Hindawi
Complexity
Volume 2019, Article ID 2864124, 12 pages
https://doi.org/10.1155/2019/2864124

Research Article

Opinion Dynamics Model Based on Cognitive Styles: Field-Dependence and Field-Independence

Xi Chen,[1,2] Shen Zhao,[1,2] and Wei Li [1,2]

[1] *School of Artificial Intelligence and Automation, Huazhong University of Science and Technology, Wuhan 430074, China*
[2] *Image Processing and Intelligent Control Key Laboratory of the Education Ministry of China, Wuhan 430074, China*

Correspondence should be addressed to Wei Li; liwei0828@mail.hust.edu.cn

Received 18 September 2018; Revised 5 January 2019; Accepted 26 January 2019; Published 11 February 2019

Academic Editor: Sara Dadras

Two distinct cognitive styles exist from the perspective of cognition: field-dependence and field-independence. In most public opinion dynamics models, people only consider that individuals update their opinions through interactions with other individuals. This represents the field-dependent cognitive style of the individual. The field-independent cognitive style is ignored in such cases. We consider both cognitive styles in public opinion dynamics and propose a public opinion evolution model based on cognitive styles (CS model). The opinions of neighbors and experiences of the individual represent field-dependent cognition and field-independent cognition, respectively, and the individual combines both cognitive styles to update his/her own opinion. In the proposed model, the experience parameter is designed to represent the weight of the current opinion in terms of the individual's experiences and the cognitive parameter is proposed to represent the tendencies of his/her cognitive styles. We experimentally verify that the CS and Hegselmann–Krause (HK) models are similar in terms of public opinion evolution trends; with an increase in radius of confidence, the steady state of a social system shifts from divergence to polarization and eventually reaches consensus. Considering that individuals from different cultures have different degrees of inclination for the two styles, we present experiments focusing on cognitive parameter and experience parameter and analyze the evolutionary trends of opinion dynamics in different styles. We find that when an individual has a greater tendency toward the field-independent cognitive style under the influence of culture, the time required for a social system to reach a steady state will increase; the system will have greater difficultly in reaching consensus, mirroring the evolutionary trends in public opinion in the context of eastern and western cultures. The CS model constitutes an opinion dynamics model that is more consistent with the real world and may also serve as a basis for future cross-cultural research.

1. Introduction

Research on public opinion dynamics has always involved many fields of research, including sociology, psychology, informatics, and physics. These studies are mainly focused on the evolution, formation, and consensus of group/public opinions. Public opinion can have a substantial impact on public policy. The more salient the issues, the stronger the impact [1]. Social policy and public opinion are utilized as a feedback system [2]. The public health community of America models public health problems by extending opinion dynamics and analyzes the correlation between diseases and behaviors, such as alcohol and tobacco use, to study corresponding public policy interventions [3]. Chen [4] believes that different individuals have attributes that can affect opinion evolution. He presented a public opinion control strategy based on public authority and makes use of a public opinion dynamics model (the Hegselmann–Krause (HK) model [5]) to verify the effectiveness of policies. Both western and eastern scholars have studied public opinion dynamics. One of the most important goals of this research is to detect public opinion to understand the evolution of public opinion as it relates to public affairs, which provides insight into real human attitude-formation mechanisms. This exercise can aid governments in making optimal decisions.

Public opinion is a typical complex system. Influenced by social and economic factors, the evolution of public opinion presents complexity, openness, and nonlinearity [6]. The evolution of public opinion in complex systems is one of the core issues in nonlinear science [7, 8]. The model of opinion dynamics mainly explains the nonlinear characteristics of the evolution of public opinion, the goal being to study the evolution process of public opinion [9–11]. The opinion dynamics can be traced back to 1956, when French proposed a simple discrete mathematical model to study the behavioral complexity of a team [12]. Thereafter, many scholars have proposed many public opinion dynamic models based on various rules. In the Voter model, individuals are affected by neighbors and change their opinions to mirror those of their neighbors [13]. The majority rule model has been proposed [14] based on the "conformity behavior" of social psychology [15]. The difference between this model and the Voter model is that the individual changes his/her opinion to match that of the majority of his/her neighbors. Some researchers are of the opinion that the higher the number of neighbors, the greater the chance that an individual's opinion will be influenced by his/her neighbors. In other words, a higher number of neighbors can be more persuasive. The Sznajd model is the improved Voter model [16]. The basic idea is that if two or more neighbors were to persuade an individual, and then he/she would be more inclined to align his/her opinion to theirs.

Almost all of the above models and their extended models express individual opinions with discrete values and usually use -1 (against), 0 (neutral), and +1 (concurring) to express opinions, respectively. In real life, there are often fuzzy value phenomena that are difficult to be accurately divided by individual opinions. Therefore, some scholars use the numerical values within the interval $[0, 1]$ to represent individual opinions, which is called a continuous opinion dynamics model. The continuous opinion dynamics model mainly includes the Deffuant model [17] and the HK model [5]. These two models are also known as bounded confidence models, because they both follow the rule of bounded confidence; that is, individuals only change their opinions due to their neighbors within the radius of confidence [18], which conforms to the "selective exposure" of social psychology [19]. Recently, the bounded confidence model has received a significant response in the field of public opinion dynamics. Many scholars have made different improvements on it and suggested extensions to it in order to reasonably study the evolution of public opinion. Pineda et al. [20] studied the Deffuant model with noisy effects. Chen et al. [21] considered three types of different social acquaintance networks (independence-priority acquaintance network, kinship-priority acquaintance network, and hybrid acquaintance network) and utilized the Deffuant model to conduct experimental simulation analysis of public opinion evolution. These three acquaintance networks are similar to networks of western acquaintances, traditional Chinese acquaintances, and modern Chinese acquaintances, respectively. Finally, a culture-policy-driven mechanism for opinion dynamics was proposed based on the simulation results. Grauwin's research on the Deffuant model found that when the difference in individual opinions is greater than the confidence radius, opinions correction with a certain probability was beneficial to the convergence and uniformity of opinions [22]. If Deffuant model concerns the slow interaction between two individuals, the HK model refers to the interactions between multiple individuals. Similarly, Miguel [23] notes the effects of noise on the classical HK model and showed that, at a certain probability, individuals have the opportunity to change their opinions spontaneously. Lorenz [24] believes that there is heterogeneity in the confidence radius of individuals. According to the differences in the confidence radius, individuals can be divided into open-minded individuals and closed-minded individuals. Su [25] believes that the HK model should be considered for directed networks. In the Bulletin Board System (BBS), an individual can be influenced by opinion providers but cannot influence the opinions of opinion providers. This is a typical observation and learning process, and its conclusions are of great significance to the formation and decision-making process of group opinions. Some scholars have introduced "paranoid" psychology into the HK model to study the influence of a few paranoid individuals in the social group on the evolution of opinions [26]. Regarding the classical HK model, Fu proposes an evolution model of opinion that considers the parameters of self-confidence [27]. Confidence is reflected in the degree of persistence in self-confidence, and nonconfidence is reflected in the degree of trust in other people's opinions. Some scholars have studied the HK opinion evolution model with competitive opinion leaders [28]. Some scholars believe that the individual's confidence radius should not be fixed and should be influenced by individual confidence and neighbor influence. Thus, a time-varying bounded confidence model is proposed [29]. It can be seen from the above that many scholars have improved and expanded the classical public opinion dynamics to make it more consistent with reality, so as to explore the internal laws and mechanisms of real social public opinion. However, from the cognitive perspective, in both the Deffuant model and HK model, individuals only cognize through interactions with their surrounding neighbors before updating their opinions.

