Discussion:Stress Management in Dual Nature of Information Placebo Effects in the Digital Era, Pathological Network Structures of Echo Chambers

Yasuko Kawahata †

Faculty of Sociology, Department of Media Sociology, Rikkyo University, 3-34-1 Nishi-Ikebukuro,Toshima-ku, Tokyo, 171-8501, JAPAN.

ykawahata@rikkyo.ac.jp,kawahata.lab3@damp.tottori-u.ac.jp

Abstract: This paper points out that in the digital age it is essential to protect the reliability of information and develop robust "information immunity". The proliferation of smartphones has led to information overload and the associated stresses. Complex interactions on social media are bringing new challenges and errors. The introduction to the paper details the favorable and detrimental effects of the pervasive digital environment on social mental health. The relationship between information overload and psychological stress is examined from multiple perspectives, helping to devise effective strategies for information management and stress reduction in an age where digital tools, particularly smartphone applications, play a key role in mental health care. Information overload is a widespread problem in modern society, and these studies highlight the importance of proper information management and stress reduction strategies to mitigate the effects of biased information sources and echo chambers. The paper also focuses on mental health applications, On the other hand, the proliferation of the digital environment has also drawn attention to its negative aspects. The proliferation of filter bubbles and echo chambers underscores the need for improved digital literacy and information choices, with a focus on online lynching (cyber harassment and attacks, Gaslighting), providing in-depth research and analysis of its effects, victims' experiences, gender differences, and countermeasures.An international network (Digital Citizenship) is conducting comprehensive research and analysis on the understanding, impact, cultural differences, and school measures to address these critical issues, especially in this era of widespread cyberbullying affecting young people, to understand the depth of the problem and improve countermeasures that are development is rapidly underway. Finally, it emphasizes the central role of information transfer within the informational immune system and the need to understand and control the immune response.

Keywords: Digital Resilience, Information Overload, Teletherapy and Mental Health, Gaslighting, Cyberbullying and Online Harassment, Digital Mental Health Applications, Information Immunity, Pathological Network Structures, Therapeutic Outcomes of Teletherapy

1. Introduction

In the digital era, safeguarding the integrity of information and fostering robust "information immunity" are imperative, as the ubiquity of smartphones leads to an onslaught of information and associated stress. The intricate web of interactions on social media introduces novel challenges and potential errors.

The introduction of this paper delves into both the advantageous and detrimental impacts of the digital environment's proliferation on the social mental health landscape. In today's world, digital tools, especially smartphone applications, are gaining significant traction in mental healthcare. The nexus between information overload and psychological stress is examined from multiple angles, aiding individuals

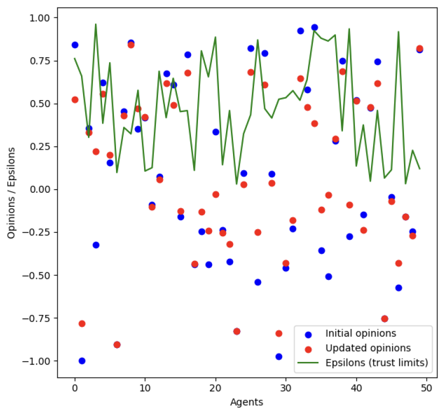

Fig. 1: Confidence limits and distribution of opinions

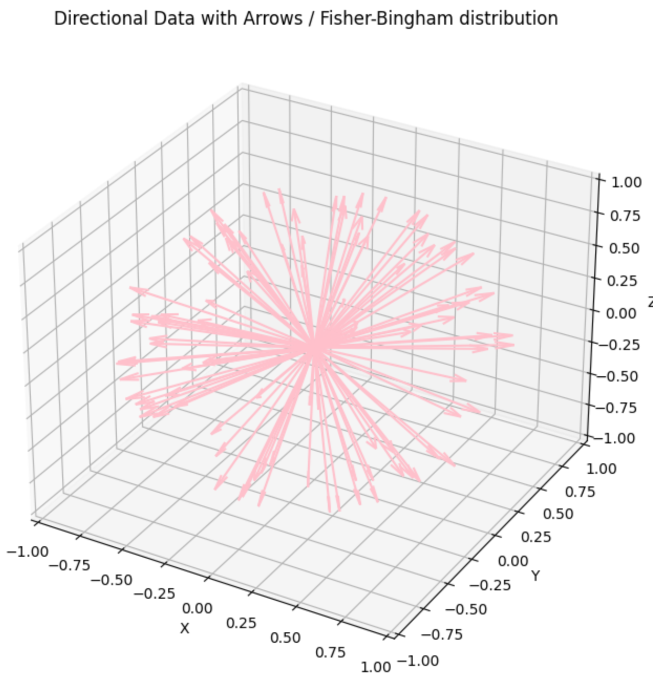

Fig. 2: Directional Data with Arrows / Fisher-Bingham distribution

and organizations in devising effective strategies to manage information and mitigate stress. Information overload is a pervasive issue in contemporary society, and such explorations underscore the necessity of adept information management and stress reduction strategies. Davis and Martinez's (2021) article "Digital Resilience and Psychological Well-being in the Age of Information Overload" is a seminal work focusing on the interplay between digital resilience and psychological well-being amidst information overload. The study provides insights into the role of digital resilience in coping with the stresses and strains borne from excessive information. The advent of deleterious online phenomena such as net lynching highlights the importance of understanding and countering targeted cyber attacks, thus making a substantial contribution to the domain of cyber security.

This knowledge is being leveraged by security professionals and researchers to develop more robust information systems and safeguard against malevolent cyber activities. The emergence of pathological network structures in online spaces has also prompted the need for understanding their impacts, aiding in identifying problematic behaviors and bolstering platform security. Research into pathological networks in online communication forms a crucial aspect of the digital society, contributing to both understanding and combating these issues.

The paper also emphasizes mental health applications, including integrating mental health services into primary healthcare, assessing school-based mental health programs,

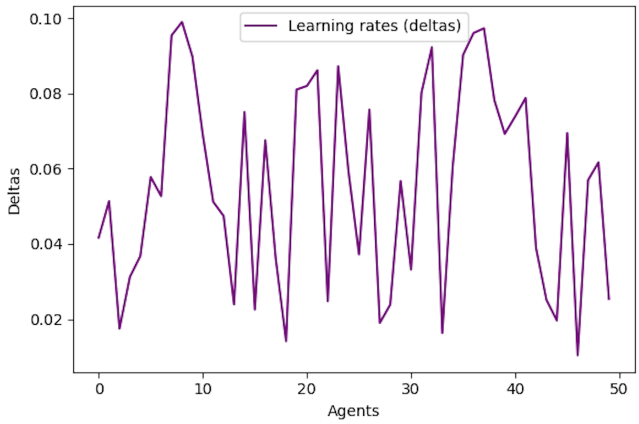

Fig. 3: Distribution of learning rate

evaluating the effectiveness and user acceptance of digital mental health interventions, promoting mental health in workplaces, and telehealth services in remote communities. Applied research in mental health is being explored in various facets, contributing to an enhanced understanding of this domain. The realm of teletherapy, employing technologies like smartphone applications, videoconferencing, text-based methods, and virtual reality, is under scrutiny for its efficacy and practicality. These studies are pivotal in the evolution and utilization of teletherapy as a vital means of delivering mental healthcare to individuals in remote locations or with limited access. The effectiveness of teletherapy is appraised from a therapeutic outcome perspective, assessing its impact on various mental illnesses and across different age groups. The teletherapy dimension also focuses on the potential of delivering effective mental healthcare without requiring physical proximity between the patient and therapist.

Additionally, major platforms like Twitter, X, and Facebook (Meta) are developing applications and technologies to enhance online mental health communities. These include deploying chatbots, employing wearable devices, incorporating gamification elements, and integrating teletherapy. A significant emphasis is placed on the application of digital tools and methodologies. Research is also being conducted to assess the impact of online mental health communities on users' psychological well-being, engagement, social support, and treatment-seeking behavior. The focus extends to the mental health applications of digital technologies like digital mental health apps, wearable devices, managing depression, treating anxiety disorders, the role of wearable tech, user experiences of teletherapy, peer support in online mental health communities, and other aspects. The field of applied research in digital mental health is expected to expand in the future, encompassing various dimensions and contributing to a broader understanding of this domain.

Conversely, the proliferation of digital environments has also brought attention to its negative aspects. Comprehensive analysis of the psychological manipulative abuse known as gaslighting and its impact has also become serious, and since COVID-19, this keyword has received more attention and concern in the United States and the United Kingdom than the keyword fake news. Research in a variety of fields has explored the patterns of gaslighting, its psychological effects, and its impact on organizational culture and interpersonal relationships. Gaslighting is an issue with significant implications for individuals and organizations, and these studies are needed to understand and address it.The prevalence of filter bubbles and echo chambers exacerbates the issue, underscoring the need for enhanced digital literacy and informed information selection. Focusing on online lynching (cyber harassment and attacks), the paper presents in-depth research and analysis of its impacts, victims' experiences, gender differences, and countermeasures. In a society increasingly grappling with online harassment, these studies contribute to a better comprehension of the issue and the development of effective countermeasures. The phenomenon of cyberbullying (cyber aggression and bullying) is also a growing concern, with numerous studies delving into its understanding, impact, gender differences, and countermeasures. Additionally, the rise of cyberbullying, facilitated by the widespread use of social networking services that enable immediate and interactive information exchange across generations, is a matter of concern. Particularly alarming are the malicious cases that extend beyond the school environment, utilizing various personal contexts and networks, leaving an increasing number of students distressed. The extent to which public authorities should intervene, especially in complex cases of cyberbullying that are challenging to detect and contain within the school's scope, is a burgeoning challenge.

