Enhancing Game Worlds through Agent-Based Simulation: Increasing Realism using Big Five Traits and Resource Inequality

Raito Kamishima s1300175 Supervised by Prof. Maxim Mozgovoy

Abstract

This research explores the emergence of autonomous social structures in agent-based simulations by incorporating personality traits into trust-building logic. The objective is to create a "living digital society" where NPCs (Non-Player Characters) independently form relationships and social events unfold without player intervention. Two scenarios were compared: Case A, where agents follow a uniform logic, and Case B, where agents possess distinct personality traits that ensure behavioral consistency. The simulation results revealed that personality diversity functions as a critical "social glue." While Case B exhibited higher resource inequality (Gini coefficient: 0.32) compared to Case A (0.22), it achieved a significantly higher mean trust level (57 vs. 52). Furthermore, network analysis at a high trust threshold (T>70) demonstrated that Case B maintained a robust, well-distributed social fabric, whereas Case A suffered from fragmentation and node isolation. These findings suggest that individual personalities are essential for fostering social resilience and spontaneous social dynamics. This study contributes to the development of autonomous NPCs capable of sustaining complex, authentic social ecosystems that evolve independently in the background of digital environments.

1. Introduction

1.1 Background

In recent years, the development of autonomous agents capable of interacting within digital environments has become a significant field of research. While conventional multi-agent systems and decision-making models have primarily focused on computational efficiency and utility maximization, the impact of "individuality" on social stability and trust remains insufficiently explored [1]. In existing digital environments, such as video games, Non-Player Characters (NPCs) often function as mere tools for information retrieval, operating on scripted, uniform logic that fails to replicate the complex social dynamics found in reality. Real-world social phenomena—such as the formation of factions, economic disparities, and evolving interpersonal relationships—occur continuously and independently of any single individual's involvement.

1.2 Related Works

The integration of personality traits into computational models has gained significant attention as a means to enhance the realism of social simulations. Historically, agent-based models (ABMs) exploring social dilemmas have relied on simplified, fixed strategies such as "Tit-for-Tat." While these models provide foundational insights into cooperation, they often overlook the psychological heterogeneity that drives human decision-making.

Psychological research has established that personality traits are primary predictors of cooperative behavior. Specifically, Hilbig and Zettler [4] identified Agreeableness as a crucial factor in prosocial tendencies within social dilemmas. From an evolutionary perspective, Nettle[5] argued that personality variations represent strategic adaptations for resource acquisition. In the context of computational modeling, Luo et al. [6] demonstrated that incorporating Big Five traits into ABMs leads to more plausible social dynamics compared to homogeneous agent populations.

More recently, Newsham and Prince [7] showed that inducing OCEAN personality traits into autonomous agents significantly influences their planning and decision-making processes. While their work focuses on LLM-based task selection at an individual level, this study extends the scope by applying these traits to the dynamics of social trust and long-term resource distribution within a multi-agent population. By employing the Gini coefficient—a standard measure of economic inequality—this research addresses a critical gap: how microscopic personality differences aggregate into macroscopic social inequality over time.

1.3 Research Objectives

Trust is a fundamental element in maintaining long-term cooperative relationships within any agent collective. However, a lack of behavioral consistency often prevents the emergence of authentic social realism in artificial societies. This study focuses on the Five-Factor Model (OCEAN) as a framework to implement personality traits into autonomous agents to address this gap [2]. The objective of this research is to quantitatively evaluate how these personality factors influence the formation of trust and the distribution of resources within an agent society. By comparing uniform agents (Case A) with personality-driven agents (Case B), we aim to demonstrate that individuality-driven consistency fosters higher social trust and structural resilience. Furthermore, the findings provide an experimental foundation for developing autonomous social entities capable of sustaining a "living world" where social events and relationships unfold spontaneously in the background of a digital ecosystem.

2. Method

2.1 Agent Architecture and Decision-making Logic

We implemented an agent-based model to evaluate the impact of personality on social trust [3]. Each agent i makes a stochastic choice to either cooperate ('C') or defect ('D') based on a cooperation probability P_{coop}.