As per the Oxford dictionary, cognition is "the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses" [30]. In the evolution of public opinion, the interaction between individuals is a cognitive process. Individuals process information via cognition to update their own opinions. Witkin [31] suggested that there are two cognitive styles for processing information: the field-dependent and field-independent cognitive styles. Witkin also designed the embedded figures test (EFT) in 1974, which is a famous measure to distinguish between field-independence and field-dependence. He calls those who rely too much on their environment to make judgments as field dependents and those who judge by themselves as field-independent [32]. The field-dependent cognitive style refers to the tendency of people to rely on external references or external environmental cues when processing information. The field-independent cognitive style refers to the tendency of people to process information based on internal perceptual cues. When the two cognitive styles of field-dependence and field-independence were proposed, they quickly became a research hotspot in the field of cognitive psychology [33–36]. Since then, the cognition method has been widely studied in the educational field [37–40]. However, research on social psychology has revealed that field-dependence and field-independence may be cultural variations of cognitive style. People from different cultural backgrounds have different tendencies toward these two cognitive styles [41]. One study has suggested that Chinese people tend toward field-dependence more than American people, which may be the result of cultural preferences [42].

Currently, most research on opinion dynamics focuses on the idea that an entire social system evolves based on interactions between individuals. For example, in the HK model, an individual updates his/her opinions by averaging the opinions of all neighbors that meet a given confidence threshold [43]. Because this model relies on the opinions of others (i.e., on external references), it is based on the cognitive style of individual field-dependence. Although there are many improved HK models that have introduced the concepts of self-reliance, bigotry, and individuals considering their own opinions during the evolution process [26, 27, 44], these are merely copies of the original or current opinions of individuals and are not truly based on internal cues. Based on the above information, it can be seen that, in classical opinion evolution models and their extensions, the individual field-dependent cognitive style has been considered, but the individual field-independent cognitive style has been ignored. However, people in the real world are complex and often utilize both cognitive styles. Therefore, it is necessary to consider the individual field-independent cognitive style in opinion dynamics.

In this paper, we introduce the field-independent cognitive style of individuals into opinion dynamics and propose a public opinion evolution model based on cognitive styles (the CS model), which has the following two main motivations.

(i) Psychology is implicitly responsible for individual external behavior. Referring to psychology, researchers constantly formulate relevant rules to promote the development and improvement of the opinion dynamics model. However, in reality, the change in individual opinions is the result of individual cognition. Thus, it is necessary to introduce cognitive psychology more deeply into the opinion dynamics model.

(ii) The classical bounded confidence model (taking the HK model as an example) only considers the interaction of individuals with their neighbors within the radius of confidence. In a sense, this can be regarded as part of the individual's field-dependent cognitive style. However, in the real evolution of opinions, when an individual's opinions are updated, they are not only influenced by their neighbors, but also influenced by his/her own experience or thinking. For example, in the scenario of public opinion evolution on a policy, each individual's opinion is not only influenced by other individuals, but also based on his/her thoughts or experience.

The contribution of our proposed method is to introduce the individual's field-independent cognitive style based on the classical HK model. The experience parameter is used to construct the field-independent cognitive part of the individual, and the classical HK model is regarded as the field-dependent cognitive part of the individual. It is proposed that cognitive parameter not only represents the tendency of individuals to the field-independent or field-dependent cognitive style, but also integrates the individual's field independent and field-dependent cognitive styles when he/she updates his/her opinions. Our improvement allows individuals to update their opinions not only according to their neighbors' opinions within the bounded confidence (HK model, field-dependent cognition), but also according to their own experiences (field-independent cognition). In this way, the HK model is enriched to make it more realistic.

The rest of this paper is arranged as follows. In Section 2, we provide a detailed discussion of the two cognitive styles of individual field-independence and field-dependence and propose a public opinion dynamics model considering different cognitive styles. Section 3 presents the numerical simulation results and analysis of the CS model. The discussion and conclusions are presented in Section 4.

2. Model

2.1. Field-Independent and Field-Dependent Cognitive Styles of Individuals. From the description of cognitive psychology, field-independence and field-dependence are two cognitive styles that emphasize the concept that individuals differ in processing information [45]. The former focuses on internal perception and the latter focuses on external influences in cognitive processes [46]. In most public opinion dynamics models, the interactions between individuals and their neighbors (external) are the main mechanism for updating individual opinions. These models only consider the cognitive style of individual field-dependence. However, in the real world, field-independent cognitive styles of individuals also exist during the evolution of public opinion. In the fields of psychology or pedagogy, these types of cognitive studies tend to adopt absolute definitions, which represent dichotomous thinking. In other words, a person either has a field-independent cognitive style or field-dependent cognitive style [47–49]. In a public opinion evolution system, if individuals are absolutely field-independent, the system will develop various opinions and have difficulty reaching polarization, let alone convergence. This concept does not agree with real human sociality [50] or major phenomena in reality, such as mass incidents [51, 52]. To be accurate, individuals in a social system are more complex and should have both field-independent and field-dependent cognitive styles simultaneously. In other words, in the process of public opinion evolution, an individual will be influenced by external factors, but will be also guided by internal cues. However, because of the influence of culture and other factors, certain individuals tend to be more field-dependent cognitive and others are more inclined to field-independent. During the evolution of public opinion, the opinions of individuals after interactions with others should be codetermined by the two cognitive styles. Based on research on the feeding behavior of birds, the operational mechanism of the particle swarm method simulates biological groups and their social behavior. Each iteration changes individual velocities according to individual experiences and the group's flight experiences to make corresponding adjustments [53].

This is consistent with the concept that individuals update their opinions according to both field-dependence and field-independence in the evolution of public opinion. In the field of statistical physics, as per the model proposed by relevant research, agents (atoms) change their state based on noise or temperature (internal characteristics) as well as external factors (interaction with neighbors) [54, 55]. In the process of public opinion evolution, the traditional opinion dynamics model (the HK model) only considers the cognitive style of individual field-dependence; it is necessary to introduce the cognitive style of individual field-independence. In this manner, the model can be made more consistent with the real world.

2.2. CS Model. We consider the classical HK model as an example and consider the field-independent cognitive style of individuals in this model. To construct the HK model, we consider n agents in a system, the set of which is denoted as $N = \{1, 2, 3, 4, ...n\}$, where agent $i \in N$. The opinion of agent i at time t is represented by $x_i(t) \in (0, 1)$. Initially, each agent has an opinion $x_i(0)$, where $x_i(0) \in (0, 1)$. The initial opinions of the agents in the system are subject to a particular distribution, such as a uniform or normal distribution. Each agent has its own threshold of confidence ε_i. When the difference between its opinion and the opinions of its neighbors is less than the confidence threshold, the agent will choose to interact with its neighbors. The discrete-time HK model is described by

$$x_i(t+1) = \begin{cases} \frac{1}{|N_i(t)|} \sum_{j \in \overline{N_i}(t)} x_j(t), & \overline{N_i}(t) \neq \emptyset \\ x_i(t), & otherwise \end{cases} \tag{1}$$

where $N_i(t) = \{j \in V \mid |x_i(t) - x_j(t)| \leq \varepsilon_i\}$ is the opinion neighbor set of agent i at time t and $|N_i(t)|$ is the number of neighbor interactions.

