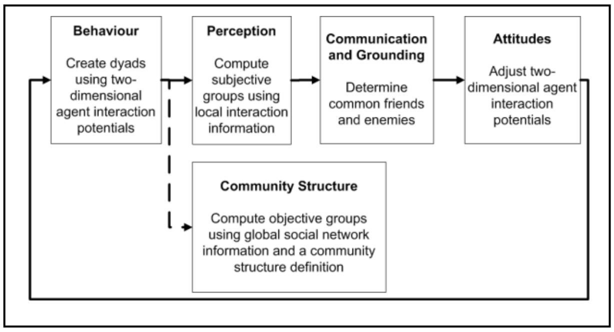

Figure 1. Logic of a single time step in *ABCSocNet*. The logic is separated into distinct phases corresponding to social psychological models of agent behaviour, communication and cognition. Objective groups are computed using information from the entire social network while agents use locally updated social network information. Each agent has its own perception of the artificial society.

Category-based or "typing" cognitive processes were modeled by Ward's (1963) hierarchical clustering method. Network-based or "linking" cognitive processes were modeled by single-linkage hierarchical clustering. Both methods were implemented using the Lance and Williams' (1966) flexible method. Following Milligan and Cooper (1985), a study was conducted to determine a robust choice of community structure definition or hierarchical clustering stopping rule applicable for possible conditions arising in the simulation. A number of definitions were tested using known data sets representing different initial number of groups. A global measure called the weighted modularity (Newman, 2004) was eventually selected to define groups, keeping in mind known problems with resolution limits (Fortunato & Barthélemy, 2007). The cognition type (typing versus linking), communication type (friendship versus enemyship presence), number of groups and group size were the main independent variables. In order to identify groups in the agent population, three different hierarchical clustering methods were used independently from the agent cognitive process. They were single-linkage, the group average method, and Ward clustering. The weighted modularity index was used as the community structure measure. Initial conditions for simulations were set so that there were one to five groups at the beginning. In early studies, several different configurations of initial groups were explored; however, in this study, one configuration was selected that was representative of the data pattern for each condition. The population size was twenty agents. So for one initial group, there was a single group of ten agents in a background of ten agents. For two initial groups, there were two groups of ten agents each. For three initial groups, there were two groups of seven agents and one group of six agents. For four initial groups, there were four groups of five agents each. For five initial groups, there were five groups of four agents each (See Figure 2).

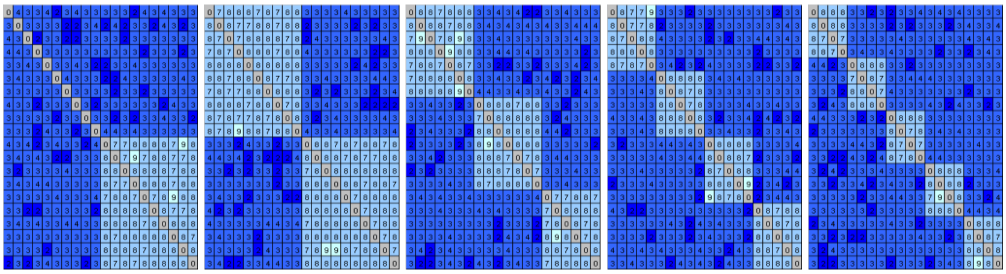

Figure 2. Initial group sizes used for the Unconfounded Study in adjacency matrix format. From left to right are the initial interaction counts for one to five initial groups. The light blue regions represent the groups. Rows and columns represent agents. The grey diagonal consists of zeroes as agents cannot interact with themselves.

Each simulation run was for two hundred and ten time steps. Each run was replicated twenty times using unique random number seeds. Results from individual time steps were combined into twenty blocks each containing ten time steps. A factorial design was used and the results analyzed using an ANOVA with the objective clustering method, initial number of groups, cognition, enemyship communication, friendship communication and time as the independent variables. The dependent variables were the smallest group size, largest group size and group stability at each time block. The group stability was defined by a generalized Small's (1977) formula, similar to Jaccard's (1901) index for cluster similarity. The data were blocked into ten time step blocks for the analysis. Groups were calculated using a moving window of size twenty time steps. The first twenty time steps were omitted to allow the formation of a moving window.