In Case A (Control Group), the decision is based solely on the current trust level T_{ij} toward the partner j:

$$P_{coop} = 0.5 + \frac{T_{ij} - 50}{100} \times 0.4$$

In Case B (Experimental Group), we integrated the Five-Factor Model. The probability is formulated by incorporating Agreeableness (A_i), Neuroticism (N_i), Openness (O_i), and a resource-based "hunger factor" (H_i):

$$P_{coop} = P_{base} + F_{trust} + E_{pers} + \text{Noise}_O + H_i$$

where:

- $P_{base} = 0.4$ is the constant baseline.
- $F_{trust} = \frac{T_{ij} - 50}{100} \times 0.3$ represents the weight of experience.
- $E_{pers} = (A_i \times 0.4) - (N_i \times 0.2)$ defines the fixed personality effect.
- $\text{Noise}_O = (O_i - 0.5) \times 0.1 \times \text{random}(-1,1)$ introduces behavioral diversity.
- H_i: If an agent's resource falls below the HUNGER_THRESHOLD (set to 20), a penalty is applied to P_{coop} to simulate survival-driven defection.

While the trust update formulas and the specific parameters (e.g., 0.5) are uniquely developed for this model to reflect personality-driven consistency, they are designed based on established conceptual frameworks of social exchange theory and validated through a series of preliminary simulations to ensure social stability.

2.2 Trust Update and Learning Bias

Trust levels are updated dynamically following each interaction based on a payoff matrix (R=7, T=10, S=0, P=3). Specifically, Case B implements a Personality-driven Learning Bias where trust updates (ΔT) are scaled by personality traits:

- Positive Update:
  $$\Delta T_{pos} = \Delta \times (1 + A_i \times 0.5)$$
- Negative Update:
  $$\Delta T_{neg} = \Delta \times (1 + C_i \times 0.3)$$

Instead of treating personality traits as static labels, this model operationalizes them as dynamic modifiers of social learning. While it is often assumed that **Agreeable** agents build trust faster and **Conscientious** agents are more sensitive to betrayals, we provide a formal rationale for these mappings based on psychological frameworks:

1. **Agreeableness (A) as Prosocial Reinforcement**: Agreeableness is characterized by a "trusting-by-default" posture and a motivation to maintain social harmony. In the context of our model, this trait functions as an accelerator for trust accumulation during successful cooperation. For an Agreeable agent, a positive interaction is not merely a resource gain but a reinforcement of a social bond, justifying a higher learning rate in trust-building compared to the baseline.
2. **Conscientiousness (C) as Normative Sensitivity**: Conscientiousness involves a high regard for rules, duties, and reciprocal expectations. For a highly Conscientious agent, a betrayal is perceived as a significant violation of a "social contract." Therefore, we modeled this trait as a penalty amplifier for trust erosion. The rationale is that individuals who prioritize order and reliability are psychologically more sensitive to "norm-breaking" behavior, leading to a more drastic withdrawal of trust to mitigate future risks.

By translating these traits into differential rates of trust update, the model moves beyond simple strategy-switching and instead simulates how microscopic psychological predispositions aggregate into diverse macroscopic social patterns.

2.3. Simulation Environment and Parameters

The simulation consists of $N = 20$ agents interacting over 100 discrete steps. Each step, agents are randomly paired. To ensure statistical robustness, we conducted 50 independent iterations for each case and calculated the mean and standard error.

Table 1. Experimental Parameters

Parameter	Parameter
Number of Agents	20
Total Steps	100
Initial Trust / Resource	50 / 100
Maintenance Cost	5 units / step
Personality Distribution	Uniform[0, 1]

The resource distribution within the simulation is governed by iterative bilateral interactions based on the **Prisoner's Dilemma** payoff matrix. In each time step, the resource level (R_i) of agent i is updated according to the following payoff structure and environmental costs:

Table 2. Payoff Matrix

Agent Action	Parter Action	Payoff Resource	Terminology
D	C	10	Temptation
C	C	7	Reward
D	D	3	Punishment
C	D	0	Sucker's Payoff

The simulation follows three core rules regarding agent behavior and resource management:

- **Decision-Making**: Agents choose to Cooperate (C) or Defect (D) based on their trust toward a partner. This choice is probabilistic; higher trust increases the likelihood of cooperation.
- **Maintenance Cost**: Every interaction incurs a Maintenance Cost of 5 units. This constant deduction acts as environmental pressure, requiring agents to gain resources continuously to survive.
- **Hunger Threshold**: A behavioral shift occurs at the Hunger Threshold (20 units). If resources fall below this level, the "Hunger Factor" reduces the cooperation probability by up to 0.3, prioritizing individual survival through defection.