When the field-independent cognitive style of individuals is considered in public opinion dynamics, we simplify the definition of cognition and form a corresponding hypothesis. Suppose that, during the evolution of public opinion, in terms of the field-independent cognitive style, the individual will gain opinions only through his/her own experiences. The experiences of the individual are simplified as opinions in his/her memory, and we only consider their opinions at the last moment in discrete time. Therefore, we propose a public opinion evolution model based on cognitive styles (the CS model), as described by

$$\begin{aligned} x_i(t+1) &= c \cdot [\omega \cdot x_i(t) + (1-\omega) \cdot x_i(t-1)] + (1-c) \\ &\quad \cdot \frac{1}{|N_i|} \sum_{j \in N_i} x_j(t) \\ N_i(t) &= \{j \in V \mid |x_i(t) - x_j(t)| \leq \varepsilon_i\} \end{aligned} \tag{2}$$

$\omega \cdot x_i(t) + (1-\omega) \cdot x_i(t-1)$ is the opinion that agent$i$gains based on the field-independent cognitive style. ω is a set of experience parameters that represent the weight of the opinion at time t on the agent's experience. $(1-\omega)$ represents the weight of the opinion at time $t-1$ on the agent's experience, which is the opinion at the last moment in memory. $(1/|N_i|) \sum_{j \in N_i} x_j(t)$ is the opinion that agent i gains based on the field-dependent cognitive style, which is defined by the HK model. c is the set of cognitive parameters that represents the tendency of an individual's cognitive style. The value of the cognitive parameter c is the proportion of individual opinion determined by the field-independent cognitive style. Therefore, 1 - c represents the proportion of individual opinion determined by the field-dependent cognitive style $c + 1 - c = 1$, which indicates that individual opinions are codetermined by the two cognitive styles. For example, in the process of marketing, our opinions towards a product will be influenced by the opinions of our friends and relatives, and we will also judge the product based on our own experience and finally determine our opinions. The process of our opinions on the film is similar. We are influenced by film reviews, and we also make judgments based on our field-independent cognition. Similarly, in the CS model proposed in this paper, for each iteration, the individual opinion value is updated according to the individual's own experience (field-independent cognition) and the opinions values of other neighboring individuals (field-dependent cognition).

3. Numerical Simulations

The CS model was studied by utilizing agent-based modeling and simulations. For the sake of convenience, we assume that the social system is homogeneous, meaning that all individuals in a given system have the same confidence threshold and same tendency for cognitive styles. Our simulations comprised 1,000 agents in the public opinion evolution system. The relational network for the agents in the simulation system was fully connected, which means that any agent could know the opinions of all other agents during the evolution of public opinion. The reason for selecting a fully connected network was to avoid the effects of network topology on simulation results. The opinions of the agents are quantized as continuous values between 0 and 1. To avoid the effects of initial opinions on the simulation results, the initial opinions of the agents followed a uniform distribution between 0 and 1. In the experiments described below, we mainly studied the influences of the individual field-independent and field-dependent cognitive styles (cognitive parameter c), and the influence of the individual experience parameter (ω) on the evolution of public opinion in the social system. We define the steady state of the system as follows: if the opinion of all individuals does not continue to change, the system becomes steady [56]. In addition, when the difference between two opinion values is less than 0.0001, we regard the two opinions as the same opinion. Two observation indicators were utilized to measure the impact of these factors on the evolution of public opinion. The first is the steady state of the social system, which can be represented by the number of opinion clusters when the system reaches a steady state. The other is steady time, which is how long the system takes to reach a steady state. The block diagram of the simulation experiment design is shown in Figure 1.

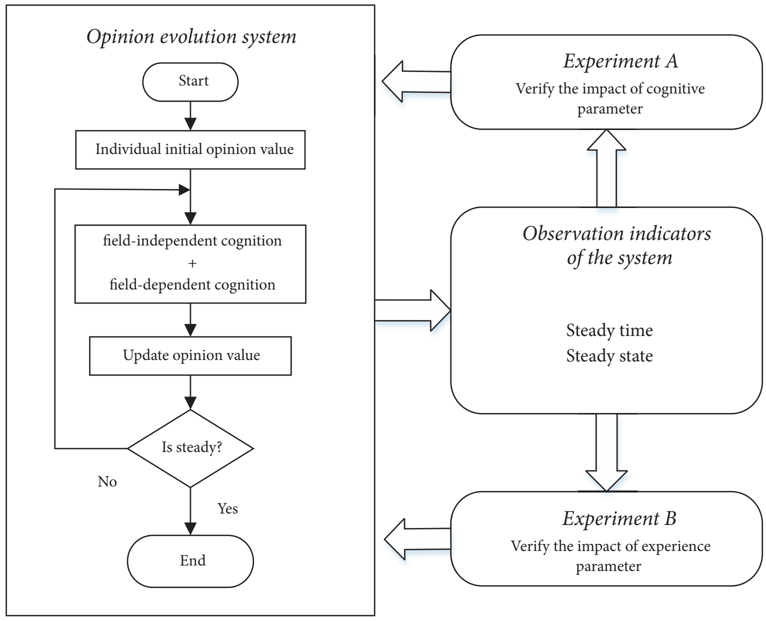

Figure 1: Block diagram of the simulation experiment design.

3.1. Impact of Field-Independence and Field-Dependence Cognitive Styles on Evolution of Public Opinion. First, we study the impact of cognitive parameters (c) on the evolution of public opinion, which represents the tendencies of individual cognitive styles. In our simulations, we consider a constant set of experience parameters ($\omega = 0.5$) to facilitate the analysis of cognitive styles and their influence on public opinion evolution. Figure 2 presents the simulation results of the HK model with different confidence thresholds, in which the X-axis represents the system evolution time, and the Y-axis represents the opinion values of individuals in the system. As shown in Figure 2, for the classical HK model, with a confidence threshold of 0.1, there were four clusters of opinion when the system reached a steady state. When the confidence threshold increased to 0.2, the entire system became polarized into two opinion clusters when it reached a steady state. With a confidence threshold of 0.25, all opinions in the social system reached consensus at a steady state. Therefore, in the HK model, the confidence thresholds of 0.1, 0.2, and 0.25 correspond to divergence, polarization, and consensus, respectively, which are the three steady states of the social system. In order to study the impact of cognitive styles on public opinion evolution for different steady states of a social system, we set the confidence threshold to values of $\varepsilon_i \in [0.1, 0.2, 0.21, 0.22, 0.23, 0.24, 0.25]$. Simultaneously, we set the cognitive parameter to values of $c \in [0, 0.1, 0.2, 0.3, 0.4, .0.5, 0.6, 0.7, 0.8, 0.9]$.

