Analyzing the Emergence and Dynamics of Pluralistic Ignorance with Agent-Based Models

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Abstract. Opinions are shaped at an individual level by social interactions and personal experience. The ways in which it shapes and changes is a topic of interest for opinion studies. Researchers have also explored the intricate dynamics of social phenomena such as polarization, the spiral of silence, and pluralistic ignorance. Pluralistic ignorance is a condition when the real opinion in a society is different from the spoken ideas. It is not clear how a difference in opinions between what someone says publicly (expressed opinion) and what they truly think (private opinion) arises, spreads, and continues to exist over time. To better understand this phenomenon, an Expressed-Private Opinion model was used to analyze how this discrepancy changes over time, using agent-based modeling. The study categorized agent types into four groups based on parameters, followed by an analysis of a society in which these types of agents are connected. It has demonstrated that individuals holding majority opinions are susceptible to being influenced by the minority. This susceptibility arises from social pressure, which can lead people to conceal their true opinion and conform to the assumed majority opinion. In certain societies, individuals are less likely to conform to the minority opinion when they receive early support or encounter voices that uphold their own opinions.

Keywords: Agent-based Modeling · Pluralistic Ignorance · Social Simulation · Opinion Dynamics .

1 Introduction

An individual's opinions are shaped through their interactions with others and the personal experiences. As people engage in social networks, they exchange ideas and establish relationships, which play a significant role in the way their opinions change. Researchers have conducted numerous studies exploring the formation and evolution of these opinions. One intriguing aspect of opinion studies is the 'spiral of silence,' which relates to how individuals perceive the political climate and their likelihood of expressing their views [1]. To find answers to real-life situations, various studies were conducted on different issues, including politics [2] , the diffusion of innovations [3], and climate change [4].

Pluralistic ignorance (PI) can be defined as a circumstance in which most members of a group privately oppose a norm while supposing (incorrectly) that the majority of others embrace it [5]. In other words, it refers to a situation in which a society's actual opinion differs from its publicly expressed opinion. There are still many unanswered questions concerning the causes of pluralistic ignorance [6].

The majority of people find it difficult to express their opinions in an environment where others' opinions are different from their own. People are more likely to express their own opinions when there are people with the same opinions around. High social support for a favored opinion acts as positive feedback, reinforcing the value associated with that perspective [7]. Failure to conform might result in decreased social position, social rejection, and even expulsion [8]. Even, when they are afraid of declaring an honest internal opinion, some prefer to follow the majority, even if it is not their own opinion.

There are different definitions in the literature, but in this study, the term "private opinion" means an individual's personal thoughts about a topic, which are not shared publicly. "Expressed opinion," on the other hand, refers to opinions that are publicly communicated. It is believed that individuals cannot know what others are privately thinking; they only know what they express publicly. Therefore, people can express different opinions than what they actually think. This may cause a discrepancy between private and expressed opinions in society. Empirical data and socio-psychological literature extensively document such discrepancies, with notable connections even to significant political events, such as the Arab Spring movement [9].

Study of pluralistic ignorance can be key to understanding the diffusion of ideas and the complex dynamics of opinion. Extremists play a crucial role in creating a divergence between private and expressed opinions within the general population [10]. The impact of minority opinions on the majority and the potential ways to reduce this influence remain uncertain. However, this paper offers valuable insights into comprehending how extremists can influence opinions within social networks, even as a minority, and how to potentially diminish this influence.

2   Methodology

Opinion dynamics is a field of study focused on understanding how opinions develop and transform over time. Researchers employ mathematical models, theoretical and empirical studies and computer simulations to explore the evolution of opinions. Mathematical and computer models aid in the formal investigation of both the interaction of internal psychological factors as well as the feedback between opinion change and social impact among a large number of people [11]. By analyzing a network using mathematical techniques, it is possible to identify and quantify differences that arise as a result of small changes to certain parameters. This way, scientists can learn more about the system's dynamics and how it responds to various inputs. Due to their ability to directly connect the

characteristics and behavior of people with their collective impacts, agent-based models are a useful tool for researching how social behavior is influenced by individual behavior [11].

