The Simulation of Society Evolution Based on the Impact of Communication Messages

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Mario Žuličeк, PhD
University of Rijeka (Rijeka, Hrvatska)
eMail: mario.zulicek@uniri.hr

Assoc. Prof. **Darijo Čerepinko**, PhD
University North (Koprivnica, Hrvatska)
eMail: darijo.cerepinko@unin.hr

Abstract

The way messages are structured may have a significant impact on individual behaviors and collaborative interactions within different social contexts. Some studies suggest that certain types of messages could influence various aspects of personality. This research utilizes social interaction simulation tools to examine the potential modifications achievable through various messaging models. Simulations in the social sciences enable research to be conducted with multiple iterations, as such studies would be either unfeasible, prohibitively costly, or ethically questionable to carry out in real-world settings. The findings indicate that, when interaction rules are established and adhered to, particular message types can enhance altruistic behavior and the proportion of agents exhibiting fair or honest behavior. This, in turn, may contribute to enhanced collaboration and support the overall long-term stability of the social systems.

Key words: simulation of social evolution, personality change, influence of communication messages

1. Introduction

The importance of developing simulations for studying social evolution has been underscored by research showing that individual behavior varies depending on whether interactions occur just once or are repeated multiple times (Axelrod, 1997; Rand et al., 2009; Sewell, 2010; Frey & Rusch, 2012; de Weerd et al., 2014). Simulations in the social sciences enable researchers to conduct experiments involving numerous repetitions, i.e. studies that would be either impossible or prohibitively expensive in real-world settings.

Hižak (2020) defines simulation models as computer-based frameworks that allow researchers to observe processes over specified time periods. He argues that simulation modeling is ideal for studying systems governed by numerous variables–systems that are too costly, too slow, or simply impractical to study experimentally. For instance, simulations are used to model X-ray scattering on interstellar dust. Moreover, certain scientific inquiries pose ethical challenges that make empirical testing untenable; simulations offer a viable alternative in such cases. Hižak includes evolutionary game theory among these ethically sensitive areas. He notes that simulations have been used since the 1960s, and their evolution has led to platforms that support the observation of agent (participant or player) behavior under defined rules and characteristics.

The relationship between societal development and member characteristics was explored by Van Segbroeck et al. (2012) using evolutionary simulation. Their study revealed that when groups consist of individuals with diverse personalities and varying desires for resource allocation, cooperation and fairness tend to emerge as dominant strategies. These traits arise as compromises among conflicting interests and are especially favored when the group's long-term survival is at stake.

This research was enabled through computer simulations rooted in game theory, particularly a framework known as Evolutionary Game Theory. Sigmund and Nowak (1999) describe this field as an intersection of population ecology and game theory. They identify two core components of evolutionary games: strategy and payoff. In simulations, a strategy is not a conscious decision but an inherited trait shaped through agent interactions. The payoff refers to the benefit an agent gains after an interaction, whether in single encounters or across multiple simulation cycles. All agents belong to the same population and compete for access to limited resources. Sigmund and Nowak explain: "If several variants of a trait occur in a population, then natural selection leads to an increase in the frequency of those variants with higher fitness. If the success of a trait does not depend on its frequency, this will eventually lead to the fixation of the optimal variant. However, if the success of a trait is frequency-dependent, its increase may lead to a population composition where other variants perform better; this can be analyzed using Game Theory" (Sigmund & Nowak, 1999, p. 503). This dynamic mirrors population ecology, where an increase in available resources leads to a rise in exploiters. As the number of exploiters grows, resource scarcity increases, which then reduces the number of exploiters - creating a cyclical pattern.

Adami et al. (2016) describe Evolutionary Game Theory as a mathematical framework that facilitates the simulation of scenarios involving players or agents, incorporating all behavioral influences, strategy evolution, and conflict outcomes. They emphasize that while mathematical models can predict outcomes in simple cases (e.g., few agents and low mutation rates), simulations are essential for exploring more complex situations. Most research in this field focuses on the coexistence of multiple strategies and their interactions. Adami et al. recommend that simulations should not insist on the continuous presence of all strategies but instead explore how various strategy combinations perform in dynamic environments. This adaptability is what renders such simulations truly evolutionary. While the mathematical framework has its limitations, agent-based computer simulations can overcome them by enabling agents to learn from conflict and adapt to new conditions. Despite these constraints, they assert that mathematical modeling remains the foundation upon which simulations are built.