Figure 3 presents the simulation results for the steady state of the social system with different confidence thresholds and cognitive parameters (c). The green, yellow, and red rectangles represent divergence, polarization, and consensus, respectively, which are the three steady states of the social system. When $c = 0$, the model is equal to the classical HK model. If the confidence threshold is 0.1, regardless of the cognitive parameter value, the steady state of the social system is divergence. When the confidence threshold is gradually changed from 0.2 to 0.25, the steady state of the social system gradually changes from polarization to consensus. One can see that when considering the field-independent cognitive style of individuals, the tendency of the new model for the steady state of the system to change with the confidence threshold is similar to that of the classical HK model. As the confidence threshold increases, the steady state of the system changes from divergence to polarization and eventually reaches consensus. However, there are differences between the new model and the classical HK model. When the confidence threshold is 0.21, the steady state of the system in the classical HK model is consensus, but the steady state of the system considering the field-independent cognitive style is still polarization. When the confidence threshold is 0.22, the steady state of the system in which the cognitive parameter value was no more than 0.5 ($c \le 0.5$) also changes to consensus, but the steady state of the system where the cognitive parameter value is no less than 0.6 ($c \ge 0.6$) is still polarization. After the confidence threshold increases to 0.23, except for the steady state of the system in which the cognitive parameter value was no less than 0.8 ($c \ge 0.8$), the steady state of the systems has already reached consensus. Once the confidence threshold reaches 0.24, regardless of the cognitive parameter value, all steady states of the social systems reach consensus. Based on the above analysis, we can conclude the value of the cognitive parameter has an impact on the steady state of a social system. These results also reveal that the tendencies of individuals toward field-independent and field-dependent cognitive styles have an impact on the evolution of public opinion. The larger the value of the cognitive parameter (c), the larger the proportion of individual opinions that are determined by the field-independent cognitive style. Specifically, individuals are more inclined toward the field-independent cognitive style during

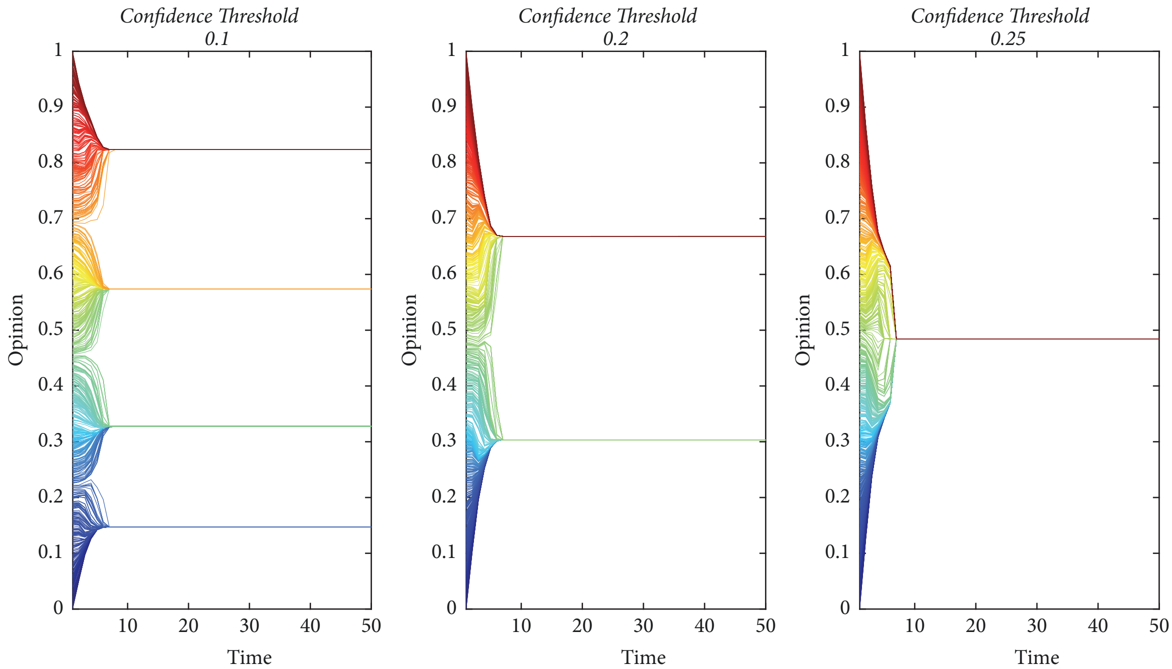

Figure 2: Opinion evolution results for the HK model with different confidence thresholds.

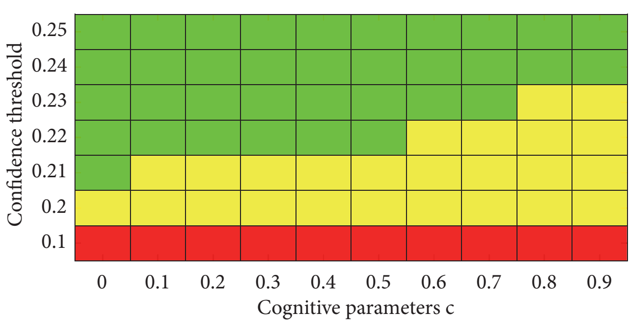

Figure 3: Steady state of a social system with different confidence thresholds and cognitive parameters (c).

the evolution of public opinion, which makes it more difficult for the steady state of the social system to reach consensus. On the contrary, the smaller the value of the cognitive parameter c, the easier it is to reach consensus.

To study the influence of cognitive styles on the steady time of opinion evolution, we compare the steady times with different cognitive parameter values for the three steady states of a social system (divergence, polarization, and consensus). As mentioned previously, the confidence thresholds we select are 0.1, 0.2, and 0.25 ($\varepsilon_i \in [0.1, 0.2, 0.25]$); regardless of the cognitive parameter values, the steady state of the social system always moves toward divergence, polarization, and convergence, respectively. In the same manner, we set the cognitive parameter $c \in [0, 0.1, 0.2, 0.3, 0.4, .0.5, 0.6, 0.7, 0.8, 0.9]$ in order to study the impact of cognitive style on the steady time of opinion evolution.

Figure 4 presents the simulation results for the steady time of the social system for different values of the cognitive parameter (c) for three steady states (divergence, polarization, and consensus). When $c = 0$, the model is equal to the classical HK model. One can see from Figure 4 that compared to the classical HK model ($c = 0$), the proposed system requires a longer time to reach steady state ($c \neq 0$). It can also be seen that irrespective of the steady state of the social system (divergence, polarization, or convergence), as the value of the cognitive parameter (c) increases, the time required for the social system to reach steady state increases. This suggests that the more the individuals are inclined toward the field-independent cognitive style during the evolution of public opinion, the more time the social system requires to reach a steady state; thus, stability is more difficult to achieve.

Above all, we focus on analyzing the impact of the cognitive parameter (c) on the evolution of public opinion. When the cognitive parameter is 0 ($c = 0$), only the individual's field-dependent cognitive style is considered, but the individual field-independent cognitive style is ignored. At this time, the CS model degenerates into the classical HK model. When $c = 0$, the simulation experimental data reflect the results of the evolution of the classical HK model. Compared with the classical HK model, the CS model has a longer evolution time and it is more difficult to reach consensus in the system. In addition, the larger the value of the cognitive parameter (c), the greater the proportion of field-independent cognitive styles for individuals. This means that individuals have a stronger tendency to follow the field-independent cognitive style during the evolution of public opinion. Thus, individuals will focus more on internal perception and less on external influences when updating their own opinions. In other words, individuals are more likely to perform independent cognition and less likely to consider the opinions of their neighbors within the confidence range. However, opinion dynamics is a fusion

