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# Identifying emergence process of group panic buying behavior under the COVID-19 pandemic

Tinggui Chen<sup>a,b,\*</sup>, Yumei Jin<sup>a</sup>, Jianjun Yang<sup>c</sup>, Guodong Cong<sup>d</sup>

<sup>a</sup> School of Statistics and Mathematics, Zhejiang Gongshang University, Hangzhou, 310018, China

<sup>b</sup> Collaborative Innovation Center of Statistical Data Engineering Technology & Application, Zhejiang Gongshang University, Hangzhou, 310018, China

<sup>c</sup> Department of Computer Science and Information Systems, University of North Georgia, Oakwood, GA, 30566, USA

<sup>d</sup> School of Tourism and Urban-Rural Planning, Zhejiang Gongshang University, Hangzhou, 310018, China

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## ABSTRACT

The sudden COVID-19 caused frequent incidents of large-scale material panic buying, resulting in imbalance in supply and demand of goods and threatening social stability. It is of great significance to analyze the formation of group panic buying and help alleviate such action. This paper takes the panic buying phenomenon as the research target, quantifies the internal and external factors affecting individual buying behavior, restores the selection process of individual buying behavior, and constructs the emergence model of group panic buying behavior by using the idea of cluster dynamics. Through simulations, we find that: (1) The epidemic information intensity has a significant impact on the emergence of group rush buying behavior. (2) Government intervention plays a significant role in reducing the scale of group rush buying. Besides, the effects of intervention reach the best before people who do not participate in rush buying disappear. In addition, we also discuss the impact, limitations and future research directions.

## 1. Introduction

Since the outbreak of COVID-19, there have been many panic buying events in the world (Islam et al., 2021), which not only involve the panic buying of anti-epidemic and living supplies such as facemasks, disinfectant water, grain and oil, but also the hoarding of supplies that are not related to epidemic prevention. For example, China snapped up Shuanghuanglian medicine (a dose of Chinese herbal medicine uses to prevent from getting cold), Japan snapped up granite, Italy snapped up toilet paper and other events. Because these sudden public health events have the characteristics of fast propagation, strong urgency and unpredictability, they are very easy to lead to people's overreaction to such events and group panic buying behavior. In addition to the influence of individual needs (Mathes, 1981), Mary et al. (2020) found that herd mentality played a vital role in the formation process, and the crisis almost made them lose their mind. Moreover, social media also plays a catalytic role in the dissemination of public opinion (Naeem, 2021). Online information dissemination makes up for the limitations of offline time and space, making the spread of panic faster and group behavior easier to form. The emergence of such group behavior is similar to the

consistency of cluster system in cluster dynamics (Ren, 2006), which is manifested in the unified formation of group by individual behavior. This kind of irrational large-scale hoarding of materials can easily cause a rapid increase in market demand in the short term, a shortage of goods, and even a supply chain rupture, which will seriously cause an overall imbalance of supply and demand in the society (Wang and Holly, 2020), and even result in turbulence of social stability (Maital and Barzani, 2020). Furthermore, panic buying may have extremely bad effects to economic development, enterprise production and other aspects in the society. Based on this, it has important theoretical and practical significance to study the group panic buying and its influencing factors, as well as to explore the underlying reasons for its formation.

Generally speaking, panic buying often accompanies the outbreak of public health emergencies, such as: the panic buying of Banlangen (a dose of Chinese herbal medicine uses to prevent from getting cold) and white vinegar caused by SARS in 2003, the panic buying of garlic caused by the H1N1 influenza in 2009, the panic buying of salt caused by the Fukushima nuclear leak in Japan in 2011 (Rubin et al., 2009), and the panic buying of facemasks, disinfectant and other materials caused by COVID-19. These panic buying incidents occur frequently, resulting in

\* Corresponding author. School of Statistics and Mathematics, Zhejiang Gongshang University, Hangzhou, 310018, China.

E-mail addresses: [ctgsimon@mail.zjgsu.edu.cn](mailto:ctgsimon@mail.zjgsu.edu.cn) (T. Chen), [jin15093389121@163.com](mailto:jin15093389121@163.com) (Y. Jin), [Jianjun.Yang@ung.edu](mailto:Jianjun.Yang@ung.edu) (J. Yang), [cgd@mail.zjgsu.edu.cn](mailto:cgd@mail.zjgsu.edu.cn) (G. Cong).