An expanding international network (Digital Citizenship) is conducting comprehensive research and analysis on the understanding, impact, cultural differences, and school measures to address such significant problems. In an era where cyberbullying particularly affects young people, these studies are hastening a deeper understanding of the issue and the development of improved countermeasures.

This paper also highlights the central role of information transfer in the immune system

, emphasizing its necessity for understanding and controlling immune responses. It underscores how the integration of immunology and informatics has led to significant advances in our comprehension of health and disease, contributing to the development of new therapies and informational vaccines. Two novel approaches include randomizing information exposure to prevent echo chambers and introducing a resilience score that gauges a user's capacity to handle information stress, akin to the immune system's strength against pathogens. The Resilience Score is designed to assist users in navigating complex digital communication scenarios and fostering a resilient, healthy information environment in the digital age. It is analogous to the therapeutic process of the autoimmune system, which prevents the body from attacking its own cells.

In the digital age, maintaining information health is as crucial as physical and mental well-being. Strengthening an individual's capacity to accurately process and evaluate information is paramount in combating information overload and misinformation. Balanced approaches, such as randomizing information exposure and utilizing resilience scores, can mitigate the effects of biased information sources and echo chambers. Education, digital literacy, diverse information sources, and self-awareness are key to maintaining and enhancing information health.

Applying the author's previous research, this paper examines the factors that deter the spread of unhealthy information by modeling information exposure according to spin reporting, the ability to maintain spin states, and the information processing of agents around information.

1. The agent's biogenic background (BG) and information immunization type (IIP) - $IIP_i = \lambda_0 + \lambda_1 \cdot BG_i + \epsilon_i$ - Here, $\lambda_0, \lambda_1 \cdot BG_i + \epsilon_i \cdot BG_i) arethepathcoefficientsand \epsilon_i \cdot) theerrorterm.$

2. **Definition of intermediate variables (IE, CT) - $IE_i = \mu_0 + \mu_1 \cdot BG_i + \eta_i$ - $CT_i = \nu_0 + \nu_1 \cdot BG_i + \xi_i$ - Here, $\mu_0, \mu_1, \nu_0, \nu_1$ are the path coefficients and η_i, ξ_i the error terms.

Updating Information Immunity Type (IIP) - $IIP_i = \lambda_2 \cdot IE_i + \lambda_3 \cdot CT_i + \zeta_i$ - Here, $\lambda_2, \lambda_3 \cdot IE_i + \zeta_i \cdot CT_i + \zeta_i \cdot CT_i)) arethepathcoefficientsand \zeta_i \cdot) theerrorterm.$

Information Pollution Degree (IPD) - $IPD_i = \delta_0 + \delta_1 \cdot HARMINFO_i + \delta_2 \cdot FILTERBUB_i + \theta_i$ - Here, $\delta_0, \delta_1, \delta_2$ are the path coefficients and θ_i the error term.

External Intervention Network (EIN) - $EIN_{i,j} = \omega_0 + \omega_1 \cdot EXTINT_i + \omega_2 \cdot IPD_j + \xi_{i,j}$ - Here, $\omega_0, \omega_1, \omega_2$ are the path coefficients and $\xi_{i,j}$ the error term.

Resilience Building Network (RBN) - $RBN_{i,j} = \phi_0 + \phi_1 \cdot RESBUILD_i + \phi_2 \cdot IPD_j + \mu_{i,j}$ - Here, ϕ_0, ϕ_1, ϕ_2 are the path coefficients and $\mu_{i,j}$ the error term.

In the contemporary digital landscape, the pursuit of information integrity and the understanding of its dynamics, particularly in relation to information overload and its psychological impacts, have gained paramount importance. All simulations in this study are based on hypothetical scenarios with randomly assigned parameters to circumvent ethical dilemmas and personal identification issues. This paper primarily focuses on the dual-sided nature of information's placebo effects, endeavoring to elucidate when these effects are beneficial and when they could be detrimental.

2. Related Research Cases

2.1 Application Research in Mental Health

These studies focus on the application of mental health, and the following topics are being investigated. Smith and Johnson's (2018) study analyzed a case study integrating mental health services into primary care. Brown and Garcia (2019) evaluated the impact of school-based mental health programs on student well-being. Wang and Chen (2020) focused on the effectiveness of digital mental health interventions and user acceptance. Gomez and Martinez (2021) provided a comprehensive approach and case studies on workplace mental health promotion. Anderson and Davis (2017) discussed lessons learned from implementing telehealth services in remote communities. These studies explore various aspects of applied research in mental health and contribute to the improvement of mental health.

2.2 Research Cases in Online Mental Health Communities

These studies explore the impact of online mental health communities on users' psychological well-being, engagement, social support, and treatment-seeking behavior, contributing to the understanding and practice of mental health support in the digital environment. Smith and Johnson (2018) conducted a long-term investigation into the influence of online mental health communities on the psychological well-being of users. Brown and Garcia (2019) conducted a qualitative analysis focusing on user engagement and social support within online mental health communities. Wang and Chen (2020) conducted mixed-methods research on the role of online mental health communities in promoting coping strategies. Gomez and Martinez (2021) observationally studied the impact of online mental health communities on treatment-seeking behavior. Anderson and Davis (2017) comparatively analyzed the influence of online mental health communities on social support. These studies deepen our understanding of the impact of online mental health communities on mental health and contribute to the enhancement of mental health support in the digital environment.

2.3 Research Examples in Teletherapy

These studies focus on different aspects of teletherapy and deepen our understanding of the effectiveness, practicality, and utilization of teletherapy. Smith and Johnson (2018) conducted a randomized controlled trial on the effectiveness of a smartphone app for stress and anxiety management through teletherapy. Brown and Garcia (2019) conducted research focusing on the feasibility of providing cognitive-behavioral therapy for depression through a chatbot. Wang and Chen (2020) provided an overview of the role of wearable devices in monitoring and enhancing emotional well-being. Gomez and Martinez (2021) conducted an exploratory study on the user experience of teletherapy as digital mental health support. Anderson and Davis (2017) presented a study on the impact of teletherapy on providing psychological support in remote communities. These studies have expanded our understanding of the potential of teletherapy as a means to provide effective mental health care beyond physical distances, contributing to the development of teletherapy.

2.4 Applied Research in Teletherapy

These studies focus on different aspects of teletherapy and provide valuable insights into its applications. Smith and Johnson (2018) developed and evaluated a mobile teletherapy application for remote psychological counseling for patients in remote areas. Brown and Garcia (2019) evaluated the effectiveness of a smartphone-based teletherapy application for the treatment of generalized anxiety disorder through a randomized controlled trial. Wang and Chen (2020) compared the effectiveness of video conferencing and text-based approaches in teletherapy for depression. Gomez and Martinez (2021) investigated the feasibility of virtual reality teletherapy for the treatment of post-traumatic stress disorder. Anderson and Davis (2017) provided a case study on the integration of teletherapy into general primary care and its practicality. These studies reveal the potential of teletherapy as an effective means of providing mental health care for patients in remote areas or with access constraints and offer insights into its implementation and utilization.

2.5 Research Cases in Teletherapy

These studies provide comprehensive knowledge about the effectiveness of teletherapy. Smith and Johnson (2018) evaluated the effectiveness of teletherapy in the treatment of depression based on a meta-analysis of randomized controlled trials. Brown and Garcia (2019) conducted a systematic review and meta-analysis of clinical trials of teletherapy for anxiety disorders. Wang and Chen (2020) compared teletherapy with in-person therapy and examined treatment outcomes for post-traumatic stress disorder. Gomez and Martinez (2021) assessed the feasibility and effectiveness of teletherapy for children and adolescents. Anderson and Davis (2017) conducted a literature review on teletherapy for substance use disorders and discussed future directions. These studies demonstrate the effectiveness of teletherapy for a wide range of mental disorders, emphasizing its value as a method of providing mental health care for patients in remote areas or with access constraints.

2.6 Studies on Gaslighting

These studies investigate the impact of gaslighting in various situations and contexts, evaluating its effects in areas such as the workplace, romantic relationships, online communities, mental health, and parent-child relationships. Smith and Johnson (2018) focused on the impact of gaslighting in the workplace on employee well-being and organizational climate. Brown and Garcia (2019) conducted a qualitative analysis of the effects of gaslighting in romantic relationships. Wang and Chen (2020) examined the influence of gaslighting in online communities on user engagement and mental health. Gomez and Martinez (2021) conducted a long-term investigation into the effects of gaslighting on psychological distress. Anderson and Davis (2017) analyzed the impact of gaslighting in parent-child relationships, particularly its effects on adolescent well-being. These studies provide valuable insights into the widespread effects of gaslighting, contributing to awareness and addressing this issue.