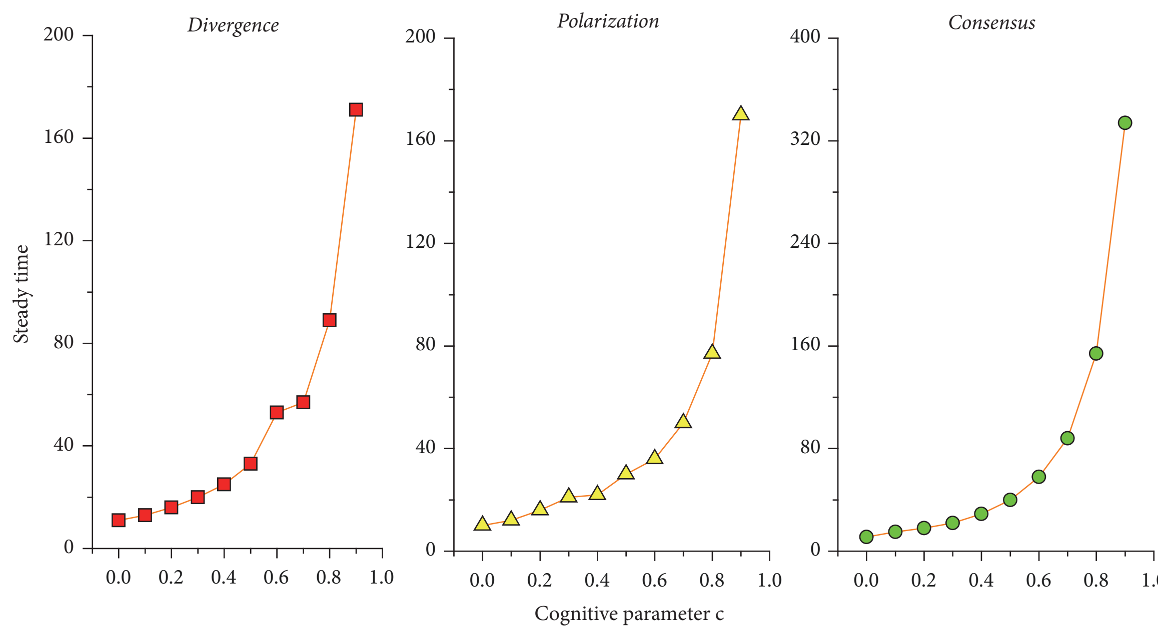

Figure 4: Steady times for the three steady states of the social system (divergence, polarization, and consensus) for different cognitive parameters (c).

process in which individual opinions are based on specific rules [57]. When an individual iterates to update his/her own opinion value, not only based on his/her neighbors' opinion value, but also based on his/her own experience, it is equivalent to weakening the influence of his/her neighbors' opinion value on the assimilation of individual opinion value. This slows down the trend of the unity of group opinion value and strengthens the retention of unique opinions in the system. Thus, the social system needs a longer time to reach a steady state. It also means that the system has greater difficulty reaching consensus and is more prone to polarization or even divergence. In the process of public opinion evolution, if the opinion value of the individual is shaped only by neighbors, then it is naturally easy to reach consensus, but, in reality, the individual opinion value is not only derived from other individuals, but also based on internal experience. Thus, it is difficult for the overall opinion value to become consensus. For example, in the process of marketing, an individual's opinion on a product depends more on his/her own experience or thinking and less on the reputation of relatives and friends. Thus, his/her opinion is more difficult to change, and, given the group's differing opinion on the product, it is difficult to reach consensus. Consider another example, where people's opinions on a film are derived more from their own experience or thinking and are less influenced by the film review. Therefore, it is difficult to agree upon an overall opinion. Considering the field-independent cognitive style of the individual, the simulation results of public opinion evolution are more realistic. Therefore, the CS model is an improvement of the classical HK model. In addition, the value of the cognitive parameter (c) reflects the individual's tendency to follow the field-independent or field-dependent cognitive style. Previous studies have shown that people with different cultural backgrounds have different tendencies toward these two cognitive styles. Therefore, the value of cognitive parameter (c) can be used to represent individuals with different cultural backgrounds. The model we propose here can be used to explore different trends of public opinion evolution in different cultural backgrounds, while providing a reference for cross-cultural research.

3.2. Impact of the Experience Parameter (ω) on Evolution of Public Opinion. Next, we study the impact of the experience parameter (ω) on the evolution of public opinion. Similar to Section 3.1, in order to study the impact of the experience parameter ω on the steady state of a social system, in our simulations, we set the cognitive parameter $c \in [0.1, 0.2, 0.3, 0.4, .0.5, 0.6, 0.7, 0.8, 0.9]$ and changed the experience parameter ω from 0 to 1. Thus, $\omega \in [0, 0.1, 0.2, 0.3, 0.4, .0.5, 0.6, 0.7, 0.8, 0.9, 1]$. When the value of the experience parameter is zero ($\omega = 0$), individuals only consider their opinions from the last moment in memory based on the field-independent cognitive style. When the value of the experience parameter is one ($\omega = 1$), individuals do not consider their opinions from the last moment in memory based on the field-independent cognitive style. These values are the two extremes of the experience parameter ω.

Figure 5 presents the simulation results for the steady state of the social system with different confidence thresholds, experience parameters (ω), and cognitive parameters (c). We choose these confidence thresholds ($\varepsilon_i \in [0.21, 0.22, 0.23, 0.24]$) because, in this case, when the value of the experience parameter (ω) varies, the steady state of the social system may change based on the value of the cognitive parameter (c). Similar to Section 3.1, the green and yellow rectangles represent consensus and polarization, respectively, which are the two steady states of the social system. As the value of the cognitive parameter (c) increases from 0.1 to 0.9,

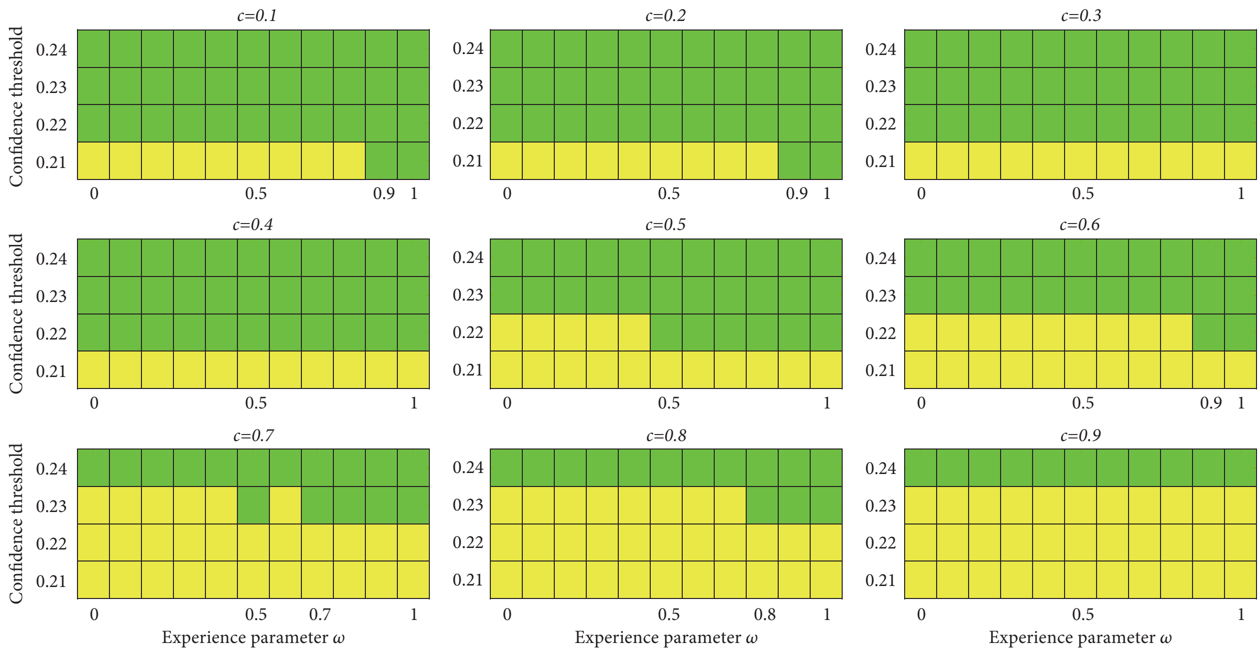

FIGURE 5: Steady state of the social system with different confidence thresholds, experience parameters (ω), and cognitive parameters (c).