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man-made shortages of materials and broken commodity supply chains (Dulam et al., 2021), thus seriously affecting the process of national governance and endangering the safety of people's lives and property. This paper takes the panic buying event caused by the outbreak of COVID-19 at the end of 2019 as the case to study the evolution mechanism and influencing factors of panic buying. So far, scholars have conducted research on panic buying behavior, including analysis of people's psychological factors (Zhang and Zhou, 2021), news influence (Yasir Arafat et al., 2020), etc. However, there is still short of considering the combination of internal and external factors from a systematic perspective. Also, most of them are based on qualitative research (Leung et al., 2021), while quantitative research is relatively rare. In terms of the methodology, multiple linear regression (Yoshizaki et al., 2020) and structural equation model (Omar et al., 2021) are mostly used for analysis, but these types of methods have certain limitations and cannot solve the problem of nonlinearity and multicollinearity. Based on this, it is necessary to establish a reasonable and effective mathematical model against the phenomenon of panic buying to explore the emergence of group behavior. As such, a mathematical model is established to transform the panic buying group phenomenon into a series of formulas that can be solved mathematically. Through the setting of variables, the occurrence law of the group phenomenon can also be found, so as to find out which factors have significant impacts on the panic buying group phenomenon.

This study uses resource scarcity, crowd psychology (Sime, 1995) and cluster dynamics to explore the relationships among government measures, psychological factors and peer influence for panic buying behavior. It mainly makes contributions from several aspects: firstly, this study establishes a model to quantify the internal and external factors affecting individual panic buying behavior as force. From the perspective of mechanics, this study observes the change of individual force to reflect the change of individual buying behavior, and explores the factors that affect individual buying behavior. As far as we know, this idea has not been concerned yet. According to the research (Yuen et al., 2020), at present, half of the exploration on the causes of panic buying adopts correlation analysis (Lins and Aquino, 2020; Bentall et al., 2021), followed by qualitative analysis (Taylor, 2021; Barnes et al., 2021; Kaur and Malik, 2020), and less simulation is involved. Moreover, Kai et al. (2015) and Dong et al. (2017) found that a single network structure could not fully reflect the actual public opinion transmission, so they proposed an online and offline two-tier coupling network model. In this study, the effects of these two levels are also fully considered and the model is established. Subsequently, we establish the information interaction model between individuals based on the idea of cluster dynamics (Bernardi and Scianna, 2020), which has been used to expand the sociological model and find the cluster effect between pedestrians and scenic spots (Kwak et al., 2013). In fact, using the idea of cluster dynamics can well explain the emergence of group behavior. However, it has not been used to analyze the formation of group panic buying behavior. As a result, this study attempts to provide a new insight into group panic behavior.

The structure of the rest of the paper is organized as follows: the second section is literature review; the third section describes the methodology used in this study; the fourth section constructs the emergence model of group behavior, and carries out simulation experiments on the model based on BA network, considering the influence of internal and external factors on the emergence scale of group panic buying; the fifth section verifies the effectiveness of the model through practical cases; the sixth section is the theoretical significance and management contribution of this study; the seventh section is the summary of the paper and also gives the comparison with the results of peer work; the last section explores the limitations of this study and the future research directions.

## 2. Literature review

Due to the characteristics of strong harm, rapid spread, and wide range of influence, panic buying has caused widespread concerns in the academic community. Arafat et al. (2020) defined panic buying: phenomenon of a sudden increase in buying of one or more essential goods in excess of regular need provoked by adversity, usually a disaster or an outbreak resulting in an imbalance between supply and demand. It usually occurs after major disasters, wars and other events, and seriously threatens social stability. Generally speaking, panic buying behavior is affected by individual internal psychological changes and external environmental stimuli. In addition, for the formation of group behavior, communication is an important process. The following subsections will analyze the literature according to these three aspects.