2.1   Expressed —Private Opinion Model

Our publicly expressed opinions frequently diverge from our private ones [11]. However, some people have expressed opinions that differ from the private opinion. There have been various studies about how expressed and private opinions are changed. To change the opinion of the people in the network at each time step, the DeGroot model employs a discrete-time weighted averaging approach [12]. The Friedkin-Johnsen model characterizes the process of group opinion change as an interpersonal accommodation in which each member of a group dynamically weighs his or her own and other people's opinions on an issue [13].One of the extensions of Friedkin–Johnsen, Expressed – Private Opinion (EPO) model is developed by Mengbin Ye [14]. This model aims to represent opinion distinctions as expressed and private opinions.

In this model, the agent's expressed opinion $(\hat{y}_i)$ can change based on the susceptibility to social pressure (ϕ_i) of the agent, and the inner-private opinion (y_i) changes according to the flexibility of the mind set parameter (λ_i). Agents give varying weights (w_{ij}) to their neighbours to represent the relationships.

$$y_i(t+1) = \lambda_i w_{ii} y_i(t) + \lambda_i \sum_{j \neq i}^{n} w_{ij} \hat{y}_j(t) + (1 - \lambda_i) y_i(0) \tag{1}$$

Private opinion change in the EPO model is given in equation (1).

$$\hat{y}_i(t) = (1 - \phi_i) y_i(t) + \phi_i \sum_{j=0}^{n} w_{ij} \hat{y}_j(t-1) \tag{2}$$

By using the equation (2), agents update their expressed opinion. In each time step, all agents first express their opinion and learn the neighbor's expressed opinion, then update private opinion and expressed opinion.

Different versions of the EPO models are studied such that at each time step, a single individual changes his or her opinion in an asynchronous EPO model [15]. Whereas, at least one agent updates his or her expressed opinion is studied in an EPO model with asynchronous and synchronous updating [12]. In both model, it is shown that if characteristically homogeneous agents are not attached to their initial opinions, it leads to convergence, as in the EPO model. Social networks of characteristically heterogeneous agents have not been studied yet. Only the similarly expressed opinions of other people are considered as opinion neighbors in the modified EPO (MEPO) model [16]. MEPO model focuses on the susceptibility to social pressure parameter and proposes three distinct function settings.

2.2   Agent - Based Modeling

In order to study opinion dynamics, different techniques were used, such as logic [17], mathematical modelling [18] and agent-based modelling. In this study, agent-based modelling technique is used to analyze opinion dynamics. Agent-based simulation can help to experiment with diverse cases and help to analyze different scenarios. Agent-based models are useful tools for examining how individual behavior influences society's opinion change, such as political polarization and cultural dissemination [19]. Researchers can use agent-based models to examine how and why a series of interactions among individuals leads to a collective result.

3   Model Description

We use NetLogo software to implement the EPO Model with agent-based modeling. The EPO model encompasses continuous private and expressed opinions that are bound within the range of 0 and 1. Communication between agents is non-symmetric, which is captured via directed links. The moderate-sized community with different ideas is studied. The model consists of 100 nodes, with an average node degree of 35 (n=100, k=35).

Furthermore, within the EPO model, an agent's mindset, which refers to an openness to new ideas, is denoted by the parameter λ_i , where a value of 1 signifies a flexible mindset and a value of 0 represents a rigid mindset.

Additionally, susceptibility to social pressure is indicated by the parameter ϕ_i, meaning the degree to which an individual is influenced by the opinions of others in a social environment. A value of 1 denotes maximum susceptibility, and a value of 0 denotes total immunity to social pressure.

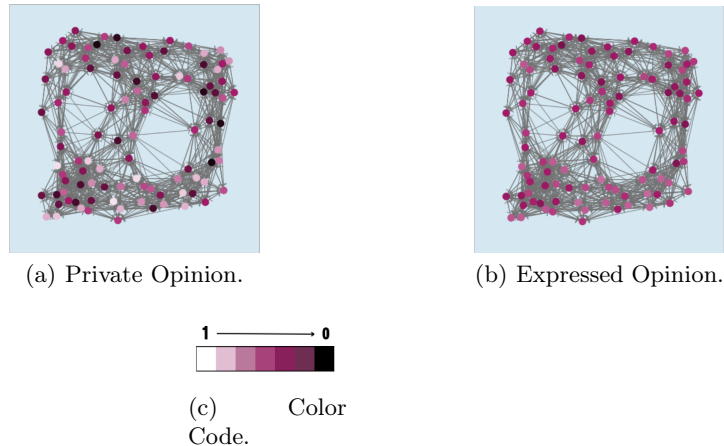(a) Private Opinion.

(b) Expressed Opinion.