the social system requires a larger confidence threshold to change from polarization to consensus, which is consistent with the results in Section 3.1. Additionally, with the same confidence threshold and cognitive parameter (c), the smaller the value of the experience parameter (ω) is, the more difficult it is for the system to reach consensus. When the experience parameter (ω) is greater than a certain value, the system state changes from polarization to consensus. For example, with a confidence threshold of 0.21 and $c = 0.1$, the system state reaches polarization when the value of the experience parameter is no more than 0.8 ($\omega \leq 0.8$), but reaches consensus when the value of the experience parameter is no less than 0.9 ($\omega \geq 0.9$). With a confidence threshold of 0.22 and $c = 0.5$, the system state reaches polarization when the value of the experience parameter is no more than 0.4 ($\omega \leq 0.4$), but reaches consensus when the value of the experience parameter is no less than 0.5 ($\omega \geq 0.5$). With a confidence threshold of 0.23 and $c = 0.8$, the system state reaches polarization when the value of the experience parameter is no more than 0.7 ($\omega \leq 0.7$), but reaches consensus when the value of the experience parameter is no more than 0.8 ($\omega \geq 0.8$). This indicates that the smaller the value of the experience parameter (ω) is, the harder it is for the steady state of the social system to reach consensus. Additionally, the impact of the experience parameter (ω) on the steady state of the social system is affected by the cognitive parameter (c).

Next, we study the impact of the experience parameter (ω) on the steady time of opinion evolution. One can see from Figure 5 that when the confidence threshold is 0.25, regardless of the value of the cognitive parameter (c) and experience parameter (ω), the steady state of the social system always reaches consensus. Therefore, to maintain a constant steady state of the social system, we select a confidence threshold of 0.25 for our simulation experiments.

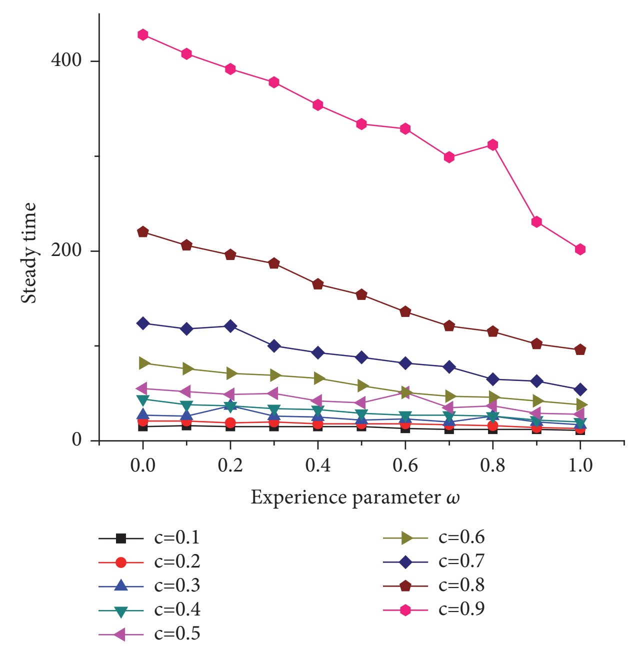

FIGURE 6: Steady time with different cognitive parameters (c) and experience parameters (ω) and a constant confidence threshold of 0.25.

Figure 6 presents the simulation results for steady time with different experience parameters (ω) and cognitive parameters (c) when the steady state of the social system is always consensus. From Figure 6, the time required for the system to become steady becomes longer as the value of the cognitive parameter (c) increases, which is consistent with the previous experiment in Section 3.1. The lines in Figure 6 generally trend downward, which indicates that the larger the value of the experience parameter (ω), the shorter the steady time. As the value of the cognitive parameter (c) increases, the slopes of the lines become steeper. Therefore, the experience parameter (ω) can impact the steady time of a social system. With an increase in the cognitive parameter (c), the impact on the steady time of the social system is even stronger.

From the above analysis, we can conclude that the experience parameter (ω) has an impact on the steady state and steady time of a social system. When the experience parameter is 1 ($\omega = 1$), individuals only use the current opinions value as the result of field-independent cognition and do not fully conduct independent field cognition from their experience. At this time, from the perspective of the model form, the CS model is degraded to the MHK model [27]. However, in fact, individuals are not field-independent cognitively, but possess a kind of persistence or confidence in their original opinions. Compared with the MHK model, the CS model takes longer to evolve, and the opinion values are more difficult to converge. Simultaneously, the larger the value of the experience parameter (ω) is, the easier it is for the steady state of a social system to reach consensus, and less time is required for the social system to become steady. This may be because the larger the value of the experience parameter (ω), the lower the individual weigh his/her opinion from the last moment in memory, and the more he/she relies on his/her opinion from the current moment. This promotes and accelerates the interaction of individuals with other individuals and causes the opinions of individuals to become increasingly biased toward the group opinion. Additionally, the larger the value of the cognitive parameter (c), the greater the impact of the experience parameter (ω) on the evolution of public opinion. Individuals become more inclined toward the field-independent cognitive style and the proportion of their opinions gained via field-independent cognition is larger when they update their opinions. This means that the impact of experience parameters on the evolution of public opinion is greater. Persistence or self-confidence in the value of one's opinion at the last moment is only a copy of one's opinion value and cannot be categorized as field-independent cognition of the individual. During the evolution of public opinion, in reality, individual opinions will also be based on their own experience, which is the function of field-independent cognition of the individual. Therefore, we use the experience parameter to construct the independent cognition of individual field, which has a realistic basis. As we all know, it is difficult to change the opinions of people who have had certain experiences during the course of their work or personal lives. For example, if an individual is very experienced with regard to the story/background of a film, it is difficult to change his opinion. Consider another example. In the marketing process, if a person has experience with a product, his/her opinion is difficult to change. Therefore, the results of our simulation experiment analysis are consistent with reality.

4. Conclusion and Discussion

In this study, the field-independent cognitive style of individuals was considered in the context of opinion dynamics, and a public opinion evolution model based on cognitive styles (the CS model) was proposed. In the CS model, individuals involved in the evolution of public opinion not only change their opinions based on the opinions of their neighbors by utilizing a confidence threshold (the field-dependent cognitive style), but also refer to their own experiences (the field-independent cognitive style). By combining these two methods of cognition, an individual can update his/her opinion rationally. The CS model proposed in this paper was compared to the classical HK model. The simulation results revealed that the CS model is similar to the classical HK model in some respects. For example, with an increase in the confidence threshold, the steady state of the social system changes from divergence to polarization and eventually reaches consensus. The difference is that when considering the field-independent cognition of the individual, the individual's opinion value is not only affected by his/her neighbors, but also based on his/her own experience, which weakens the fusion of group opinions and more likely retains the unique opinions in the system, thus slowing down the trend of unification of group opinion values. Therefore, compared to the classical HK model, the state of public opinion evolution will be more difficult to converge, and the time required for system stability will be longer.