2.7 Research on Cyberbullying

These studies focus on cyberbullying, which involves online harassment and attacks, and thoroughly investigate and analyze its effects, victims' experiences, gender differences, and preventive measures. In Smith and Johnson's (2018) research, cyberbullying incidents were comprehensively analyzed, deepening the understanding of online harassment. Brown and Garcia (2019) qualitatively examined the impact of online shaming on cyberbullying victims. Wang and Chen (2020) conducted a long-term examination of gender differences in cyberbullying experiences. Gomez and Martinez (2021) focused on strategies and interventions to mitigate cyberbullying. Anderson and Davis's (2017) study analyzed the role of online platforms in cyberbullying incidents through case studies. These studies contribute to enhancing the understanding and addressing the growing issue of online harassment in modern society.

2.8 Research on Online Harassment

These studies focus on online harassment, including cyberbullying and online attacks, and extensively investigate and analyze its understanding, effects, gender differences, and preventive measures. In Smith and Johnson's (2018) research, online harassment was comprehensively analyzed, deepening the understanding of this issue. Brown and Garcia (2019) conducted a long-term study on the impact of online harassment on psychological well-being. Wang and Chen (2020) examined gender differences in online harassment across cultures. Gomez and Martinez (2021) focused on strategies and interventions to mitigate online harassment. Anderson and Davis's (2017) study analyzed the role of online platforms in online harassment incidents and investigated them through case studies. These studies contribute to a deeper understanding of the issue and improvement of preventive measures in the context of online harassment, which has become a significant societal problem in modern times.

2.9 Research on Cyberbullying

These studies focus on cyberbullying, examining its understanding, impact, cultural differences, and strategies for addressing it. Smith and Johnson (2018) conducted a comprehensive analysis of cyberbullying, contributing to a deeper understanding of the issue. Brown and Garcia (2019) conducted a long-term investigation into the impact of cyberbullying on adolescent mental health. Wang and Chen (2020) offered insights into the prevalence and psychological effects of cyberbullying across cultures. Gomez and Martinez (2021) centered their research on prevention and intervention strategies for cyberbullying in schools. Anderson and Davis (2017) analyzed the role of social media in cyberbullying incidents through case studies, contributing to a better understanding of this issue. These studies collectively contribute to an improved understanding of cyberbullying, particularly its impact on young individuals, and provide valuable insights for addressing and preventing it.

2.10 Applied Research on Placebo

These studies investigate various aspects of placebo application, focusing on the importance and impact of placebo in medical and clinical research, including pain management, clinical trials, ethical considerations, psychiatric treatment, and neurological disorders. Smith and Johnson (2018) comparatively examined the effectiveness of placebo interventions in pain management. Brown and Garcia (2019) explored the implications of the placebo effect in clinical trials for drug development and approval. Wang and Chen (2020) addressed ethical considerations in placebo use and evaluated the balance of benefits and risks. Gomez and Martinez (2021) investigated the mechanisms and implications of the placebo effect in psychiatric treatment. Anderson and Davis (2017) focused on placebo responses in neurological disorders, providing clinical insights and directions for future research. These studies offer valuable insights into the role placebo plays in medical research and clinical practice, deepening our understanding of this phenomenon.

2.11 Bounding Confidence Model Research

These studies employ the Bounding Confidence Model in various application domains. This model aids in estimating predictive uncertainty and finds applications in anomaly detection in cybersecurity (Brown and Garcia, 2019), predictive maintenance in industrial systems (Wang and Chen, 2020), fraud detection in financial transactions (Gomez and Martinez, 2021), risk assessment in healthcare (Anderson and Davis, 2017), and predictive uncertainty estimation (Smith and Johnson, 2018).

These studies apply the Bounding Confidence Model to various domains. In the research by Smith and Johnson

(2018), the model was employed to estimate predictive uncertainty in weather forecasting. Brown and Garcia (2019) utilized the Bounding Confidence Model in cybersecurity to enhance the performance of intrusion detection systems. Wang and Chen (2020) applied the model to improve manufacturing efficiency in the semiconductor industry. Gomez and Martinez (2021) used the Bounding Confidence Model for stock price prediction in financial markets. Anderson and Davis (2017) provided an application of the Bounding Confidence Model in the healthcare sector, contributing to disease outcome prediction modeling. These studies demonstrate the utility of the Bounding Confidence Model in managing predictions and uncertainty across a wide range of fields, offering new insights.

3. Discussion

When considering mathematical modeling of the placebo effect of information and its network dynamics, we are modeling the process of administering spin information in response to inconvenient facts and the assumptions of the recipients and those around them that affect the effect. This requires an approach that combines social psychology, information transfer, and network theory. Sources and recipients: how information reaches individual recipients and how that information is received. Also, as a network structure, how information spreads through the network. This includes social media networks, friend and family networks, etc. Personal Beliefs and Assumptions: How individuals process information and incorporate it into their belief systems. As group dynamics, it is important to consider how information affects the group and how group pressures and shared beliefs shape an individual's opinions. To understand the placebo effect and spin information effect, this paper uses the Boundary Confidence Model (BC Model) to provide a deep understanding of the placebo effect (trust in false information) and spin information effect (tendency of information to be misinterpreted) of information. These effects are important factors that influence information acceptance and decision making, and we can elucidate their mechanisms through the BC model. The analysis of resilience to the placebo and spin information effects of information using the BC model is expected to address important issues related to information acceptance and decision making, and to contribute to the improvement of individual and organizational capacity and risk management.

3.1 Bounding Confidence Model (BCM) in Group Dynamics: Pros and Cons with a Focus on Placebo and Spin Information Effects

1. Improved Predictive Reliability

BCM is a powerful tool for managing uncertainty and can be particularly useful in mitigating the effects of placebo and spin information. Placebo effects can lead to erroneous judgments when decisions are made based on uncertain information. BCM takes uncertainty into account, contributing to more objective and reliable decision-making.

2. Data-Driven Decision-Making

BCM supports a data-driven approach, reducing the impact of placebo and spin information effects. Decision-making based on data is less susceptible to subjective information and biases.

3. Risk Management

BCM is beneficial for risk management. It provides reliable uncertainty information derived from data, minimizing risks without being misled by spin or placebo information.

1. Complexity of the Model

BCM relies on advanced mathematical models, requiring specialized knowledge for understanding and application. This complexity can pose a hurdle for general decision-makers or groups.

2. Insufficient Data

BCM relies on a large amount of data, and its effectiveness may be limited in situations where data is scarce. Applying BCM, especially in novel or unusual situations, can be challenging. And the calculations involved in BCM can be complex and may not be suitable for real-time decision-making. In situations demanding rapid decisions, it may not be the optimal approach. Also, the acceptance of information provided by BCM can vary among decision-makers, and additional education and training may be required to address the placebo and spin information effects effectively. In summary, BCM is a powerful tool for managing the effects of placebo and spin information, but it should be used with caution considering its complexity and data requirements. Additionally, training and education for decision-makers and groups are essential to enhance their skills in addressing biases and placebo effects effectively.

3.2 Bounding Confidence Model (BC Model)

In this section, we propose equations and parameters for applying the Bounding Confidence (BC) Model to the placebo effect of information. First, we establish a basic framework, and then introduce specific equations.

1. **Agents (Individuals)**: Each agent i in the network holds an opinion o_i about information. This opinion can be represented, for example, within the range of -1 (completely negative) to +1 (completely positive).

2. **Network Structure**: The relationships between agents are modeled as a graph, and there may be edges with weights

w_{ij} between agents i and j. This represents the strength of their relationship and the frequency of information exchange.

3. **Bound of Trust**: Each agent has a bound of trust ϵ, which is the maximum difference in opinions they can accept.

1. **Opinion Update**: The opinion $o_i(t+1)$ of agent i is updated at the next time step as follows:

$$o_i(t+1) = o_i(t) + \delta \sum_{j \in N(i)} w_{ij}(o_j(t) - o_i(t))$$

Here, $N(i)$ is the set of adjacent agents to i, and δ represents the strength (learning rate) of opinion update.

2. **Filtering by Bound of Trust**:

$$w_{ij}(t) = \begin{cases} 1 & \text{if } |o_j(t) - o_i(t)| \leq \epsilon \\ 0 & \text{otherwise} \end{cases}$$

In other words, agent i considers only the opinions of agents j that fall within its bound of trust.

3.2.1 Parameters

- **Initial Values of Opinions**: $o_i(0)$ is assigned randomly or based on a specific distribution. - **Learning Rate** δ: Typically takes a small positive value (e.g., 0.01 to 0.1). - **Bound of Trust** ϵ: This is a value between 0 and 1, typically in the range of 0.2 to 0.5.

This model can be used to simulate opinion formation and information diffusion, allowing for the analysis of dynamic behavior under different network structures and initial conditions.

Considerations on the Placebo Effect of Information

The provided network graph showcases a dense web of interconnections among agents, which could represent social media platforms where individuals are exposed to an abundance of information.

In such a network:The placebo effect of information can be interpreted as the influence of non-factual or biased information on individuals' opinions. When agents adjust their opinions based on the surrounding information, it may lead to a reinforcement of existing beliefs, akin to a placebo effect where the belief in the information's validity can cause actual changes in opinions, regardless of the information's factual accuracy. - The dense network suggests rapid dissemination of information, which can amplify the placebo effect as agents are likely to encounter and be influenced by the same information multiple times.