(c)   Color Code.

Fig. 1: NetLogo Representation.

Figure (1) shows the Expressed - Private Opinion model representation on NetLogo software. The nodes within the figure serve as a visual representation of agents, which are then linked together to form social networks. It should be noted that the links between nodes are uni-directional. Private opinion is shown in Figure (1(a)) where Figure (1(b)) represents expressed opinion. Notably, the colors within Figure (1), provide insight into the variation between the private and expressed opinions of the agents. In the expressed opinion, the node colors appear to be almost coherent, whereas in the private opinion representation, the node colors tend to exhibit a greater degree of variability.

3.1 Agent Types

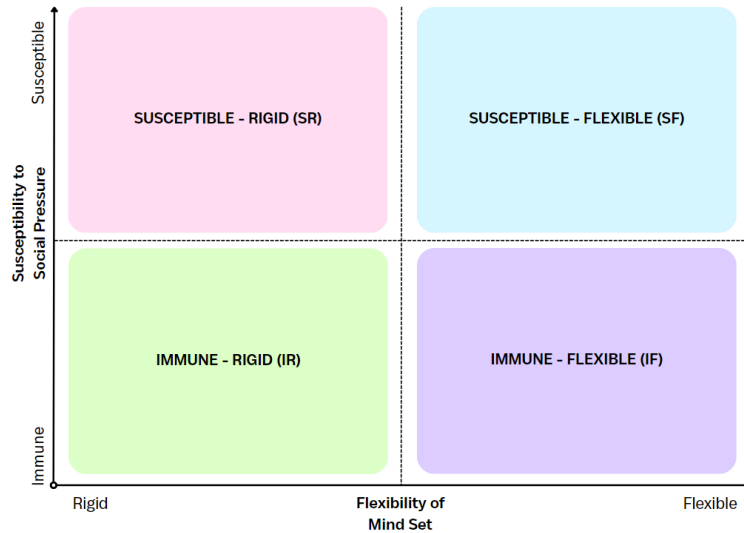We introduced 4 types of agents representing different personalities.

Fig. 2: Agent types with respect to mind set and susceptibility to social pressure.

Susceptible - Rigid A person with high susceptibility to social pressure and a rigid mindset may exhibit a strong inclination to conform to social norms, even if they do not personally agree with them. Their resistance to change can make it challenging for them to adapt to new ideas.

Immune - Rigid A person who is resistant to societal pressure and has a rigid mindset may be zealous about their opinions, and may be hesitant to accept different viewpoints or change their opinion. Even in the face of criticism or societal pressure, they frequently act and believe in accordance with their opinions.

Susceptible - Flexible One who maintains societal harmony. They may find it difficult to preserve a deep belief in their own opinion. This person's opinions are molded and affected by their social network, and they are frequently willing to change their minds based on the opinions of others.

Immune - Flexible These agents could be quite open to new concepts and thoughts and be prepared to take into account different approaches or methods of accomplishing things. This person is open-minded and flexible in their ideas and opinions, frequently changing their minds in reaction to new knowledge.

4   Simulation Experiments

This study encompasses an examination of three distinct societal cases. The first case involves a society where the agents are characteristically homogeneous, i.e., predefined agent types with initial randomly uniform distributed opinions. The second case entails a society where 10% of the agents exhibit susceptibility to social pressure and rigidity, while the remaining 90% is other agent types. The last one aims to compare two distinct scenarios within a community. The first scenario involves individuals who initially express an opinion which aligns with the prevailing majority opinion. In contrast, the second scenario entails a situation where some individuals, who are part of the initial majority, begin to voice their genuine opinions on the same issue after a time.

4.1   Case 1: Characteristically Homogeneous Agents

Figure (3) is a comprehensive visualization of the runs of the simulation experiment, whereby each row of the figure represents a distinct agent type, while the columns show the corresponding simulation ticks. Initially, all agent types exhibit identical distributions of varying opinion values, which are represented by the blue and red box plots. 50 replications were carried out during the simulation phase. The graphic is used to illustrate the distribution of opinions between 0 and 1 at simulation ticks 1, 15, and 30.The objective of this experiment is to identify the baseline before studying with heterogeneous societies.