2.4 Evaluation Metrics

To quantify the inequality of resource distribution among agents, we employ the Gini coefficient (G), which is defined as:

$$G = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} |x_i - x_j|}{2n^2 \bar{x}}$$

where n denotes the total number of agents, x_i and x_j are the resources held by individual agents, and $\bar{x}$ represents the mean resource value. A Gini coefficient of 0 indicates perfect equality, while a value approaching 1 signifies higher wealth concentration.

2.5 Social Network Analysis

To visualize social structures, we utilized the network library to generate trust networks. In these graphs, node colors are mapped to total resources using the "plasma" color scale (Yellow: High, Purple: Low). To highlight significant social bonds, only edges representing strong trust ($T_{ij} \geq 70$) were visualized.

3. Results

3.1. Evolution of Average Trust and Statistical Significance

Figure 3.1.1 illustrates the transition of the average social trust level over 100 simulation steps. The final mean trust for **Case A (Personality OFF)** was **52**, whereas **Case B (Personality ON)** reached **57**. This indicates that the introduction of personality traits improved the overall social trust foundation by approximately 9.6%.

From a statistical perspective, the error bars (Standard Error, ± SE) for Case A were extremely narrow, demonstrating high predictability and stability due to the uniform agent logic. In contrast, the error bars for Case B were wider and showed a trend of expansion over time. This suggests that the diversity of personalities introduces a level of stochastic emergence into the social dynamics. At step 100, the error bars of the two cases do not overlap, confirming that the trust improvement in Case B is statistically significant.

Furthermore, to address the internal distribution of trust beyond the mean values, we evaluated the Standard Deviation (SD) of trust levels across all agent pairs at Step 100. While Case A maintained a highly uniform distribution with an SD of approximately 1.03, Case B exhibited a wider variance with an SD of 3.14.

Although both cases remain relatively stable, the threefold increase in SD in Case B signifies a notable emergence of social heterogeneity. This indicates that the introduction of personality traits leads to a more diverse trust landscape, where individual relationship strengths vary more significantly compared to the uniform logic of Case A. A representative histogram (Figure 3.1.2) further illustrates this shift; while Case A displays a sharp, singular peak, Case B shows a broader, more dispersed distribution. This increased "trust variance" at the microscopic level provides the necessary psychological variation that eventually manifests as the macroscopic resource inequality observed in the Gini coefficient analysis.

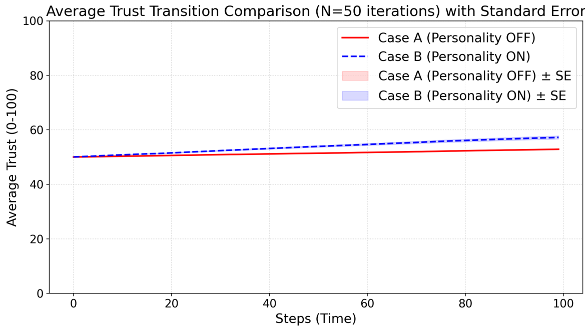

Fig. 3.1.1: Transition of average trust levels

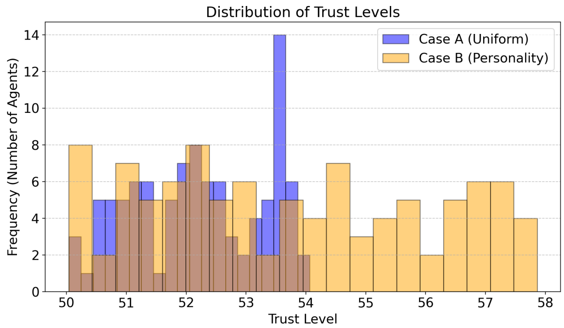

Fig. 3.1.2: Distribution of Inter-Agent Trust Levels at Step 100

3.2. Analysis of Resource Distribution via Gini Coefficient

Figure 3.2 shows the transition of the Gini coefficient, which serves as an indicator of resource distribution inequality. The final Gini coefficient was **0.22 for Case A** and **0.32 for Case B**.The fact that the Gini coefficient in Case B increased by approximately 45% compared to Case A indicates that differences in individual personality traits create gaps in resource acquisition efficiency, thereby promoting social stratification. Furthermore, the variance of the Gini coefficient in Case B increased over time, revealing that societies with higher diversity face greater uncertainty regarding long-term resource distribution.