Trust Boundaries (ϵ) Implications

The second graph illustrates individual agents' original and updated opinions, with the trust boundaries indicated by the green line: Trust boundaries (ϵ) reflect the range within which

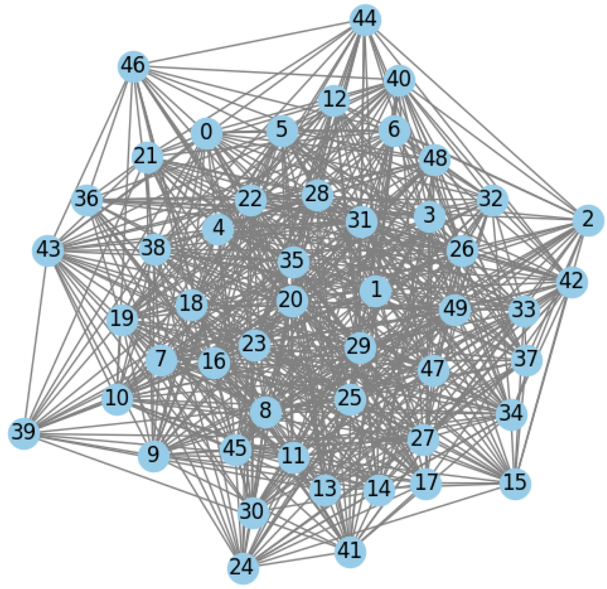

Fig. 4: Diversity of agent network

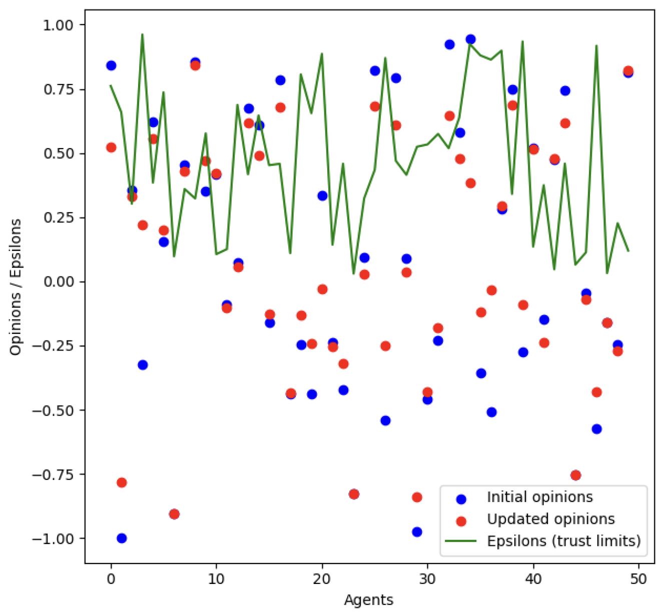

Fig. 5: Confidence limits and distribution of opinions

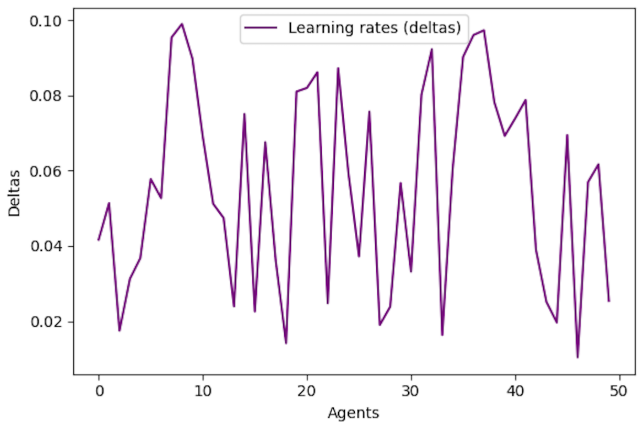

Fig. 6: Distribution of learning rate

agents are willing to consider altering their opinions. This is crucial in preventing information echo chambers, where agents only accept information aligning with their preconceived notions. If the trust boundaries are too narrow, agents may become resistant to new information, inhibiting growth and adaptation. Conversely, too wide boundaries might lead to volatility in opinions, where agents are too easily swayed by new information. The graph shows varied ϵ values across agents, suggesting a diversity in openness to new information, which can lead to a more balanced overall opinion spectrum within the network.

Learning Rates (δ) Insights

The third graph displays the learning rates (δ) across different agents:

The learning rate (δ) determines the speed at which agents update their opinions. Higher rates indicate a greater influence of new information on revising current beliefs. - Fluctuations in δ across agents may result in diverse rates of opinion change within the network, creating a dynamic environment where some agents are quick to adopt new information while others are more conservative. In terms of mental health implications, varying δ can reflect the resilience of individuals to information stress. Agents with lower δ might represent individuals who are less affected by information overload, maintaining a more stable psychological state.

General Observations

The interconnected nature of the network and the dynamics of opinion change underscore the complexity of managing information integrity and psychological well-being in the digital age. The models and simulations based on the BC Model can provide insights into the mechanisms by which information affects individuals' mental health and the potential strategies to foster resilience in the face of information overload.

In conclusion, the presented graphs and the BC Model offer a valuable framework for understanding the psychological impacts of the digital information landscape. They highlight the importance of fostering digital literacy, promoting diverse information sources, and developing robust mental health interventions to navigate the challenges of the digital era.

3.3 Fisher-Bingham distribution for evaluating the opinion distribution the Bounding Confidence Model (BC Model) in the Context of Group Dynamics

In the context of group dynamics, when incorporating random bounds of trust and opinion distributions into the Bounding Confidence (BC) Model using the Fisher-Bingham distribution, the model is extended as follows:

1. **Random Bounds of Trust**: Each agent i has an individual bound of trust ϵ_i generated from a uniform distribution or another appropriate probability distribution. This allows different agents to accept varying degrees of opinion differences.

$$\epsilon_i \sim U(a, b)$$

Here, $U(a, b)$ represents a uniform distribution over the interval $[a, b]$, where a and b are chosen lower and upper bounds.

2. **Modification of Opinion Update**: Since the bounds of trust are random, the equation for opinion update is also modified as follows:

$$w_{ij}(t) = \begin{cases} 1 & \text{if } |o_j(t) - o_i(t)| \leq \epsilon_i \\ 0 & \text{otherwise} \end{cases}$$

To use the Fisher-Bingham distribution for evaluating the opinion distribution, opinions o_i need to be treated as multi-dimensional feature vectors. The Fisher-Bingham distribution is commonly employed in directional statistics to model the distribution of multi-dimensional directional data.

Multi-Dimensional Opinions

Model opinions o_i as multi-dimensional vectors, where each dimension can represent opinions on different aspects or elements.

Application of the Fisher-Bingham Distribution

The distribution of opinion vectors is modeled using the Fisher-Bingham distribution, allowing us to understand how opinions are distributed in different directions.

3.3.1 Mathematical Expression

Fisher-Bingham Distribution

$$f(\mathbf{o}; \mathbf{A}, \mathbf{B}) = \frac{1}{C(\mathbf{A}, \mathbf{B})} \exp\left(\mathbf{o}^\top \mathbf{A}\mathbf{o} + \mathbf{B}^\top \mathbf{o}\right)$$

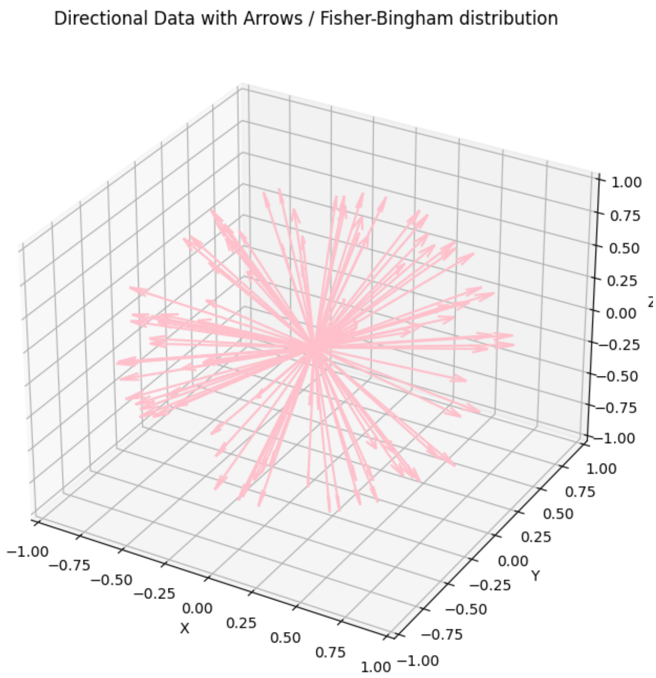

Fig. 7: 3D:Fisher-Bingham Distribution

Here, **o** represents the opinion vector, **A** and **B** are distribution parameters, and $C(\mathbf{A}, \mathbf{B})$ is the normalization constant.

This extended model allows for a more detailed analysis of how agents with different bounds of trust process information and form opinions. Additionally, using the Fisher-Bingham distribution enables a deeper understanding of the multi-dimensional characteristics of opinions and their distribution.

1. Vector Magnitude and Information Influence

The length of each arrow might represent the strength or influence of a piece of information or message on individuals within a network. Longer arrows could indicate more potent information that has a stronger placebo effect on the receiver's beliefs or behaviors.

2. Central Origin and Shared Source

The common origin point from which all arrows emanate may symbolize a shared source of information, such as a social media platform or news outlet. The diversity of arrow directions could then represent the varied interpretations or influences that a single piece of information can have on different individuals.