Pacheco et al. (2006) proposed enhancements to evolutionary simulations by incorporating the frequency and duration of agent interactions. They argue that evaluating interactions based on productivity helps identify conditions under which cooperation outperforms non-cooperation from an evolutionary standpoint. This approach is feasible in simulations with limited populations and diverse strategies or personalities. However, they also caution that predefining simulation parameters can shape evolutionary dynamics and thus influence outcomes. The simulated environment cannot fully replicate the complexities of the real world. Hižak (2020) acknowledges these limitations but maintains that evolutionary simulations still allow for essential research that would otherwise be unethical, unfeasible, or too costly.

Based on this theoretical foundation, we can conclude that evolutionary simulations offer a practical substitute for long-term, resource-intensive social science research. These simulations have advanced to a point where they can qualitatively model societal evolution while accounting for various environmental and individual-level variables. Despite their limitations, the benefits of using simulations in social research are substantial. Most notably, many simulations emphasize the importance of altruism for group longevity, highlighting the dangers of short-term thinking and negative social reputations.

Individual personality traits significantly influence how people perceive situations and make decisions. Traits such as modesty, honesty, and greed are especially influential in determining cooperative behavior. Studies show that high levels of modesty and honesty, combined with low levels of greed, correlate with more effective group cooperation (Tice et al., 1995; Moreno Okuno & Mosiño, 2020; Wang et al., 2011). According to Hudson and Fraley (2015), personality can change over time due to major life events, social aspirations, or personal development goals. Additional research supports the idea that personality traits can shift in response to important life experiences, particularly in areas like relationships and careers (Bleidorn et al., 2016), environmental awareness (Hopwood et al., 2021), social inte-

gration among students (Quinlan, 2006), and personal growth initiatives (Stevenson & Cregg, 2011). These changes are most significant when individuals receive external support in setting and pursuing personal goals.

Recent findings (Žuliček, 2023) suggest that communication strategies can also influence personality development. Grounded in game theory, this research shows that messages promoting rational decision-making and group belonging have the greatest effect on encouraging altruism. This aligns with studies using the Ultimate Bargaining Game, which demonstrate that players who adopt rational approaches often prefer equitable resource distribution—challenging classical economic assumptions about rationality (Mussel et al., 2013). Likewise, players generally exhibit altruism when making or accepting offers in this game context (Suneja & Das, 2023). Further evidence suggests that altruistic behavior is more likely during interactions with in-group members, pointing to the role of in-group bias.

The aim of this paper is to explore how personality changes impact the long-term sustainability of social groups and society as a whole, using simulations of social evolution as the primary investigative method.

2. Methodology

In this study, the computer application NetLogo was used to implement a simulation titled "Divide the Cake" (Wilensky, 1997). This is an evolutionary simulation featuring three types of agents, each representing a distinct personality type: modest, honest, and greedy. The agents operate within a bounded environment defined as a field covered with finite resources, which the agents attempt to access and utilize.

Each personality type is associated with a different resource claim:

- Modest agents aim to use one-third of the total available resources.
- Honest agents aim to use one-half.
- Greedy agents attempt to use two-thirds.

Because the sum of these appetites exceeds 100% of the available resources, agents are in competition with one another. They move within the defined field according to predetermined rules and parameters. When two agents encounter each other at the same location: a) if their combined resource claims are less than or equal to 100%, each receives their desired share; b) if their combined claims exceed 100%, both agents die as a result of the conflict.

Following these interactions, agents participate in a reproduction lottery, where the probability of reproducing is directly proportional to the level of appetite. This mechanism compensates for the disadvantage that higher-appetite agents face in conflict scenarios, allowing their traits to potentially persist in the population.

The simulation allows users to manipulate four key parameters:

1. Initial number of agents (range: 0–1000)
2. Percentage of each personality type (specified individually)
3. Maximum distance an agent can move per cycle (range: 0–10)
4. Viscosity – a coefficient representing the difficulty of agent movement within the field (range: 0–1)

In this context, viscosity refers to the resistance to movement; higher viscosity values make movement more difficult.

To assess how personality dynamics, evolve over time, two sets of simulations were conducted:

- The first set served as the control group, simulating population evolution based solely on baseline personality data.
- The second set constituted the experimental group, simulating population evolution after the application of a communication message model shown to be most effective in promoting altruistic behavior (Žuliček, 2023).