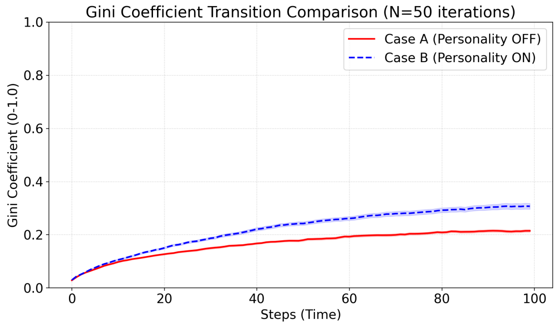

Fig. 3.2: Transition of Gini coefficients

3.3 Qualitative Evaluation of Social Network Structure

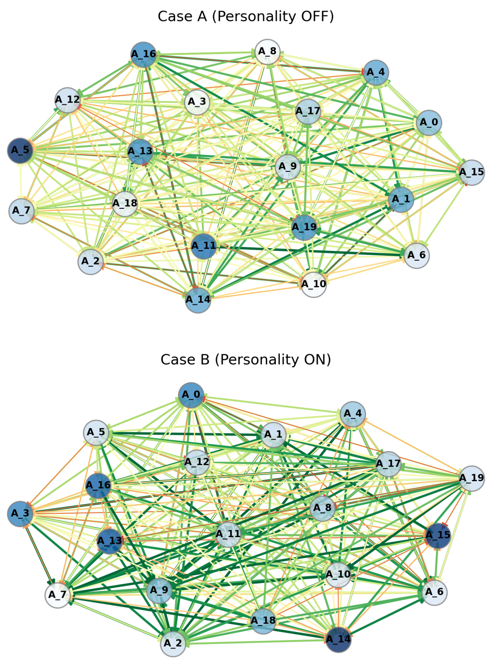

Fig. 3.3: Comparison of full-edge networks (Threshold=0)

To visualize the social structure at the final step, an analysis was conducted using network diagrams based on the Spring Layout algorithm. Crucially, the mathematical trust formulas defined in this model determine the "functional connectivity" of the network; when trust drops significantly, the link undergoes "functional decoupling," becoming dormant despite physical proximity. Therefore, to capture the active topology, a filtering analysis focusing on strong bonds (Trust Threshold $T > 70$) was applied. This revealed the following contrasting structures:

1. Case A (Uniform Society): While some internal clusters were formed, several nodes appeared isolated or positioned far from the center. This suggests that in a uniform strategy lacking behavioral consistency (personality), it is difficult to reintegrate individuals into the social fabric once a cooperative bond is stagnated.
2. Case B (Personality Society): The network exhibited a robust and well-distributed structure, maintaining a uniform spatial distribution without leaning toward specific exclusive factions.

This visually demonstrates that personality traits act as a "social glue," suppressing node isolation and fostering a Social Resilience that allows for the reconstruction of deep trust relationships across the entire population.

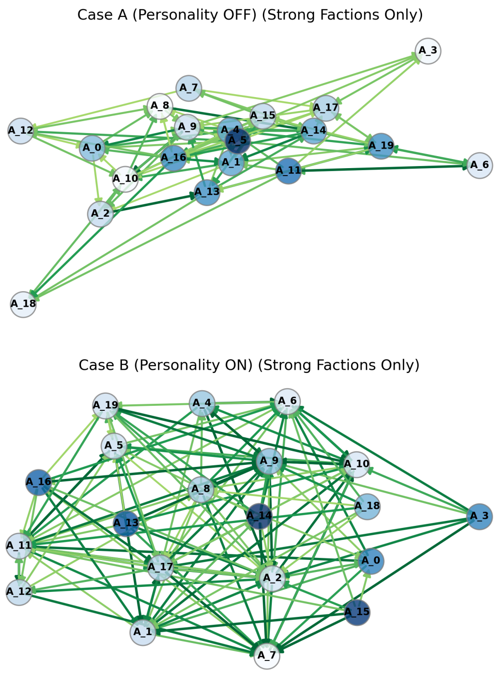

Fig.3.4: Social structures under high trust threshold (Threshold=70)

4. Discussion

4.1. Emergence of an Autonomous Social Ecosystem

The most significant finding of this study is that a stable social structure can emerge without any external intervention or centralized control. In Case B, agents built a resilient network independently, driven solely by their internal personality traits. This mirrors real-world social dynamics, where complex events and relationships unfold constantly beyond an individual's direct involvement. The "uniform" network observed in Case B suggests that personality acts as an underlying protocol that maintains social cohesion autonomously, even in a decentralized environment.