Susceptible - Rigid High susceptibility to social pressure and a rigid mindset represent a society with established and traditional opinions however topics may be politically sensitive, leading to high susceptibility. By failing to reflect the
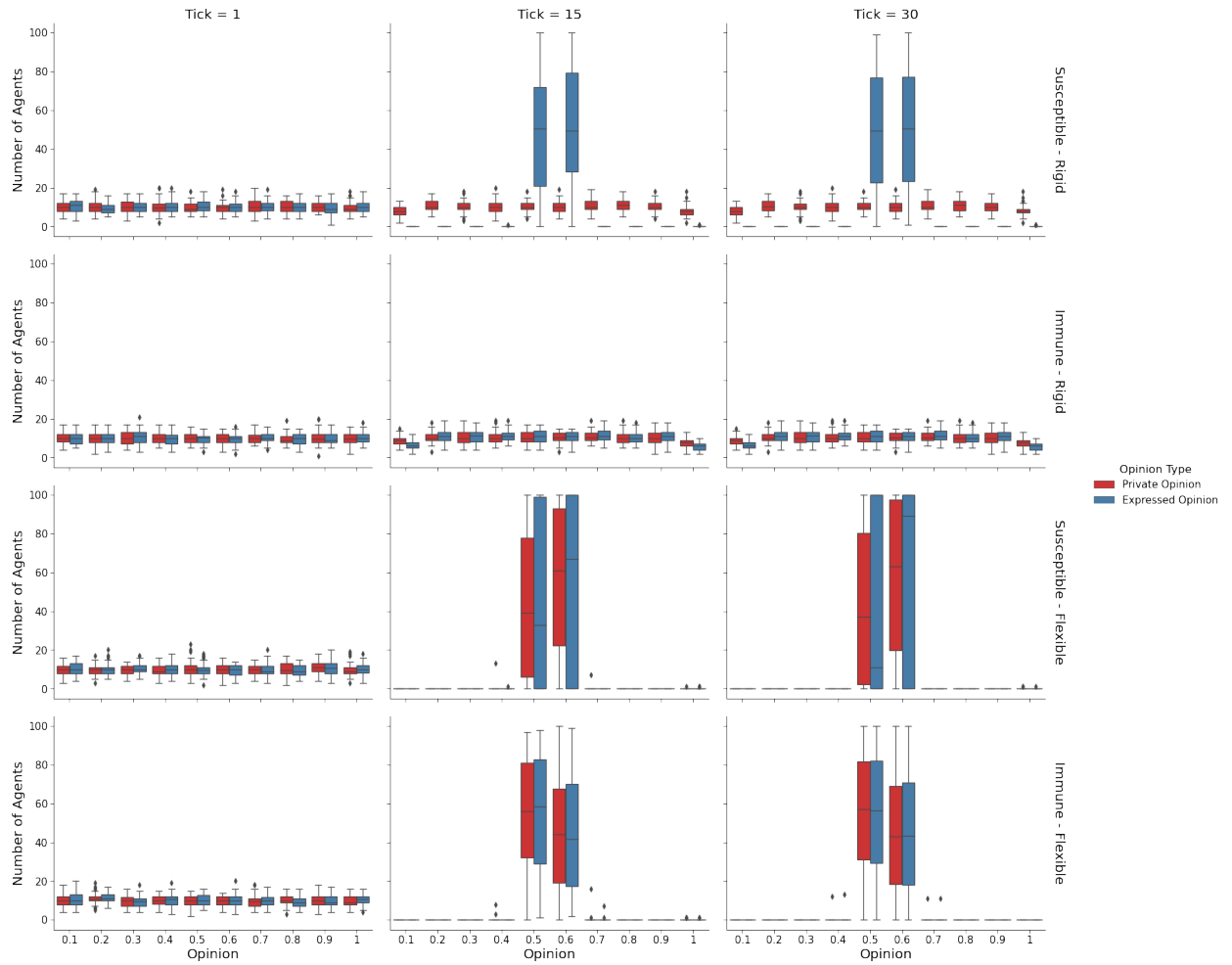
Fig. 3: Society with Characteristically Homogeneous Agents.

underlying complexity and diversity of society's majority opinion, just analyzing the notion being presented will result in an incorrect conclusion. Although the expressed opinions may give the impression that society is in agreement or unanimity, a closer examination exposes important differences and subtleties in the individuals' internal opinions.

Immune - Rigid Given that the agents descriptions exhibit rigidity and immunity to social pressure, it can be observed that the distribution of both their private and expressed opinions remains constant throughout the simulation, with no significant changes, as expected.