### 2.1. Panic buying psychological factors

The first aspect is the research on the influence of individual internal psychological changes on panic buying behavior. According to Enny Sri Hartati, Executive Director of the Institute for Development of Economics and Finance (INDEF), this purchase fear is caused by psychological factors, which are usually caused by imperfect or incomplete information obtained by the public. Individuals' psychological factors largely determine the choice of their panic buying behavior. Some typical literatures are as follows: By analyzing the psychological factors of panic buying, Yuen et al. (2020) found that the psychological reasons of panic buying mainly included four parts: personal perception of health crisis threat and product scarcity, fear of unknown, human response to external crisis and social psychological factors affected by personal social networks. Garbe et al. (2020) found that emotional tendency could predict the perceived threat of covid-19 and indirectly affect storage behavior. In addition, people's sense of responsibility was related to toilet paper storage, meaning that people with high sense of responsibility tended to store more toilet paper. Kemp et al. (2014) proposed that uncertainty would cause people's fear, and the emergence of fear led to purchase behavior. Yuen et al. (2021) used structural equation method to study panic buying centered on survival psychology and Maslow's motivation theory. The research emphasized that physiological, safety, social and respect needs would affect panic buying. Ma et al. (2018) found that the way consumers thought affected people's attitude towards out of stock. Taylor (2021) proposed that when people were afraid of real but short-term scarcity, there would be a snowball effect. The phenomenon of large-scale rush buying was more likely to be initiated by people with high fear, and rush buying was a means for them to escape unpleasant external stimuli. Gao and Liu (2017) proposed a dynamic network model integrating psychological factors to understand the temporal and spatial characteristics of human behavior in extreme events, and tested the effectiveness of the model through the case of panic buying in the 2011 Japanese earthquake. The above literature mainly studies from a psychological perspective that in a panic environment, the growth of anxiety, depression and other emotions will prompt individuals to participate in panic buying. However, these literatures do not consider the impact of dynamic changes in the external environment on the individual's internal emotional perception, and most of them are qualitative studies by using questionnaire surveys.

### 2.2. Panic buying external factors

The second aspect is the research on the influence of external environmental stimuli on panic buying behavior. The influence of external factors on individual panic buying behavior is mainly concentrated on changes in epidemic information. This part is dominated by government announcements and the media. The current representative literature is as follows: Barnes et al. (2021) used compensation control theory, big data and text analysis to find the benefits of social media for early warning of potential demand. Keane and Neal (2021) found that the

government's announcement of movement restrictions at the beginning of the pandemic was more likely to cause panic than later, and the travel restrictions would not cause panic among consumers. [Prentice et al. \(2021\)](#) discussed the possible external factors causing panic buying and found that the intervention of the government and enterprises affected the participation of panic buying, while social groups had minor impact. [Tan et al. \(2021\)](#) used partial least squares structural equation model to analyze and found that online news had a direct impact on perceived possibility and individual attitude. [Sulaiman et al. \(2021\)](#) classified antecedents, set up influencer nodes or opinion leader nodes in social media, and explored the role of social media in panic buying. [Ahmad and Murad \(2020\)](#) found that social media had a significant impact on the spread of panic and had a potential negative impact on people's mental health. There was a significant positive statistical correlation between its use and the spread of panic. By analyzing the impact of global media on rush buying behavior, [Mary et al. \(2020\)](#) found that consumer behavior during the COVID-19 crisis was consistent with that during major disasters in history. The above literature mainly studies the influence of external environmental factors on individual panic buying behavior, but mostly focuses on the role of media. It does not fully consider the changes of external environmental information and surrounding social individuals, and cannot well restore the actual interaction situation.

### 2.3. Spread of panic buying

Some studies have shown that emotion can be contagious, and it is precisely because of the infection of emotion that the group phenomenon is caused. For example, [Du et al. \(2011\)](#) regarded emotional infection as a process of unconscious expression and transmission of similar emotions. [Liu et al. \(2013\)](#) thought that in emergencies, the group characteristics were different from those in general, and the phenomenon of emotional infection was faster. [Hoffman \(2001\)](#) believed that emotional infection was emotional cognition and control formed by conscious performance. It can be seen that conformity is also a factor inducing purchase behavior. [Frank and Schvaneveldt \(2016\)](#) proposed that when people could not decide whether to make panic purchase, they would observe the choices of those individuals who took action earlier and follow up. Therefore, fully considering the process and interaction of emotional infection is the key to correctly reflect the group phenomenon.

From the above analysis, it can be seen that the existing literature mainly studies panic buying behavior from a single dimension, i.e. either internal psychological factors or external environmental ones. Few literatures combine both to analyze the panic buying behavior. In fact, the panic buying behavior is caused by the environment and the individual together ([Laato et al., 2020](#)). Based on this, this paper builds a mathematics model to identify the emergence process of group panic buying behavior based on cluster dynamics in accordance to the internal driving force dominated by individual emotions and the external attraction dominated by the buying environment, as well as analyzes the emergence process of group panic buying behavior through simulation to explore internal evolution mechanism.