3. 3D Spread and Information Diversity

The spread of arrows in three-dimensional space suggests the complex and multi-faceted nature of information dissemination and its impact. It highlights how information can travel and evolve in various directions, affecting people differently

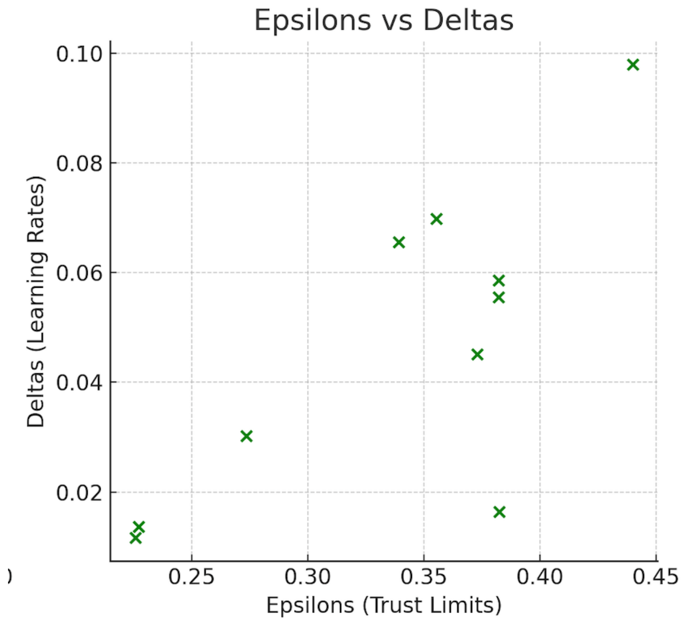

Fig. 8: (ϵ) and learning rates (δ) among agents within a network

based on their personal biases (information immunity) and backgrounds.

4. Fisher-Bingham Distribution

If this graph is indeed an attempt to visualize the Fisher-Bingham distribution of directional data, it emphasizes the complexity of predicting the placebo effect of information. This distribution is commonly used in directional statistics to model data on spheres or other manifolds, which in this context could represent the spherical nature of the information ecosystem where all points (information) are equidistant from the center (reality or truth). Regarding the mathematical model for analyzing relationships, the graph could be illustrating how different factors such as BG, IE, CT, and IIP influence the direction and magnitude of an individual's opinion (represented by the vectors). The model composition points to a system where background factors and personal skills shape one's resistance or susceptibility to misinformation.The linear path model suggested for the construction of the mathematical model would benefit from incorporating the directional nature of influence as shown in the graph. Each variable's impact on an individual's opinion and their ability to recover from information errors could be represented as vectors, with the path coefficients indicating the direction and strength of these influences. Estimating these parameters accurately would then be key to understanding and predicting the effects of information on individuals within the digital information landscape.

Results shows to plot the relationship between trust limits (ϵ) and learning rates (δ) among agents within a network, based on the Bounding Confidence Model.

Trust Limits (Epsilons)

These represent the threshold within which an agent is willing to consider new information. Higher ϵ values suggest greater openness, where an agent is more likely to be influenced by surrounding opinions. In the context of information placebo, higher trust limits might make an agent more susceptible to accepting and internalizing information, regardless of its veracity.

Learning Rates (Deltas)

This indicates how quickly an agent updates their opinions in response to new information. A higher δ means the agent is more adaptive or reactive to the information environment. In terms of placebo effects, a high learning rate could lead to quicker assimilation of information, which could enhance the placebo effect as the agent rapidly integrates the new, possibly misleading, information into their belief system.

Correlation Between Epsilons and Deltas

The graph suggests that there might be a relationship between an agent's openness to new information (ϵ) and their adaptability (δ). One might hypothesize that agents with higher openness might also have higher adaptability, allowing them to navigate the information environment more fluidly. However, this could also make them more vulnerable to misinformation if they lack critical evaluation skills.

Implications for Information Immunity

The graph could be used to identify agents who are potentially more resistant or susceptible to the placebo effect of information. Those with low ϵ and δ might be more resistant, as they are less likely to accept new information and change their opinions. In contrast, those with high ϵ and δ might be more susceptible to information placebo effects but also more adaptable in dynamic information environments. The mathematical model mentioned in the text suggests using linear regression or structural equation modeling to quantify these relationships and estimate the path coefficients. This approach would allow for a nuanced analysis of how inherent background (BG), information exposure (IE), critical thinking skills (CT), and information immunity type (IIP) interact to shape an individual's information literacy and susceptibility to misinformation.In summary, the "Epsilons vs Deltas" graph provides a visual representation that could be instrumental in understanding individual differences in response to information overload and the placebo effect of information. By analyzing these dynamics, one can develop strategies to enhance information immunity and reduce the likelihood of being misled by inaccurate or biased information in the digital age.

3.4 Mathematical Model for Analyzing Relationships

The proposed mathematical model, including the conditional equations, is used to analyze the relationships between an individual's inherent background (BG), information exposure (IE), critical thinking skills (CT), information immunity type (IIP), and the difficulty of recovering from information literacy errors (IRRD). This model quantifies the interactions between these variables and helps understand how they particularly influence the reception and processing of information.

1. Inherent Background (BG) and Its Influence

- BG represents an individual's educational background, socioeconomic status, cultural background, and more. - BG directly influences information immunity type (IIP), information exposure (IE), and critical thinking skills (CT).

2. Information Exposure (IE) and Critical Thinking Skills (CT)

These intermediate variables represent the quantity and quality of information an individual encounters in daily life (IE) and the ability to analyze and evaluate information (CT). These variables affect information immunity type (IIP).

3. Information Immunity Type (IIP)

Indicates how immune an individual is to misinformation or biased information.IIP is influenced by inherent background, information exposure, and critical thinking skills.

4. Difficulty of Recovering from Information Literacy Errors (IRRD)

Represents how challenging it is for an individual to correct errors in information literacy. IRRD is influenced by inherent background, information literacy errors, susceptibility to opinions in the surrounding context, and the degree of bias.

3.4.1 Construction of the Mathematical Model

1. Linear Path Model

Since the conditional equations above indicate linear relationships, they can be expressed using linear regression models or structural equation models (SEM). These models are suitable for quantifying correlations and causations between variables.

2. Parameter Estimation

Model path coefficients (e.g., $\lambda_0, \lambda_1, \mu_0, \mu_1, \nu_0, \nu_1$) need to be statistically estimated using data. Error terms (e.g.,

$\epsilon_i, \eta_i, \xi_i, \zeta_i$) capture the uncertainty of the model and provide individual variations to each variable.

4. Conclusion

Definition of Equations

1. Agent's Innate Background (BG) and Information Immunity Profile (IIP)

- $IIP_i = \lambda_0 + \lambda_1 \cdot BG_i + \epsilon_i$ - Here, λ_0, λ_1 represent path coefficients, and ϵ_i denotes the error term.

2. Definition of Intermediate Variables (IE, CT)

- $IE_i = \mu_0 + \mu_1 \cdot BG_i + \eta_i$ - $CT_i = \nu_0 + \nu_1 \cdot BG_i + \xi_i$ - $\mu_0, \mu_1, \nu_0, \nu_1$ are path coefficients, and η_i, ξ_i are error terms.

3. Update of Information Immunity Profile (IIP)

- $IIP_i = \lambda_2 \cdot IE_i + \lambda_3 \cdot CT_i + \zeta_i$ - λ_2, λ_3 represent path coefficients, and ζ_i denotes the error term.

Agent's Opinion Update

1. Initial Values of Agent's Opinions

- The initial opinion $o_i(0)$ of agent i is set randomly or based on a specific distribution.

2. Computation of Opinion Updates

- At each time step, agent i's opinion $o_i(t+1)$ is updated as follows: - $o_i(t+1) = o_i(t) + \delta \sum_{j \in N(i)} w_{ij}(t)(o_j(t) - o_i(t))$ - $w_{ij}(t) = \begin{cases} 1 & \text{if } |o_j(t) - o_i(t)| \leq \epsilon_i \\ 0 & \text{otherwise} \end{cases}$ - ϵ_i represents the trust boundary determined based on IIP_i.

1. Determination of Parameters

- Path coefficients like $\lambda_0, \lambda_1, \mu_0, \mu_1, \nu_0, \nu_1, \lambda_2, \lambda_3$ are statistically estimated based on data.

2. Computation of Agent Characteristics

- Calculate BG, IE, CT, IIP for each agent.

3. Opinion Updates

- Update agent opinions using the opinion update equation mentioned above.

4. Analysis of Network Dynamics

- Over time, analyze changes in agent opinions and observe how innate background, information exposure, and critical thinking skills affect individual opinion formation and dynamics within the group.

By using this model, it becomes possible to understand how innate backgrounds, information exposure, and critical thinking skills influence individual agent opinion formation and how these factors impact opinion dynamics within the group.

1. Information Pollution Degree (IPD)

$IPD_i = \delta_0 + \delta_1 \cdot HARMINFO_i + \delta_2 \cdot FILTERBUB_i + \theta_i$ - Here, $\delta_0, \delta_1, \delta_2$ represent path coefficients, and θ_i denotes the error term.