Similarly, individuals are more inclined to the field-independent cognitive style. Thus, in the evolution of public opinion, the proportion of opinions values in their own experience is larger, and the value of neighbors in the confidence radius is less borrowed, which further weakens the assimilation of neighbors' opinions. The influence slows down the integration of public opinion as well as the trend of unification of group opinions. As a result, the system of public opinion evolution needs to be stable for a longer period of time. Thus, it is more difficult to converge and is more prone to polarization and even divergence. The cognitive parameter (c) and experience parameter (ω) both have an impact on the steady state and steady time of public opinion evolution. In the case of larger values for the cognitive parameter (c), individuals are more inclined toward the field-independent cognitive style, meaning the experience parameter (ω) has a greater impact on the evolution of public opinion.

If individuals in the public opinion evolution system are more inclined toward the field-independent cognitive style, the time required for the system to reach a steady state is longer and the steady state of the system is less likely to reach consensus. In contrast, if individuals in the public opinion evolution system are more inclined toward the field-dependent cognitive style, the time required for the system to reach a steady state is shorter and the steady state of the system is more likely to reach consensus. As mentioned above, the different tendencies of individuals towards the two cognitive styles represent two different cultures. People in western cultures are more inclined toward the field-independent cognitive style, whereas Chinese people are more inclined toward the field-dependent cognitive style. It is well-known that policymaking in certain western countries is slow and difficult [58, 59]. For example, gun control policies in the United States, where many people are killed by firearms every year, have been difficult to pass [60]. There are many reasons for this and it represents a scenario where public opinion has difficulty reaching a steady state of consensus. Similarly, perhaps because of cultural reasons, Chinese people tend to be influenced by the opinions of the people around them, and public opinion evolves quickly, often easily reaching consensus in Chinese society. Thus, cults of personality are more likely to develop in China [61–63]. These real-world examples are consistent with our simulation results. Therefore, the consideration of the field-independent cognitive style in opinion dynamics models not only is more realistic, but also serves as a basis for cross-cultural research.

In this paper, we simplified the cognitive style of individual field-independence by examining only the individual experience dimension. In future research, we will consider the field-independent cognitive style of individuals in opinion dynamics in additional dimensions to make our model richer and more realistic.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This work was supported by the National Natural Science Foundation of China under Grant no. 71571081. In addition, Shen Zhao expresses heartfelt thanks to his father and his girlfriend, Jing Liu, for their help and support over the years.

References

[1] P. Burnstein, "The impact of public opinion on public policy: a review and agenda," *Political Research Quarterly*, vol. 56, no. 1, pp. 29–40, 2003.

[2] N. Breznau and H. Andreß, *Public Opinion and Social Policy as a Feedback System: from Theory to Empirical Model Specification*, Social Science Electronic Publishing, 2016.

[3] T. W. Moore, P. D. Finley, J. M. Lineberger et al., Extending Opinion Dynamics to Model Public Health Problems and Analyze Public Policy Interventions, 2011.

[4] X. Chen, X. Xiong, M. Zhang, and W. Li, "Public authority control strategy for opinion evolution in social networks," *Chaos: An Interdisciplinary Journal of Nonlinear Science*, vol. 26, no. 8, Article ID 083105, 2016.

[5] R. Hegselmann and U. Krause, "Opinion dynamics and bounded confidence models, analysis and simulation," *Journal of Artificial Societies & Social Simulation*, vol. 5, no. 3, p. 2, 2002.

[6] C. Yin, X. Huang, Y. Chen, S. Dadras, S.-M. Zhong, and Y. Cheng, "Fractional-order exponential switching technique to enhance sliding mode control," *Applied Mathematical Modelling: Simulation and Computation for Engineering and Environmental Systems*, vol. 44, pp. 705–726, 2017.

[7] C. Yin, X. Huang, S. Dadras et al., "Design of optimal lighting control strategy based on multi-variable fractional-order extremum seeking method," *Information Sciences*, vol. 465, pp. 38–60, 2018.

[8] C. Yin, S. Dadras, X. Huang, J. Mei, H. Malek, and Y. Cheng, "Energy-saving control strategy for lighting system based on multivariate extremum seeking with Newton algorithm," *Energy Conversion and Management*, vol. 142, pp. 504–522, 2017.

[9] S. Dadras, "Path tracking using fractional order extremum seeking controller for autonomous ground vehicle," *SAE Technical Papers 2017-01-0094*, 2017.

[10] S. Dadras, S. Dadras, H. Malek, and Y. Chen, "A note on the lyapunov stability of fractional-order nonlinear systems," in *Proceedings of the ASME 2017 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, American Society of Mechanical Engineers, USA, 2017.

[11] S. Dadras, S. Dadras, and H. Momeni, "Linear matrix inequality based fractional integral sliding-mode control of uncertain fractional-order nonlinear systems," *Journal of Dynamic Systems, Measurement, and Control*, vol. 139, no. 11, Article ID 111003, 2017.

[12] J. R. P. French Jr., "A formal theory of social power," *Psychological Review*, vol. 63, no. 3, pp. 181–194, 1956.

[13] R. A. Holley and T. M. Liggett, "Ergodic theorems for weakly interacting infinite systems and the voter model," *Annals of Probability*, vol. 3, no. 4, pp. 643–663, 1975.

[14] S. Galam, "Minority opinion spreading in random geometry," *The European Physical Journal B - Condensed Matter and Complex Systems*, vol. 25, no. 4, pp. 403–406, 2002.

[15] S. Bikhchandani, D. Hirshleifer, and I. Welch, "Learning from the behavior of others: conformity, fads, and informational cascades," *Journal of Economic Perspectives (JEP)*, vol. 12, no. 3, pp. 151–170, 1998.

[16] K. Sznajd-Weron and J. Sznajd, "Opinion evolution in closed community," *International Journal of Modern Physics C*, vol. 11, no. 6, pp. 1157–1165, 2000.

[17] G. Deffuant, D. Neau, F. Amblard, and G. Weisbuch, "Mixing beliefs among interacting agents," *Advances in Complex Systems (ACS)*, vol. 3, no. 01-04, pp. 87–98, 2000.

[18] J. Lorenz, "Continuous opinion dynamics under bounded confidence: a survey," *International Journal of Modern Physics C*, vol. 18, no. 12, pp. 1819–1838, 2007.

[19] J. M. Olson and M. P. Zanna, "A new look at selective exposure," *Journal of Experimental Social Psychology*, vol. 15, no. 1, pp. 1–15, 1979.

[20] M. Pineda, R. Toral, and E. Hernández-García, "Diffusing opinions in bounded confidence processes," *The European Physical Journal D*, vol. 62, no. 1, pp. 109–117, 2011.

[21] X. Chen, X. Zhang, Z. Wu, H. Wang, G. Wang, and W. Li, "Opinion evolution in different social acquaintance networks," *Chaos: An Interdisciplinary Journal of Nonlinear Science*, vol. 27, no. 11, Article ID 113111, 11 pages, 2017.

[22] G. Sébastian and J. Pablo, "Opinion group formation and dynamics: Structures that last from nonlasting entities," *Physical Review E: Statistical, Nonlinear, and Soft Matter Physics*, vol. 85, no. 6, Article ID 066113, 2012.

[23] M. Pineda, R. Toral, and E. Hernández-García, "The noisy Hegselmann-Krause model for opinion dynamics," *The European Physical Journal B*, vol. 86, no. 12, article no. 490, 2013.

[24] J. Lorenz, "Heterogeneous bounds of confidence: meet, discuss and find consensus!," *Complexity*, vol. 15, no. 4, pp. 43–52, 2010.

[25] J. Su, B. Liu, Q. Li et al., "Coevolution of opinions and directed adaptive networks in a social group," *Journal of Artificial Societies & Social Simulation*, vol. 17, no. 2, p. 4, 2014.