3.1. Assumptions and Settings

Cognition

Agents updated their perceptions of social groups using only information from their immediate dyad encounter, rather than from all dyads in the population. The memory model was a simple exponential smoothing model with an equal weighting of past experiences to current experience. At the start of each simulation run, each agent's memory was initialized to identical interaction counts as defined by the initial group conditions. This structure was used as the basis to generate a perceived category hierarchy using the agent's cognitive process. The agent approach and avoid potentials generated the initial interaction counts via the sigmoid scaling equation $\boldsymbol{\tau} = \frac{\boldsymbol{\alpha}}{(1+e^{-\boldsymbol{\beta}\cdot(\mathbf{2\varphi-1})})(1+e^{-\boldsymbol{\beta}\cdot(\mathbf{2\omega+1})})}$, where τ represents the initial interaction count, α represents the scale factor, β represents the slope of the sigmoid curve, φ is the approach potential in the range [0, 1] and ω is the avoid potential in the range [0, 1]. This equation is depicted below in Figure 3 with $\alpha = 10$, $\beta = 4.5$. This formula "pulls apart" groups from the "background" by accentuating differences, leading to well-defined groups.

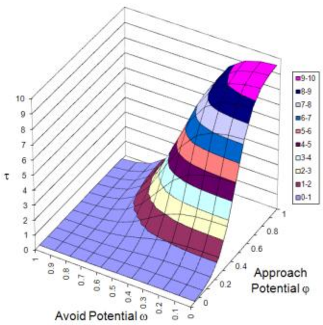

Figure 3. Sigmoid scaling of approach and avoid potentials to generate an interaction count.

At each time step, the updated agent memory was an exponentially weighted sum of the agent's current dyad interaction and the memory from the previous time step, i.e. $\boldsymbol{A_t} = \boldsymbol{\mu} \cdot \boldsymbol{M_t} + (\mathbf{1} - \boldsymbol{\mu}) \cdot \boldsymbol{A_{t-1}}$, where $\boldsymbol{A_t}$ was a matrix storing an agent's interaction count table at time $\boldsymbol{t}$, $\boldsymbol{A_{t-1}}$ was a matrix storing an agent's interaction count table at time $\boldsymbol{t-1}$, $\boldsymbol{M_t}$ was the matrix storing the interaction count for the current dyad, and $\boldsymbol{\mu = 0.5}$ was the exponential smoothing constant. The updated memory $\boldsymbol{A_t}$ was used as the input to generate an updated perceived category hierarchy to be used in communication.

Communication

A grounding model was used to model communication. First in the common ground establishment phase, both agents in a dyad decided whether they were in the same group on the basis of their perceptions of the social network among the agents. If this was mutually true, they were said to have established common ground and entered the common ground expansion phase. Depending on the particular communication model being investigated (no communication, friendship only, enemyship only or both friendship and enemyship communication) they then proceeded to look for further mutually shared ingroup and outgroup members (friendship and enemyship communications, respectively). If the agents failed to establish common ground, they did not enter the common ground expansion phase.

Behaviour

Two-dimensional approach and avoidance interaction potentials were used to model the attitude-behaviour link. If the common ground establishment phase was successful, the dyad agents increased their approach potentials toward each other. They also decreased their avoid potentials toward each other. If the common ground establishment phase was unsuccessful, their approach and avoid potentials towards each other remained unchanged. Both types of potentials were bounded in the range [0, 1].

For any communication involving friendship, if the establishment phase was successful, the agents in a dyad increased their approach potentials toward all common friends found in the expansion phase, but decreased their avoid potentials toward all common friends found in the expansion phase. For any communication involving enemyship, if the establishment phase was successful, the agents in the dyad decreased their approach potentials toward all common enemies, but increased their avoid potentials toward all common enemies found in the expansion phase. Sigmoid scaling was used to adjust agent interaction potentials. The magnitude of the adjustment depended on whether a target agent was in the common ground establishment phase or common ground expansion phase.

4. MAIN RESULTS

Although we examined the effects of cognition and communication on three different indices (largest group size, smallest group size, and stability), we report here on largest group size. We conducted cognition (typing vs. linking) x friendship communication (present vs. absent) x enemyship communication (present vs. absent) x objective clustering method (single linkage vs. group average vs. Ward) x time (1st to 20th time block) ANOVAs on the largest group (LG) size for each initial condition separately: one group through to five groups.

4.1 One Group Condition

In the one group condition, the typing cognitive process (M = 6.724) produced a smaller LG size than the linking style (M = 6.701) on the average. However, this was qualified by enemyship communication. When there was no enemyship communication, the typing and linking processes produced a similar LG size (*Ms* = 6.778 and 6.771, respectively); in the presence of enemyship communication, the typing process produced a smaller LG size (M = 6.624) than the linking process (M = 6.678).