The three personality types—modesty, honesty, and greed—were chosen based on prior findings indicating variability in personality traits (Žuliček, 2023). Personality distributions for both groups were derived from the results of HEXACO personality test (de Vries, 2013). For the control group, personality proportions were determined using HEXACO assessments conducted prior to any intervention. In the experimental group, a second HEXACO test was administered after exposure to communication messages designed to promote rational decision-making and enhance a sense of in-group belonging.

The parameters of the simulations were defined as follows:

- Initial number of players: 1000
- Maximum distance: 1
- Viscosity: 0.5

The parameters specified above were assigned these values to enhance the frequency of conflicts within the simulation. The presence of players exhibiting individual personalities was documented at four intervals—after 50, 100, 500, and 1000 cycles. Results were obtained from 10 repetitions for each test group.

The t-test of independent samples was employed to compare the proportions of individual agents at the established threshold for a long-term sustainable society, aiming to investigate the differences in proportions between the control and experimental groups.

3. Experiment

The personality level of modesty, honesty, and greed based on the two HEXACO tests conducted is shown in the table 1.

TABLE 1: Share of three measured personalities in two personality distribution tests – with control and experimental groups

Test group / % of the players with specific personality traits within total population	Modesty	Honesty	Greed
1	37%	37%	26%
2	37%	41%	22%

The initial number of agents in this experiment was set to 1000 to achieve the maximum density of agents in the field, with the most interactions between them. The maximum distance that agents can travel in one cycle was set to 1, in order to contribute to the largest possible number of interactions/conflicts between the same agents. The viscosity value was set to the media value (0.5) that may also be considered as a balanced or neutral value.

3.1. First group of simulations – share of personalities without the influence of communication messages

In the first set of simulations, the values (shares) obtained from the first HEXACO test were used as the starting values. 10 simulations were conducted and the average values of the share of each personality were recorded after 50, 100, 500 and 1000 simulation cycles. The results are shown in Table 2.

TABLE 2: Simulation results based on the personality levels from the first HEXACO test

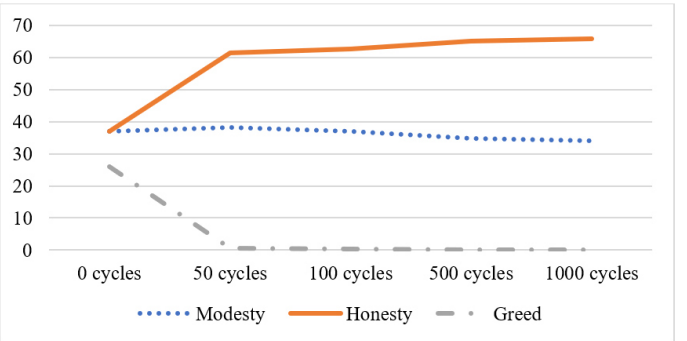
# of cycles	Modesty	Honesty	Greed
50	38,2%	61,3%	0,5%
100	37,0%	62,7%	0,4%
500	34,8%	65,0%	0,2%
1000	34,1%	65,7%	0,2%

The results shown in Table 2 display the average percentages of players displaying particular personality traits across all 10 simulations following the completion of the specified number of cycles. The results reveal two distinct trends. First, there is a noticeable and relatively rapid decline in the population of players character-

ized as greedy. Additionally, there is a significant decrease in players exhibiting modest characteristics, although this decline is less pronounced than that of the greedy players. Conversely, the number of honest players continues to increase, aligning with previous research and supporting the notion that honesty is the most effective long-term survival strategy in such social interactions.

Graph 1 shows a graphical representation of the movement of the percentage of individual personalities with regard to the number of cycles.

GRAPH 1: Display of the proportion of measured personalities according to the number of cycles, in the first group of simulations



Modest agents target one-third of the available resources, and their population adjusts accordingly throughout the simulation. The decline in the number of modest agents is partly attributable to their reproduction strategy, as defined by the game's default settings, making their decrease somewhat anticipated. Honest agents aim for half of the available resources; however, their numbers trend toward two-thirds of the total agent population, resulting in a corresponding decline in the population of greedy agents.

3.2. Second group of simulations – share of personalities based on the influence of communication messages

In the second set of simulations, the values (shares) obtained from the second HEXACO test were used as the starting values. 10 simulations were conducted and the average values of the share of each personality were recorded after 50, 100, 500 and 1000 simulation cycles. The results are shown in Table 3.