[26] J. M. Su, B. H. Liu, Q. Li et al., "Trust, evolution, and consensus of opinions in a social group," *Acta Physica Sinica*, vol. 63, no. 5, pp. 71–76, 2014.

[27] G. Fu, W. Zhang, and Z. Li, "Opinion dynamics of modified Hegselmann-Krause model in a group-based population with heterogeneous bounded confidence," *Physica A: Statistical Mechanics and its Applications*, vol. 419, pp. 558–565, 2015.

[28] S. Chen, D. H. Glass, and M. McCartney, "Characteristics of successful opinion leaders in a bounded confidence model," *Physica A: Statistical Mechanics and its Applications*, vol. 449, pp. 426–436, 2016.

[29] Y. Zhang, Q. Liu, S. Zhang, and L. Wang, "Opinion formation with time-varying bounded confidence," *Plos One*, vol. 12, no. 3, Article ID e0172982, 2017.

[30] "Cognition - definition of cognition in English from the Oxford dictionary," 2016, https://www.oxforddictionaries.com/.

[31] H. A. Witkin, "A cognitive-style approach to cross-cultural research," *International Journal of Psychology*, vol. 2, no. 4, pp. 233–250, 1967.

[32] D. R. Goodenough, H. A. Witkin, H. B. Lewis, D. Koulack, and H. Cohen, "Repression, interference, and field dependence as factors in dream forgetting," *Journal of Abnormal Psychology*, vol. 1973, no. 2, pp. 32–44, 1974.

[33] H. A. Witkin and D. R. Goodenough, "Field dependence and interpersonal behavior," *Psychological Bulletin*, vol. 84, no. 4, pp. 661–689, 1977.

[34] D. R. Goodenough, "The role of individual differences in field dependence as a factor in learning and memory," *Psychological Bulletin*, vol. 83, no. 4, pp. 675–694, 1976.

[35] F. P. McKenna, "Measures of field dependence: Cognitive style or cognitive ability?" *Journal of Personality and Social Psychology*, vol. 47, no. 3, pp. 593–603, 1984.

[36] W. Linden, "Practicing of meditation by school children and their levels of field dependence-independence, test anxiety, and reading achievement," *Journal of Consulting and Clinical Psychology*, vol. 41, no. 1, pp. 139–143, 1973.

[37] R. J. Riding and V. A. Dyer, "Extraversion, field-independence and performance on cognitive tasks in twelve-year-old children," *Journal of Research in Education*, vol. 29, no. 1, pp. 1–9, 1983.

[38] B. M. Frank and D. Keene, "The effect of learners' field independence, cognitive strategy instruction, and inherent word-list organization on free-recall memory and strategy use," *Journal of Experimental Education*, vol. 62, no. 1, pp. 14–25, 1993.

[39] C. Tinajero and M. F. Páramo, "Field dependence-independence and academic achievement: A re-examination of their relationship," *British Journal of Educational Psychology*, vol. 67, no. 2, pp. 199–212, 1997.

[40] C. Angeli, "Examining the effects of field dependence-independence on learners' problem-solving performance and interaction with a computer modeling tool: Implications for the design of joint cognitive systems," *Computers & Education*, vol. 62, pp. 221–230, 2013.

[41] P. Engelbrecht and S. G. Natzel, "Cultural variations in cognitive style: Field dependence vs field independence," *School Psychology International*, vol. 18, no. 2, pp. 155–164, 1997.

[42] M. McCool and K. St. Amant, "Field dependence and classification: implications for global information systems," *Journal of the Association for Information Science and Technology*, vol. 60, no. 6, pp. 1258–1266, 2014.

[43] A. Mirtabatabaei and F. Bullo, "On opinion dynamics in heterogeneous networks," in *Proceedings of the 2011 American Control Conference, ACC 2011*, pp. 2807–2812, USA, 2011.

[44] X. Chen, X. Zhang, Y. Xie et al., "Opinion dynamics of social-similarity-based hegselmann–krause model," *Complexity*, vol. 2017, Article ID 1820257, 12 pages, 2017.

[45] D. Pellegreno and F. Stickle, "Field-dependence/field-independence and labeling of facial affect," *Perceptual and Motor Skills*, vol. 48, no. 2, pp. 489-490, 1979.

[46] L. Tascón, M. Boccia, L. Piccardi, and J. M. Cimadevilla, "Differences in spatial memory recognition due to cognitive style," *Frontiers in Pharmacology*, vol. 8, p. 550, 2017.

[47] B. M. Frank, "Flexibility of information processing and the memory of field-independent and field-dependent learners," *Journal of Research in Personality*, vol. 17, no. 1, pp. 89–96, 1983.

[48] M. A. Guisande, C. T. Vacas, F. Cadaveira et al., "Attention and visuospatial abilities: a neuropsychological approach in field-dependent and field-independent schoolchildren," *Studia Psychologica*, vol. 54, no. 2, pp. 83–94, 2012.

[49] M. A. Guisande, M. F. Páramo, C. Tinajero, and L. S. Almeida, "Field dependence-independence (FDI) cognitive style: An analysis of attentional functioning," *Psicothema*, vol. 19, no. 4, pp. 572–577, 2007.

[50] H. Gintis, "Strong reciprocity and human sociality," *Journal of Theoretical Biology*, vol. 206, no. 2, pp. 169–179, 2000.

[51] P. A. Tao and X. Tong, "Governance of mass disturbance which caused by NIMBY," *Nanjing Journal of Social Sciences*, 2010.

[52] J. M. Paige, "Political orientation and riot participation," *American Sociological Review*, vol. 36, no. 5, pp. 810–820, 1971.

[53] R. C. Eberhart, *Swarm Intelligence*, 2001.

[54] H. E. Stanley, "Spherical model as the limit of infinite spin dimensionality," *Physical Review A: Atomic, Molecular and Optical Physics*, vol. 176, no. 2, pp. 718–722, 1968.

[55] E. Ising, "Beitrag zur theorie des ferromagnetismus," *Zeitschrift für Physik*, vol. 31, no. 1, pp. 253–258, 1925.

[56] H. Liang, Y. Yang, and X. Wang, "Opinion dynamics in networks with heterogeneous confidence and influence," *Physica A: Statistical Mechanics and its Applications*, vol. 392, no. 9, pp. 2248–2256, 2013.

[57] Y. Dong, X. Chen, H. Liang, and C.-C. Li, "Dynamics of linguistic opinion formation in bounded confidence model," *Information Fusion*, vol. 32, pp. 52–61, 2016.

[58] M. Fischer, *Reactive, Slow and. . .Innovative? Decision-making Structures and Policy Outputs*, Palgrave Macmillan, UK, 2015.

[59] M. L. Volcansek, "Judges, courts and policy-making in Western Europe," *West European Politics*, vol. 15, no. 3, pp. 1–8, 1992.

[60] The Lancet, "Gun deaths and the gun control debate in the USA," *The Lancet*, vol. 390, no. 10105, p. 1812, 2017.

[61] T. Flew and L. Yin, "Xi Dada loves Peng Mama: digital culture and the return of charismatic authority in China," *Thesis Eleven*, vol. 144, no. 1, pp. 80–99, 2018.

[62] L. R. Luqiu, "The Reappearance of the Cult of Personality in China," *East Asia*, vol. 33, no. 4, pp. 1–19, 2016.

[63] Y. Wang, "The formation mechanism of deified personality cult of Mao Zedong's and reflection: from the perspective of cultural psychology," *Social Sciences Journal of Universities in Shanxi*, 2015.