There was a two-way interaction effect of friendship and enemyship communication. In the absence of enemyship communication, friendship communication reduced the LG size (6.842 to 6.707); however, when enemyship was communicated, friendship communication increased the LG size (6.625 to 6.677).

4.2 Two Group Condition

Intriguingly, in the two group condition, there was no effect of cognition. When two groups are locked in an intergroup relationship, how agents view their social world may not matter much to what social structure they produce. There was, however, a cross-over two-way interaction effect of friendship and enemyship communication. In the absence of enemyship communication, friendship communication reduced the LG size (6.682 to 6.654); however, when enemyship was communicated, friendship communication increased the LG size (6.656 to 6.680).

4.3 Three to Five Group Conditions

In these initial conditions, the effect of cognitive processes was opposite to that in the one group condition. The typing process produced a larger LG size (3 groups=6.947 vs. 6.881; 4 groups=6.909 vs. 6.671; 5 groups=6.792 vs. 6.582).

Nevertheless, this typing vs. linking effect was moderated by enemyship communication, and further by enemyship communication and objective clustering method [3 groups, $F(2,456)=7.527$, $p<.0005$, multivariate partial $\eta^2=.056$; 4 groups, $F(2,456)=6.724$, $p<.005$, multivariate partial $\eta^2=.029$; 5 groups, $F(2,456)=3.857$, $p<.005$, multivariate partial $\eta^2=.026$]. This highest order three-way interaction is reported in Figure 4.

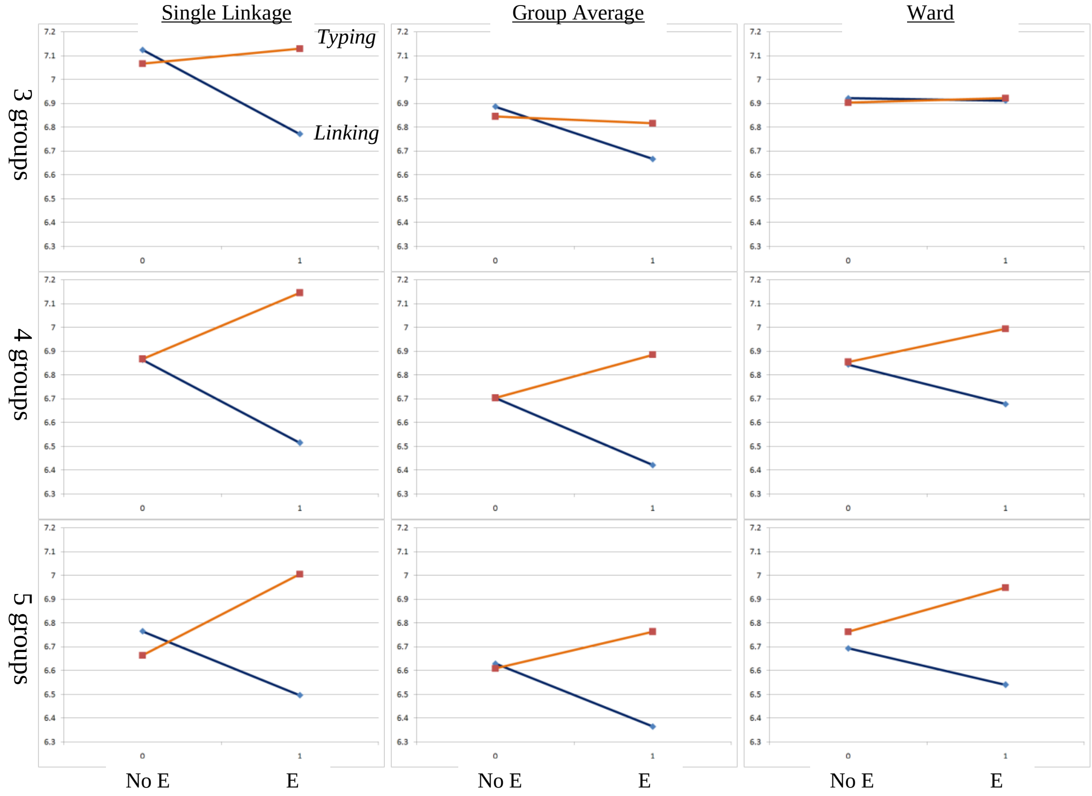

Figure 4. LG Size for three, four and five initial groups depicting an *Objective Hierarchical Clustering Method by Cognitive Process by Enemyship Communication* interaction. E = Enemyship Communication; No E = No Enemyship Communication.