In the simulations utilizing data from the second HEXACO test, similar to those based on the results of the first HEXACO test, there is a significant decrease in the number of greedy agents. Notably, the initial proportion of greedy agents in these simulations is markedly lower, while the proportion of honest agents is con-

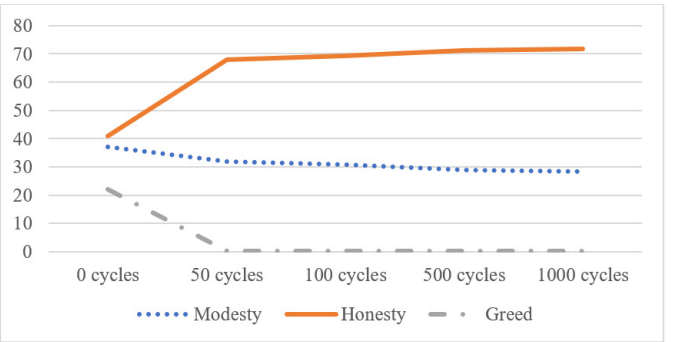
siderably higher. Consequently, after the same number of repetitions, the share of greedy agents is lower than in the first group of simulations.

The variation in the percentages of individual personality types with respect to the number of cycles in the second group of simulations is illustrated in Graph 2.

TABLE 3: Simulation results based on the personality scores from the second HEXACO test

# of cycles	Modesty	Honesty	Greed
50	31,9%	67,9%	0,2%
100	30,7%	69,2%	0,2%
500	28,8%	71,1%	0,1%
1000	28,2%	71,7%	0,1%

GRAPH 2: Display of the proportion of measured personalities according to the number of cycles, in the first group of simulations



In contrast to the first group of simulations, the proportion of modest agents falls below one-third after 50 cycles, while the proportion of honest agents rises above two-thirds. This phenomenon is attributed to the higher initial proportion of honest agents and their enhanced reproductive capacity during the simulation.

An analysis of the graphs depicting social evolution in both groups of simulations reveals that after 50 cycles, the proportions of individual personality types stabilize, exhibiting minimal variation for the remainder of the simulation.

3.3. Comparison of two sets of simulations

Based on the analysis of the two groups of simulations, a comparison of the proportions of individual personality types was conducted after 50 cycles of repetition. Visual analysis of the data reveals that the proportion of honest agents predominates in the society at this stage, thereby establishing itself as the most advantageous option.

To examine the presence of a statistically significant difference in the proportions of personality types between the two groups of simulations, an independent samples t-test was conducted and the results for Modesty were presented in Table 4.

TABLE 4: The results of the t-test of independent samples of the share of modest agents in the evolutionary simulation after 50 cycles, between the two groups of simulations

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Modesty	Equal variances assumed	,261	,616	8,876	18	,000	6,2600000	,7052502	4,77832	7,74168
	Equal variances not assumed			8,876	16,545	,000	6,2600000	,7052502	4,76893	7,75107

The Levene's test assesses the equality of variances between the two groups. Since the significance value (0.616) is greater than the common alpha level of 0.05, this indicates that the variances are equal across the groups, justifying the use of the "Equal variances assumed" row for further analysis. The t-value of 8.876 is quite high, and the p-value (0.000) is less than 0.05, indicating a highly significant difference between the means of the two groups. The mean difference of 6.260 indicates that, on average, one group scores 6.260 units higher than the other. The standard error difference of 0.705 suggests a relatively precise estimate of this difference. The analysis indicates a statistically significant difference in the modesty scores between the two groups. The equal variances assumption holds, and the results strongly suggest that one group exhibits higher levels of modesty compared to the other, with a mean difference of 6.260.

The t-test for Honesty is presented in Table 5.

TABLE 5: The results of the t-test of independent samples of the share of honest agents in the evolutionary simulation after 50 cycles, between the two groups of simulations

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Honesty	Equal variances assumed	,289	,597	-8,730	18	,000	-6,5700000	,7525734	-8,1511	-4,9889
	Equal variances not assumed			-8,730	16,421	,000	-6,5700000	,7525734	-8,1621	-4,9779

Levene's test for this trait also indicate that the variances are equal across the groups. The t-value of -8.730 is substantial, and the p-value (0.000) is well below 0.05, indicating a highly significant difference in means between the two groups. The mean difference of -6.570 indicates that one group has a mean score that is 6.570 units lower than the other group. The standard error difference of 0.753 suggests a precise estimate of this mean difference. In summary, the analysis indicates a statistically significant difference in honesty scores between the two groups.