2. External Intervention Network (EIN)

- $EIN_{i,j} = \omega_0 + \omega_1 \cdot EXTINT_i + \omega_2 \cdot IPD_j + \xi_{i,j}$ - Here, $\omega_0, \omega_1, \omega_2$ are path coefficients, and $\xi_{i,j}$ is the error term.

3. Resilience Building Network (RBN)

- $RBN_{i,j} = \phi_0 + \phi_1 \cdot RESBUILD_i + \phi_2 \cdot IPD_j + \mu_{i,j}$ - Here, ϕ_0, ϕ_1, ϕ_2 are path coefficients, and $\mu_{i,j}$ is the error term.

Computational Process

1. Calculation of Agent Characteristics

For each agent i, define or measure the values of $HARMINFO_i, FILTERBUB_i, EXTINT_i, RESBUILD_i$. Based on these values, calculate $IPD_i, EIN_{i,j}, RBN_{i,j}$.

2. Modification of Opinion Updates

Consider the influence of $IPD_i, EIN_{i,j}, RBN_{i,j}$ on the update of agent i's opinion $o_i(t+1)$. $o_i(t+1) = o_i(t) + \delta \sum_{j \in N(i)} w_{ij}(t)(o_j(t) - o_i(t))$ Where $w_{ij}(t)$ represents the strength of the relationship between agents, modified by $EIN_{i,j}$ and $RBN_{i,j}$.

3. Analysis of Network Dynamics

Simulate changes in agent opinions over time and observe opinion formation and changes within the group. Analyze the resilience of spin information maintenance, external intervention, and resilience building's impact on opinion formation, particularly in cases of high information pollution.

4.Parameter Adjustment

Adjust parameters such as $\delta_0, \delta_1, \delta_2, \omega_0, \omega_1, \omega_2, \phi_0, \phi_1, \phi_2$ to observe model behavior in different scenarios.

This model provides insights into how the placebo effect of information is maintained within a group, as well as how information pollution and external interventions influence this dynamics. It is also valuable for analyzing how a resilience building network promotes evidence-based opinion formation within the group.

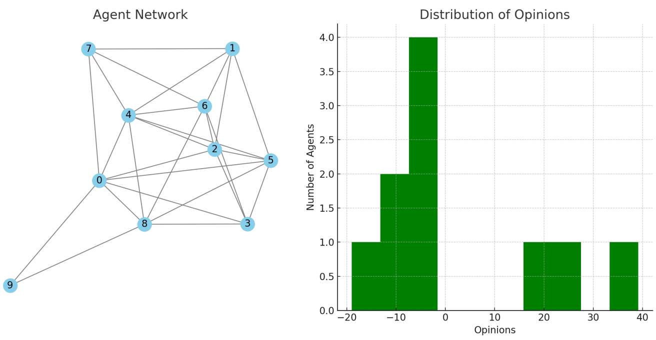

Fig. 9: Agent Network and Distribution of Opinions

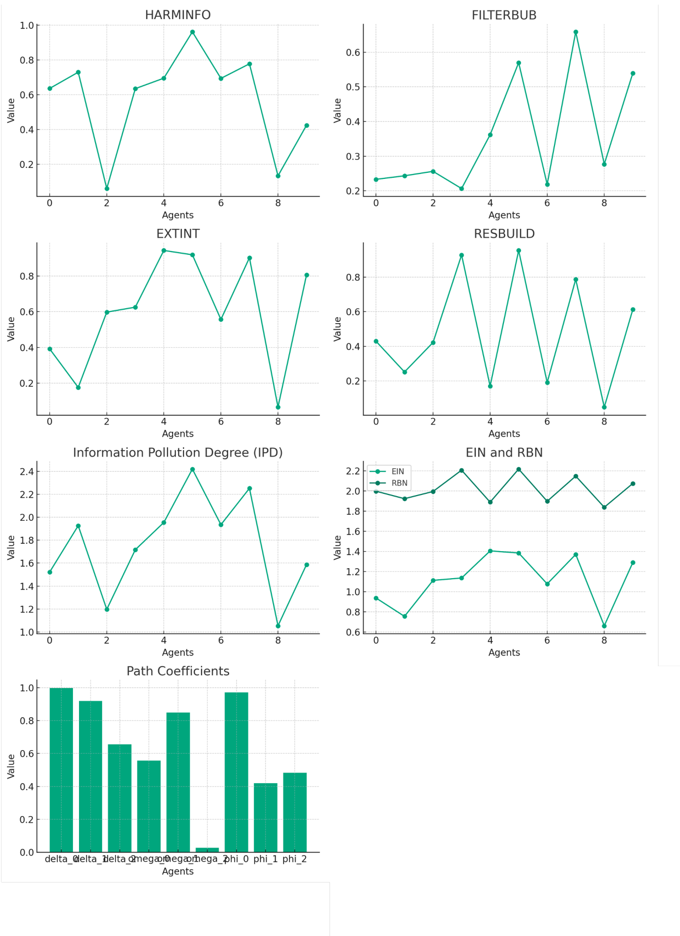

Fig. 10: (Variables and Their Impact HARMINFO and FILTERBUB, EXTINT and RESBUILD, EIN and RBN, Path Coefficients Graph

HARMINFO, FILTERBUB, EXTINT, RESBUILD Graphs

These graphs likely represent the individual values for harmful information exposure, filter bubble exposure, external interventions, and resilience-building efforts for each agent. Variability in these factors can influence agents' susceptibility to information and their ability to resist misinformation.

Information Pollution Degree (IPD) and EIN and RBN Graphs

The IPD graph shows the degree to which each agent is exposed to information pollution, while the EIN and RBN graph compares the external interventions and resilience-building measures in place. These graphs are critical for understanding the potential for misinformation to spread within the network and the effectiveness of countermeasures.

Path Coefficients Graph

This bar chart likely represents the estimated values of the path coefficients in the mathematical model. These coefficients quantify the influence of various factors on the information dynamics within the network.

Placebo Effect of Information

The placebo effect of information within this context refers to the impact of information believed to be true or beneficial, regardless of its actual validity. The agent network's structure can greatly influence this effect, with tightly knit communities potentially reinforcing the placebo effect through repeated exposure and confirmation bias.

Information Pollution Degree (IPD)

The IPD is a measure of the extent to which agents are exposed to potentially misleading or low-quality information. A high IPD could increase the likelihood of the information placebo effect, as agents may not have the means to verify the accuracy of the information they receive.

External Intervention Network (EIN)

The EIN represents efforts by external bodies (such as platforms or regulators) to influence the information environment. Effective interventions can reduce the information placebo effect by limiting exposure to misinformation.

Resilience Building Network (RBN)

The RBN measures the agents' ability to withstand misinformation. Strong RBN indicates a higher level of information immunity, which can mitigate the information placebo effect.

Parameter Adjustment

Adjusting the model's parameters can help simulate different scenarios and assess the effectiveness of interventions designed to counteract the information placebo effect. In summary, the uploaded graphs and the mathematical model provide a framework for understanding and analyzing the dynamics of information spread and its psychological effects on a network of agents. By examining factors such as information exposure, critical thinking, and resilience, the model can inform strategies to enhance information integrity and reduce the negative impact of misinformation.

Agent Network and Distribution of Opinions

The Agent Network graph depicts the connections between various agents, which could represent individuals in a social network and how they might influence each other. This network topology can affect the spread and reinforcement of opinions, potentially creating clusters of like-minded individuals or facilitating diverse discourse.

The Distribution of Opinions graph shows the range and concentration of opinions within the network. A diverse distribution suggests a wide range of beliefs or stances on a topic, while clusters indicate shared opinions, which could be due to the echo chamber effect where similar opinions are reinforced within a group.

HARMINFO and FILTERBUB

High variability in these graphs indicates that agents are exposed to different levels of harmful information and filter bubbles, which can impact their susceptibility to misinformation and the strength of their information bubbles.

EXTINT and RESBUILD

These indicate the levels of external intervention and resilience-building initiatives across the network. Consistent high values across agents for RESBUILD, for instance, suggest strong measures are in place to foster resilience against misinformation.

Information Pollution Degree (IPD)

This graph displays the degree to which agents are affected by information pollution. Fluctuations suggest that some agents are more susceptible to misinformation, which could influence the overall network's opinion dynamics.

EIN and RBN

The comparison between external intervention and resilience-building measures (EIN and RBN) across agents shows how each agent is being supported or influenced by external factors and their own resilience mechanisms.

Path Coefficients

The bar chart of Path Coefficients quantifies the strength of the relationships between different variables in the model. High path coefficients mean that the corresponding variable has a strong influence on the agent's opinion formation or information processing capabilities. For example, high coefficients for variables like HARMINFO or FILTERBUB could indicate that these factors significantly influence the likelihood of an agent being swayed by the placebo effect of information.

Computational Process

The computational process outlined, involving the calculation of characteristics and modification of opinion updates, points to a dynamic model where opinions are not static but evolve based on the interplay of various factors, including information pollution and interventions.

Network Dynamics Analysis

Simulations based on this model can reveal how resilient the network is to misinformation. If agents have high values of IPD and low values of RESBUILD, the network might be vulnerable to the spread of misinformation. Conversely, high values of EIN and RBN suggest that the network is actively combating misinformation through external interventions and internal resilience strategies.

Overall, these graphs and the associated mathematical model provide a complex picture of how information is processed within a network. They offer insights into the potential for information to act as a placebo, reinforcing existing beliefs or misconceptions, and underscore the importance of critical thinking and resilience in maintaining information integrity.