Generally speaking, the effect of cognition does not exist in the absence of enemyship communication. However, when enemyships are communicated, the typing process produces a larger group than the linking process. This general tendency – cognition affects group size when agents communicate about enemies – is discernible under most circumstances that we investigated. Nonetheless, it is safe to say that when there are initially only three groups, whether the general observation holds depends on the type of clustering method used to identify groups in the population. It appears that the generalization may hold when there are initially a number of groups.

In the four and five group conditions, we found a three-way effect of cognition, enemyship communication, and time as depicted in Figure 5 [4 groups, Wilks' Lambda=.804, $F(19,438)=5.628$, $p<.0005$, multivariate partial $\eta^2=.196$; 5 groups, Wilks' Lambda=.789, $F(19,438)=6.163$, $p<.0005$, multivariate partial $\eta^2=.211$]. As noted earlier, the typing and linking processes produced a similar size largest group when there is no enemyship communication (green line). Nonetheless, the typing process produced a larger group than the linking process when enemyship communications are present. This basic pattern grew more prominently over time: the typing and linking seemed to be fairly similar at the beginning, but different group structures evolved over time depending on the agents' cognition.

Figure 5. LG Size for four and five initial groups depicting *Time by Cognitive Process by Enemyship Communication* interaction. *Time* is on the x-axis. The LG Size is on the y-axis.

Finally, in the three, four, and five group conditions, there was an interaction of friendship and enemyship communication [3 groups: $F(1,456)=4.782$, $p<.05$, multivariate partial $\eta^2=.010$; 4 groups, $F(1,456)=168.346$, $p<.0005$, multivariate partial $\eta^2=.270$; 5 groups, $F(1,456)=53.923$, $p<.0005$, multivariate partial $\eta^2=.106$]. Enemyship communications reduce the group size when agents do not communicate about their friends. However, in the presence of friendship communications, the effect of enemyship communication appears to depend on the number of initial groups. When there are a fair number of groups (i.e., five), enemyship communications appear to have a paradoxical effect of increasing the group size. It is also another way of describing the pattern: in the presence of enemyship communications, friendship communication has little effect; in their absence, friendship communication decreases the largest group size.

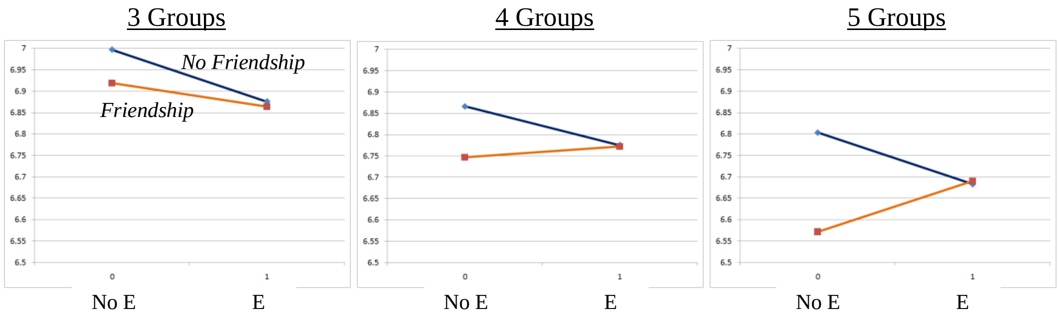

Figure 4. LG Size for three, four and five initial groups. Significant results for the two-way *Friendship Communication by Enemyship Communication* interaction for the three, four, and five groups conditions. E = Enemyship Communication; No E = No Enemyship Communication.

DISCUSSION

The results generally support the claim that micro-level cognition and communication can influence the group size. In line with the cross-cultural comparisons, the Western typing process appears to produce a larger group than the Eastern linking process under many circumstances. However, this needs to be qualified by a number of contextual variations. First, the initial group size is an important factor. When there is only one dominant group, it is the linking process that produced a larger group. There had to be three groups or more initially in order for the typing process to produce a larger group. When there are two similarly sized groups, cognition made no difference to group sizes. Second, when there were initially three or more groups, the typing process produced a larger group only when there were enemyship communications. In other words, in the social world populated by multiple groups, communicating about common enemies helped those typing agents to form a larger group over time, but shrank the linking agents' group.

Friendship and enemyship communications had different effects on group size. Regardless of the number of groups initially, when there was no enemyship communication, friendship communications reduced the group size. However, when there were enemyship communications, friendship communication increased the group size only when there were either one or two groups. When there were three or more groups initially, friendship communications did not affect the group size in the presence of enemyship communications.

If there is indeed a strength in number, and if it is an adaptive strategy to form a large group for humans, different combinations of cognitive and communicative processes appear to be more suitable depending on the initial condition of the social environment.

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