The t-test of independent samples for Greed is presented in Table 6.

TABLE 6: The results of the t-test of independent samples of the share of greedy agents in the evolutionary simulation after 50 cycles, between the two groups of simulations

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Greed	Equal variances assumed	,217	,647	4,565	18	,000	,2600	,0570	,1403	,3797
	Equal variances not assumed			4,565	17,916	,000	,2600	,0570	,1403	,3797

Levene's test indicates that the variances are equal across the groups. The t-value of 4.565 is substantial, and the p-value (0.000) is well below 0.05, indicating a highly significant difference in means between the two groups. The mean difference of 0.2600 suggests that one group has a mean greed score that is 0.2600 units higher than the other group. The analysis indicates a statistically significant

difference in greed scores between the two groups. The equal variances assumption holds, and the results strongly suggest that one group exhibits higher levels of greed compared to the other, with a mean difference of 0.2600.

Beyond the primary focus of this study, additional tests were conducted using the default settings of Group Two to evaluate the long-term survival of each of the three personality trait agents. In three out of ten simulations, the greedy agents became extinct up to 10,000 cycles.

4. Discussion and conclusion

This study investigates resource allocation strategies in social situations characterized by a balance of power, where no single group of agents possesses a decisive advantage, and the rules apply equally to all participants in the game. This equality under the law is a predominant feature of systems that prioritize principles over particular interests.

4.1. Effectiveness of long-term strategies

Given the limitation of resources, honesty emerges as the most effective long-term survival strategy, as the consistent application of rules for all leads to a reduction in the number of greedy agents, as shown in the results section. This is in line with findings of Schank et al (2015).

The implementation of messages that encourage a rational approach to decision-making, combined with the promotion of in-group bias, further enhances the success of strategies based on honesty. However, the game settings do not account for potential power imbalances, particularly those that might benefit greedy players, leaving this as a topic for future research.

4.2. Communication planning

In conclusion, social systems that base their operational principles on equality and the strict application of uniform rules should strive to plan and implement communication that fosters a rational decision-making approach and expands the domain of in-group bias. This aims to enable as many members as possible to participate equitably in the distribution of scarce resources. Assuming that the promotion of other types of messages in the communication sphere – favoring emotional rather than rational decision-making and narrowing the domain of in-group bias – leads to contrary outcomes, it is evident that this work serves as a warning regarding various social and political decisions and processes observed during the time of this study. These dynamics are likely to lead to tensions between agents and a potential alteration of the “social contract”. which rarely occurs through peaceful means.

4.3. Limitations of the study

The aim of this study was to demonstrate how small changes in personal traits can, over time, lead to significantly more profound transformations at the societal level. However, this study also has several limitations. To begin with, further research is needed to examine the influence of different types of messages on the development of personal traits. In addition, it would be valuable to conduct simulations that incorporate a broader range of parameters reflecting the complexity of everyday life. Therefore, these findings should primarily be regarded as guidelines for future research and policy-making, rather than as universally applicable or definitive conclusions.

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Simulacija evolucije društva temeljena na utjecaju komunikacijskih poruka

Sažetak

Način na koji su poruke strukturirane može imati značajan utjecaj na individualna ponašanja i suradničke interakcije u različitim društvenim kontekstima. Neka istraživanja pokazuju da određene vrste poruka mogu utjecati na različite aspekte osobnosti. Ovo istraživanje koristi alate za simulaciju društvene interakcije kako bi se ispitale potencijalne promjene koje se mogu postići kroz različite modele komunikacijskih poruka. Simulacije u društvenim znanostima omogućuju provođenje istraživanja s višestrukim ponavljanjem, s obzirom na to da bi takva istraživanja bila neizvediva, pretjerano skupa ili etički upitna za provođenje u stvarnom okruženju. Rezultati pokazuju da, kada se pravila interakcije uspostave i poštuju, određene vrste poruka mogu poboljšati altruističko ponašanje i udio agenata koji pokazuju fer ili pošteno ponašanje. To zauzvrat može doprinijeti poboljšanoj suradnji i podržati ukupnu dugoročnu stabilnost društvenih sustava.

Ključne riječi: simulacija društvene evolucije, promjena osobnosti, utjecaj komunikacijskih poruka