Susceptible - Flexible Initially, the individuals exhibit diverse opinions. However, owing to their flexible mindset, they are amenable to altering their opinions. As a result, due to the tendency of people to gravitate towards similar opinions, the expressed opinions of the individuals also converge towards a comparable opinion value, despite their susceptibility to social pressure.

Immune - Flexible Agents with a flexible mindset tend to engage in discourse over time and reach a compromise. Given their immunity to social pressure and their tendency to reflect their changing private opinion, expressed opinions also converge towards the middle, leading to a convergence of opinions.

When looking from outside, it is only possible to see the expressed opinions. Based on the blue box plots (expressed opinions), except for the second row, other societies seem identical. The first one is fundamentally different since the private opinions vary from 0 to 1. Both the third and fourth rows show similar distributions. However, the mechanism behind their dynamic behavior throughout the simulation is different. In the third row, the variance is high, indicating that they all meet at some value.

4.2   Case 2: The Influence of a Minority of Immune - Rigid Agents

Figure (4) depicts a simulation scenario in which 10% of the agents exhibit susceptibility to social pressure and rigidity, while the remaining 90% are of other types. The agents are classified based on their respective types, which are arranged along the rows, while the simulation ticks are presented along the columns.
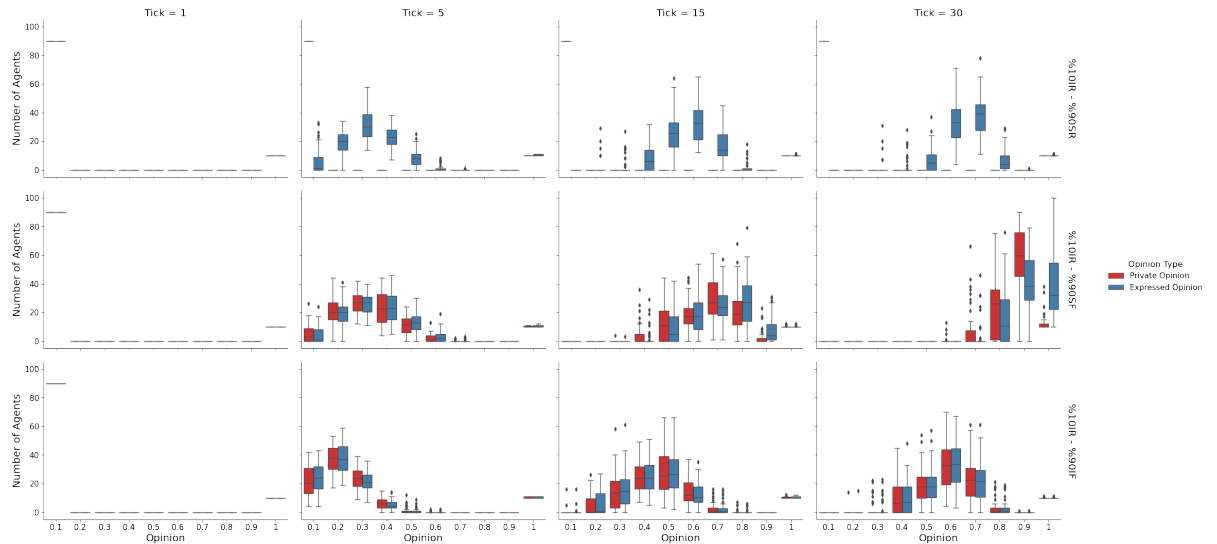
Fig. 4: Society with Immune - Rigid Agents Minority.

%10 Immune - Rigid : %90 Susceptible - Rigid Despite the fact that agents who have rigid mindsets and who are susceptible to social pressure prevail, the existence of agents who are resistant to social pressure and have a rigid mindset in society encourages a culture in which individuals hide their genuine thoughts and beliefs from others. Because of this, when people voice their opinions, the majority interprets them as representing the overall consensus, even when they do not.

10% Immune - Rigid : 90% Susceptible - Flexible Society leans toward the perspective of the minority since the majority does not express their true beliefs due to societal pressure, and because the majority has a flexible mentality, more people are persuaded to hold opinions similar to those of the minority.

10% Immune - Rigid : 90% Immune - Flexible As the majority have a flexible mindset, they gradually shift their opinions over time, independent of social pressure. The influence of minority opinions is able to sway the majority to some extent.