Aknowlegement

The author is grateful for discussion with Prof. Serge Galam and Prof.Akira Ishii. This research is supported by Grant-in-Aid for Scientific Research Project FY 2019-2021, Research Project/Area No. 19K04881, "Construction of a new theory of opinion dynamics that can describe the real picture of society by introducing trust and distrust".

References

zh

[1] Yeong-Kyu Lee, Sang-Hoon Kim (2008). A Development of Evaluation Indicators for Information Security by Means of the Coincidence Analyses. *Journal of the Korea society of IT services*.

[2] Jeri Teller-Kanzler, Thomas Dunbar, Stephen Katz (1999). Method and system for evaluating information security. Patent.

[3] Mikhail Mikhailovich Volkov (2019). Ensuring information security as a security of stable development of the state. *Theoretical Applied Science, 10.15863/TAS.2019.11.79.80*.

[4] Normaci Correia dos Santos Sena (2019). Profissional da informação no contexto de dados abertos nos legislativos da cidade de Salvador, Bahia: uma análise a partir da lógica paraconsistente. Dissertation.

[5] Matthew Bovee, Rajendra P. Srivastava, Tom L. Roberts (2004). Information quality: a conceptual framework and empirical validation.

[6] Bruce Thompson, Larry G. Daniel (1996). Seminal Readings on Reliability and Validity: A Hit Parade Bibliography. *Educational and Psychological Measurement, 10.1177/0013164496056005001*.

[7] Robert L. Brennan (2001). An Essay on the History and Future of Reliability from the Perspective of Replications. *Journal of Educational Measurement, 10.1111/J.1745-3984.2001.TB01129.X*.

[8] Ali Reza Hoseini, Seyed Farid Ghannadpour, Roya Ghamari (2020). Sustainable supplier selection by a new possibilistic hierarchical model in the context of Z-information. *Journal of Ambient Intelligence and Humanized Computing, 10.1007/S12652-020-01751-3*.

[9] Eunseong Cho (2021). Neither Cronbach's Alpha nor McDonald's Omega: A Commentary on Sijtsma and Pfadt. *Psychometrika, 10.1007/S11336-021-09801-1*.

[10] Urs Gasser (2004). Information Quality and the Law, or, How to Catch a Difficult Horse. Some Observations on the emergence of U.S. Information Quality Law. Book Chapter.

[11] James Daniel Correa De Freitas, Henrique Rego Monteiro da Hora, Dalessandro Soares Vianna, Helder Gomes Costa (2015). RIOT - a tool for estimating the reliability of surveys. *International Journal of Information and Communication Technology, 10.1504/IJICT.2015.070324*.

[12] Solange Ghernaouti-Hélie, David Simms, Igli Tashi (2011). Protecting Information in a Connected World: A Question of Security and of Confidence in Security. *Proceedings Article, 10.1109/NBIS.2011.38*.

[13] V. Tolubko, S. Kozelkov, S. Zybin, Valerii Kozlovskyi, Yuliia Boiko (2018). Criteria for Evaluating the Effectiveness of the Decision Support System. Book Chapter, *10.1007/978-3-319-91008-6*$_3$2.

[14] Urs Gasser (2003). Information Quality and the Law, or, How to Catch a Difficult Horse. *Social Science Research Network, 10.2139/SSRN.487945*.

[15] Gipiene Gailute, Matusevicienė Lina, Buzinskiene Rita. The impact of the change of the tax burden on the reliability of financial information: the case of Lithuania. Journal Article.

[16] Ivaylo Ivanov (2022). Promises and challenges of high-energy vortex states collisions. *Progress in Particle and Nuclear Physics, 10.1016/j.ppnp.2022.103987*.

[17] Li Chen, Yunbo Zhang, Han Pu (2020). Spin-Nematic Vortex States in Cold Atoms. *Physical Review Letters, 10.1103/PHYSREVLETT.125.195303*.

[18] TRUE (2017). Theory and applications of free-electron vortex states. *Physics Reports, 10.1016/J.PHYSREP.2017.05.006*.

[19] Konstantin Y. Bliokh, Igor P. Ivanov, Giulio Guzzinati, Laura Clark, R. Van Boxem, Armand Bch, Roeland Juchtmans, Miguel A. Alonso, Peter Schattschneider, Franco Nori, Johan Verbeeck (2017). Theory and applications of free-electron vortex states. *Physics Reports, 10.1016/J.PHYSREP.2017.05.006*.

[20] Jun Chen, Yao Li (2018). Discrimination of incoherent vortex states of light. *Optics Letters, 10.1364/OL.43.005595*.

[21] Bienvenu Ndagano, Isaac Nape, Benjamin Perez-Garcia, Stirling Scholes, Raul I. Hernandez-Aranda, Thomas Konrad, Martin P. J. Lavery, Andrew Forbes (2017). A deterministic detector for vector vortex states. *Scientific Reports, 10.1038/S41598-017-12739-Z*.

[22] Elena D'Alessandro (2022). Gapless vortex bound states in superconducting topological semimetals. *National Science Review, 10.1093/nsr/nwac121*.

[23] Tingxi Hu, Lu Lu (2023). Vortex states of Bose-Einstein condensates with attractive interactions. *Discrete and Continuous Dynamical Systems, 10.3934/dcds.2023003*.

[24] Bruno Paroli, Mirko Siano, Marco A. C. Potenza (2021). Dense-code free space transmission by local demultiplexing optical states of a composed vortex. *Optics Express, 10.1364/OE.417772*.

[25] Rodolpho R. Gomes, Mauro M. Doria, Antonio R. de C. Romaguera (2016). Paramagnetic excited vortex states in superconductors. *Physical Review B, 10.1103/PHYSREVB.93.214518*.

[26] Bienvenu Ndagano, Isaac Nape, Mitchell A. Cox, Carmelo Rosales-Guzmn, Andrew Forbes (2017). Creation and characterization of vector vortex modes for classical and quantum communication. *Journal of Lightwave Technology, 10.1109/JLT.2017.2766760*.

[27] Bienvenu Ndagano, Isaac Nape, Mitchell A. Cox, Carmelo Rosales-Guzmn, Andrew Forbes (2018). Creation and Detection of Vector Vortex Modes for Classical and Quantum Communication. *Journal of Lightwave Technology, 10.1109/JLT.2017.2766760*.

[28] Peter Schattschneider, Th Schachinger, Michael Stger-Pollach, Stefan Lffler, Andreas Steiger-Thirsfeld, Konstantin Y. Bliokh, Franco Nori (2014). Imaging the dynamics of free-electron Landau states. *Nature Communications, 10.1038/NCOMMS5586*.

[29] Jonathan Pinnell, Valeria Rodrguez-Fajardo, Andrew Forbes (2020). Probing the limits of vortex mode generation and detection with spatial light modulators. *Journal of the Optical Society of America B, 10.1088/2040-8986/ABCD02*.

[30] Christophe Berthod (2005). Vorticity and vortex-core states in type-II superconductors. *Physical Review B, 10.1103/PHYSREVB.71.134513*.

[31] Luigi Castiglioni, Silvia Penati, Marcia Tenser, Diego Trancanelli (2022). Interpolating Wilson loops and enriched RG flows.

[32] Shulin Chen (2022). Wilson loops in the Hamiltonian formalism. *Physical Review D, 10.1103/physrevd.105.l111501*.

[33] Hee-Cheol Kim, Min Sung Kim, Sung-Soo Kim (2021). 5d/6d Wilson loops from blowups. *Journal of High Energy Physics, 10.1007/JHEP08(2021)131*.

[34] Michael H. Gold (2022). Topological strings and Wilson loops. *Journal of High Energy Physics, 10.1007/jhep08(2022)207*.

[35] Viljami Leino, Nora Brambilla, Owe Philipsen, Christian Reisinger, Antonio Vairo, Marc Wagner (2021). The static force from generalized Wilson loops.

[36] Robert D. Pisarski (2022). Wilson loops in the Hamiltonian formalism. *Physical Review D, 10.1103/PhysRevD.105.L111501*.

[37] Nadav Drukker (2020). BPS Wilson loops and quiver varieties. *Journal of Physics A, 10.1088/1751-8121/ABA5BD*.

[38] Anna Ritz-Zwilling, Jean-Nol Fuchs, Julien Vidal (2021). Wegner-Wilson loops in string-nets. *Physical Review B, 10.1103/PHYSREVB.103.075128*.

[39] Kota Takeuchi, Tomohiro Inagaki (2023). Comprehensive Analysis of Equivalence Classes in 5D $SU(N)$ gauge theory on S^1/Z_2 Orbifold.

[40] Yoshiharu Kawamura, Takashi Miura (2009). Equivalence Classes of Boundary Conditions in SU(N) Gauge Theory on 2-dimensional Orbifolds. *Progress of Theoretical Physics, 10.1143/PTP.122.847*.

[41] Yoshiharu Kawamura, Teppei Kinami, Takeshi Miura (2008). Equivalence Classes of Boundary Conditions in Gauge Theory on Z_3 Orbifold. *Progress of Theoretical Physics, 10.1143/PTP.120.815*.

[42] Naoyuki Haba, Yutaka Hosotani, Yoshiharu Kawamura (2004). Classification and Dynamics of Equivalence Classes in SU(N) Gauge Theory on the Orbifold S1/Z2. *Progress of Theoretical Physics, 10.1143/PTP.111.265*.