4.2. Social Resilience vs. Static Stability

The contrast between Case A and Case B highlights the transition from "static uniformity" to "social dynamism." Notably, both cases yielded Gini coefficients within the realistic global spectrum (0.22–0.35). Case A produced a coefficient of approximately 0.2, mirroring the high-equality profiles of countries such as Slovakia (0.23) and Slovenia (0.24). In contrast, Case B exhibited a more pronounced level of social stratification, yielding a coefficient of approximately 0.32. According to international databases [8], this value aligns with the economic distribution of many modern developed nations, such as Japan (0.33) and the United Kingdom (0.35).

While both results are empirically plausible, the increased disparity in Case B provides a "social flexibility" that prevents total exclusion. This suggests that for a digital society to feel "authentic," it requires the inherent friction and unpredictability—and the resulting realistic stratification—that only individual personalities can provide.

4.3. NPCs as Autonomous Social Entities

This research emphasizes the significance of NPCs as autonomous social entities that exist independently of player intervention. By embedding personality-driven trust logic, we can create a system where social events—such as the formation of factions, economic shifts, and the spontaneous rise and fall of social capital—occur continuously in the background of the simulation. This model mirrors the reality of human society, where countless events and relationships unfold beyond any single individual's direct involvement. The results of Case B demonstrate that such an independent social ecosystem can maintain its own structural integrity and continue to evolve through internal dynamics.

5. Conclusion

This research investigated the impact of personality traits on the formation of autonomous social structures through an agent-based simulation. By introducing personality-driven trust logic, we successfully demonstrated the emergence of a dynamic social ecosystem that evolves independently of external intervention.

The experimental results revealed that the presence of personality (Case B) significantly enhances the quality of social relationships compared to a uniform society (Case A). While personality diversity led to an increase in resource inequality (Gini coefficient 0.32), it also produced a higher mean trust level (57) and a more resilient network structure. Specifically, the network analysis at a high trust threshold demonstrated that personality traits function as an essential "social glue," maintaining high connectivity and preventing social isolation across the population.

These findings suggest that for digital environments to mirror the complexity and authenticity of real human societies, NPCs must possess internal behavioral consistency. Such autonomous entities allow for a "living world" where social events—factions, shifts in capital, and interpersonal dynamics—unfold spontaneously in the background. Future work will focus on introducing more diverse personality models to explore how varying social protocols affect the long-term sustainability of decentralized digital societies.

6. References

[1] R. Axelrod, "The Evolution of Cooperation," Basic Books, 1984.

[2] J. M. Digman, "Personality structure: Emergence of the five-factor model," Annual Review of Psychology, vol. 41, no. 1, pp. 417-440, 1990.

[3] M. Wooldridge, "An Introduction to MultiAgent Systems," 2nd Edition, John Wiley & Sons, 2009.

[4] Hilbig, I. E., & Zettler, I. (2009). Pillars of cooperation: Honesty-Humility, Agreeableness, and social value orientations. *Personality and Individual Differences*, 47(7), 796-801.

[5] Nettle, D. (2006). The evolution of personality variation in humans. *Evolution and Human Behavior*, 27(1), 622-638.

[6] Luo, L., Yin, F., Zhang, W., & Gu, J. (2017). Enhancing Agent-Based Models with Personality Traits for Social Simulation. *Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics (SMC)*.

[7] Newsham, J., & Prince, J. (2025). Personality-Driven Autonomy: Inducing OCEAN Traits in LLM-Based Agents. *Journal of Artificial Intelligence Research* (Preprint/Current Work).

[8] Global Note. (2025). *World Gini Index Ranking*. Retrieved from https://www.globalnote.jp/post-12038.html