When we look at these three cases, the minority's constant advocacy brings the majority's opinion towards the minority. But in fact, in the first case, although the majority shows itself as expressing an opinion close to the minority's, they are thinking differently privately. In the second, the minority persuades the majority, and the private opinions move towards the minority's opinion. Third,

the majority is not as much affected by the minority as the second, since they are immune to social pressure.

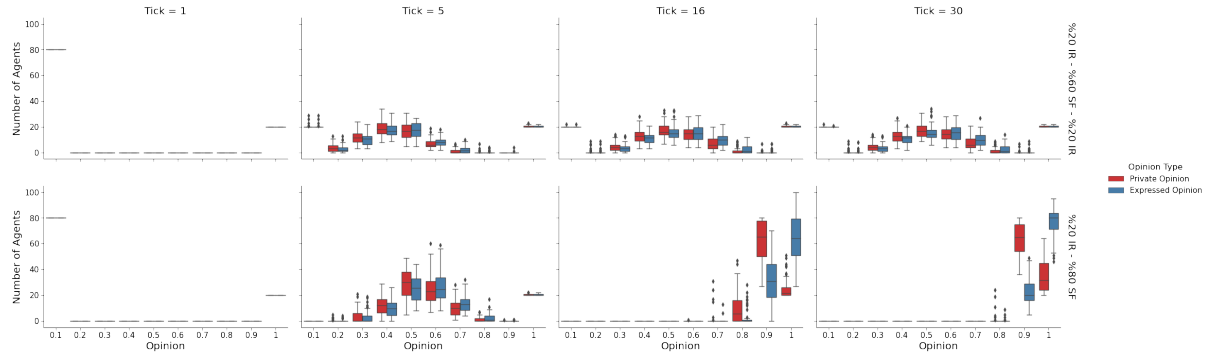### 4.3   Case 3: Minority of Immune - Rigid Agents with Two Different Scenarios

Fig. 5: Minority of Immune - Rigid Agents with Two Different Scenarios.

Figure (5) displays two distinct scenarios within a society. In the first row, we observe a community composed of 20 immune-rigid agents with an opinion of 1, 20 immune-rigid agents with an opinion of 0, and 60 susceptible-flexible agents with an opinion of 0. Although the susceptible-flexible agents represent the majority at the beginning, they strive to please both sides, leading to a shift towards a compromise in opinion.

In the second row, we see a society initially composed of %20 immune-rigid agents and %80 susceptible-flexible agents. After a certain time, 20 of the susceptible-flexible agents are asked to reveal their true beliefs. However, as the susceptible-flexible agents have already changed their minds, both opinion distributions converge to near 1 in the end.

Therefore, it is crucial for individuals to have early support or voices in favor of their opinions to prevent a shift towards the minority. This is particularly relevant in societies where social pressure can lead to individuals suppressing their true beliefs, ultimately resulting in a convergence towards minority opinion.

5   Conclusion

In conclusion, this study conducted a thorough comparison of various scenarios of opinion dynamics within a community. In Case 2, three types of societies were explored, demonstrating how the presence of a minority with a rigid mindset and

immunity to social pressure can significantly influence the majority's opinions. The dynamics of this influence depend on the unique characteristics of both the minority and the majority, providing a valuable framework for understanding how minority opinions wield influence over the majority.

The final case highlighted the significant influence of social pressure in shaping individual opinions. Thus, early support or voices endorsing individuals' opinions play a crucial role in preventing a shift towards the minority perspective. However, it is essential to acknowledge that the dynamics of this influence vary based on the unique characteristics of individuals and the social environment. The research also revealed the misperception of the minority as the majority, unveiling unresolved issues in opinion dynamics.

To address these aspects, future research endeavors aim to investigate the effect of bounded confidence on opinion change and its potential in reducing pluralistic ignorance. When people hold strong convictions and are confident in their beliefs, they may be less likely to openly discuss or express differing views. As a result, pluralistic ignorance can persist. When individuals have a certain level of confidence in their opinions but are open to considering and incorporating new information, they may be more willing to engage in constructive dialogue and exchange ideas with others.

Additionally, the study will explore how daily conversations influence the climate of opinion and assess the impact of different individuals on changes in private and expressed opinions. Unlike static networks, which represent fixed relationships between individuals, a temporal network captures the dynamic nature of interactions and how they evolve over time.

These comprehensive investigations will contribute to a better understanding of the intricate nature of opinion dynamics and will aid in the development of effective strategies to mitigate the negative effects of pluralistic ignorance within society.

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