[43] Naoyuki Haba, Yutaka Hosotani, Yoshiharu Kawamura (2003). Classification and dynamics of equivalence classes in SU(N) gauge theory on the orbifold S^1/Z_2. *Progress of Theoretical Physics, 10.1143/PTP.111.265*.

[44] David Schmeltzer, A. R. Bishop (2004). Z2 gauge theory of electron fractionalization in the t, t'-J model with uniaxial anisotropy. *Journal of Physics: Condensed Matter, 10.1088/0953-8984/16/43/014*.

[45] Samuel W. MacDowell, Ola Trnkvist (1995). Electroweak Vortices and Gauge Equivalence. *Modern Physics Letters A, 10.1142/S0217732395001186*.

[46] Green, D. P.; Palmquist, B.; Schickler, E. (2002). Partisan Hearts and Minds: Political Parties and the Social Identities of Voters. *Yale University Press*.

[47] McCoy, J.; Rahman, T.; Somer, M. (2018). Polarization and the Global Crisis of Democracy: Common Patterns, Dynamics, and Pernicious Consequences for Democratic Polities. *American Behavioral Scientist*, **62**(1), 16-42.

[48] Tucker, J. A., et al. (2018). Social Media, Political Polarization, and Political Disinformation: A Review of the Scientific Literature. SSRN.

[49] Bail, C. A. (2020). Breaking the Social Media Prism: How to Make Our Platforms Less Polarizing. *Princeton University Press*.

[50] Barberá, P. (2015). Birds of the Same Feather Tweet Together: Bayesian Ideal Point Estimation Using Twitter Data. *Political Analysis*, **23**(1), 76-91.

[51] Garimella, K., et al. (2018). Political Discourse on Social Media: Echo Chambers, Gatekeepers, and the Price of Bipartisanship. In *Proceedings of the 2018 World Wide Web Conference on World Wide Web*.

[52] Allcott, H.; Gentzkow, M. (2017). Social Media and Fake News in the 2016 Election. *Journal of Economic Perspectives*, **31**(2), 211-236.

[53] Garrett, R. K. (2009). Echo Chambers Online?: Politically Motivated Selective Exposure among Internet News Users. *Journal of Computer-Mediated Communication*, **14**(2), 265-285.

[54] Weeks, B. E.; Cassell, A. (2016). Partisan Provocation: The Role of Partisan News Use and Emotional Responses in Political Information Sharing in Social Media. *Human Communication Research*, **42**(4), 641-661.

[55] Iyengar, S.; Sood, G.; Lelkes, Y. (2012). Affect, Not Ideology: A Social Identity Perspective on Polarization. *Public Opinion Quarterly*, **76**(3), 405-431.

[56] Bimber, B. (2014). Digital Media in the Obama Campaigns of 2008 and 2012: Adaptation to the Personalized Political Communication Environment. *Journal of Information Technology & Politics*.

[57] Castellano, C., Fortunato, S., & Loreto, V. (2009). Statistical physics of social dynamics. *Reviews of Modern Physics*, **81**, 591-646.

[58] Sîrbu, A., Loreto, V., Servedio, V.D.P., & Tria, F. (2017). Opinion Dynamics: Models, Extensions and External Effects. In Loreto V. et al. (eds) Participatory Sensing, Opinions and Collective Awareness. *Understanding Complex Systems*. Springer, Cham.

[59] Deffuant, G., Neau, D., Amblard, F., & Weisbuch, G. (2000). Mixing Beliefs among Interacting Agents. *Advances in Complex Systems*, **3**, 87-98.

[60] Weisbuch, G., Deffuant, G., Amblard, F., & Nadal, J. P. (2002). Meet, Discuss and Segregate!. *Complexity*, **7**(3), 55-63.

[61] Hegselmann, R., & Krause, U. (2002). Opinion Dynamics and Bounded Confidence Models, Analysis, and Simulation. *Journal of Artificial Society and Social Simulation*, **5**, 1-33.

[62] Ishii, A. & Kawahata, Y. (2018). Opinion Dynamics Theory for Analysis of Consensus Formation and Division of Opinion on the Internet. In: Proceedings of The 22nd Asia Pacific Symposium on Intelligent and Evolutionary Systems, 71-76, arXiv:1812.11845 [physics.soc-ph].

[63] Ishii, A. (2019). Opinion Dynamics Theory Considering Trust and Suspicion in Human Relations. In: Morais D., Carreras A., de Almeida A., Vetschera R. (eds) Group Decision and Negotiation: Behavior, Models, and Support. GDN 2019. Lecture Notes in Business Information Processing 351, Springer, Cham 193-204.

[64] Ishii, A. & Kawahata, Y. (2019). Opinion dynamics theory considering interpersonal relationship of trust and distrust and media effects. In: The 33rd Annual Conference of the Japanese Society for Artificial Intelligence 33. JSAI2019 2F3-OS-5a-05.

[65] Agarwal, A., Xie, B., Vovsha, I., Rambow, O. & Passonneau, R. (2011). Sentiment analysis of twitter data. In: Proceedings of the workshop on languages in social media. Association for Computational Linguistics 30-38.

[66] Siersdorfer, S., Chelaru, S. & Nejdl, W. (2010). How useful are your comments?: analyzing and predicting youtube comments and comment ratings. In: Proceedings of the 19th international conference on World wide web. 891-900.

[67] Wilson, T., Wiebe, J., & Hoffmann, P. (2005). Recognizing contextual polarity in phrase-level sentiment analysis. In: Proceedings of the conference on human

language technology and empirical methods in natural language processing 347-354.

[68] Sasahara, H., Chen, W., Peng, H., Ciampaglia, G. L., Flammini, A. & Menczer, F. (2020). On the Inevitability of Online Echo Chambers. arXiv: 1905.03919v2.

[69] Ishii, A.; Kawahata, Y. (2018). Opinion Dynamics Theory for Analysis of Consensus Formation and Division of Opinion on the Internet. In Proceedings of The 22nd Asia Pacific Symposium on Intelligent and Evolutionary Systems (IES2018), 71-76; arXiv:1812.11845 [physics.soc-ph].

[70] Ishii, A. (2019). Opinion Dynamics Theory Considering Trust and Suspicion in Human Relations. In Group Decision and Negotiation: Behavior, Models, and Support. GDN 2019. Lecture Notes in Business Information Processing, Morais, D.; Carreras, A.; de Almeida, A.; Vetschera, R. (eds).

[71] Ishii, A.; Kawahata, Y. (2019). Opinion dynamics theory considering interpersonal relationship of trust and distrust and media effects. In The 33rd Annual Conference of the Japanese Society for Artificial Intelligence, JSAI2019 2F3-OS-5a-05.

[72] Okano, N.; Ishii, A. (2019). Isolated, untrusted people in society and charismatic person using opinion dynamics. In Proceedings of ABCSS2019 in Web Intelligence 2019, 1-6.

[73] Ishii, A.; Kawahata, Y. (2019). New Opinion dynamics theory considering interpersonal relationship of both trust and distrust. In Proceedings of ABCSS2019 in Web Intelligence 2019, 43-50.

[74] Okano, N.; Ishii, A. (2019). Sociophysics approach of simulation of charismatic person and distrusted people in society using opinion dynamics. In Proceedings of the 23rd Asia-Pacific Symposium on Intelligent and Evolutionary Systems, 238-252.

[75] Ishii, A, and Nozomi, O. (2021). Sociophysics approach of simulation of mass media effects in society using new opinion dynamics. In Intelligent Systems and Applications: Proceedings of the 2020 Intelligent Systems Conference (IntelliSys) Volume 3. Springer International Publishing.

[76] Ishii, A.; Kawahata, Y. (2020). Theory of opinion distribution in human relations where trust and distrust mixed. In Czarnowski, I., et al. (eds.), Intelligent Decision Technologies, Smart Innovation, Systems and Technologies 193.

[77] Ishii, A.; Okano, N.; Nishikawa, M. (2021). Social Simulation of Intergroup Conflicts Using a New Model of Opinion Dynamics. *Front. Phys.*, **9**:640925. doi: 10.3389/fphy.2021.640925.

[78] Ishii, A.; Yomura, I.; Okano, N. (2020). Opinion Dynamics Including both Trust and Distrust in Human Relation for Various Network Structure. In The Proceeding of TAAI 2020, in press.

[79] Fujii, M.; Ishii, A. (2020). The simulation of diffusion of innovations using new opinion dynamics. In The 2020 IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology, in press.

[80] Ishii, A, Okano, N. (2021). Social Simulation of a Divided Society Using Opinion Dynamics. In Proceedings of the 2020 IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology (in press).

[81] Ishii, A., & Okano, N. (2021). Sociophysics Approach of Simulation of Mass Media Effects in Society Using New Opinion Dynamics. In Intelligent Systems and Applications (Proceedings of the 2020 Intelligent Systems Conference (IntelliSys) Volume 3), pp. 13-28. Springer.

[82] Okano, N. & Ishii, A. (2021). Opinion dynamics on a dual network of neighbor relations and society as a whole using the Trust-Distrust model. In Springer Nature - Book Series: Transactions on Computational Science & Computational Intelligence (The 23rd International Conference on Artificial Intelligence (ICAI'21)).