## 3. Methodology

### 3.1. Propagation model

We have developed different communication models for different online and offline communication characteristics. When establishing the propagation model, we use the idea of cluster dynamics for reference. At present, common approaches are mostly used to describe the dynamic changes of the unified process of action such as pigeons and micro particles. We use the improved cluster dynamics to simulate human group panic buying behavior. Our experiments demonstrate that it is reasonable and the simulation results are in line with expectations. In

fact, [Sun and Zhao \(2007\)](#) have used this idea to study the problem of crowd evacuation in dense places. It also shows that this method is suitable for the study of group emergence behavior. After the model simulation, we also select a real case to verify the effectiveness and rationality of our proposed model, and substitute the data from the real case into our model. The simulation results are consistent with the expectation.

### 3.2. BA model

BA model ([Barabási and Réka, 1999](#)) refers to a scale-free network model proposed by Barab and Albert, which follows the power-law distribution. BA model has two characteristics: one is growth, which means that the network scale is increasing; the other is the priority connection mechanism, which means that new nodes in the network tend to connect with nodes with high connection degree. For example, articles with high citations are more likely to be read, and popular students are more likely to be recognized. It is more realistic than random networks.

The purpose of this study is to explore the scale and speed of group panic buying behavior when different factors change. The idea is to create a theoretical emergence model of group panic buying behavior caused by epidemic. Specifically, the simulation analysis in Section 4.2 is conducted through the variables of the model to intervene in the final group emergence. The method of model simulation can more intuitively see the individual's state at different times and better understand it, rather than having limitations and contingency like questionnaire survey ([Breakwell et al., 2006](#)), nor as abstract as qualitative analysis ([Kaur and Malik, 2020](#)).

## 4. Model construction and analysis

Usually, general calculation methods are very difficult to solve multi-dimensional or complex factors, while Monte Carlo method ([Rubinstein and Kroese, 2016](#)) is relatively simple to solve this problem. It solves various mathematical problems by constructing random numbers that conform to certain rules. It can calculate the approximate results on random sampling, and get more accurate results in simulation. The simulation in this paper involves group behavior, with many agents and many influencing factors. Therefore, the multi-agent method based on Monte Carlo is more in line with this topic.

In the literatures, [Planas-Sitja et al. \(2015\)](#) emphasized the importance of individual traits for group behavior. Similarly, when panic buying group behavior occurs, we cannot ignore the impact of individual traits. Existing studies show that panic Conformity psychology and social influence are the main factors of group phenomenon ([Frank and Schvaneveldt, 2016](#); [Pan et al., 2020](#)). Therefore, we mainly decompose and quantify the individual's internal panic emotion as a dimension and the external environment driven as a dimension. Combined with the characteristics of online and offline double-layer propagation, this paper establishes a model, tries to analyze this group phenomenon more completely, and observes the simulation results through various variable settings.

### 4.1. Model construction

Through the analysis of literature, we know that scholars have found the difference between offline and offline rush buying behavior. As shown in [Table 1](#), although some people take offline shopping under the epidemic, the number of people decreases significantly, and the number of online shopping increases significantly. [Agustini et al. \(2020\)](#) found that the generation speed of online shopping was significantly higher than that of offline shopping. When we build the model, we also fully consider this factor. The propagation speed on online is higher than that on offline, so as to achieve the purpose that the simulation effect is close to the real situation.

**Table 1**  
Gaps in online and offline rush buying.

Author	Finding
Bhatti et al. (2020)	52% of consumers avoid physical shopping and crowded areas. In addition, 36% avoid physical shopping.
Wang and Holly (2020)	77% of people still buy offline, 53% use online stores and 70% use WeChat group buying. It can be found that there are many online and offline buying behaviors.
Yendamuri and Vohra (2020)	In the analysis of the purchase patterns of 8600 consumers in six Southeast Asian countries, it is found that 47% of consumers have reduced offline purchases and 30% have increased online consumption.
Akesson et al. (2020)	Blockade and social distance requirements disrupt consumers' shopping habits and change from offline to online shopping.
Agustini et al. (2020)	It is found that purchases caused by panic and unplanned often occur through online channels, and the generation speed is faster than offline.

The research framework of the paper is shown in Fig. 1. The relevant parameters and variables involved in the model are shown in Tables 2 and 3. Also, agent represents individual nodes in the network, and the network scale is set to  $N$ , i.e. there are  $N$  netizen nodes in the network. The individual force situation is represented by an arbitrary number in  $[-1,1]$ . If it falls into the interval  $[-1,0]$ , it means that the individual receives a negative force and does not participate in panic buying. If it falls into the interval  $[0,1]$ , it means that individual receives a positive force and has a strong willingness to participate in panic buying.

4.1.1. The emergence of panic buying behavior offline

In the environment of COVID-19, due to the needs of prevention and control, people cannot go out at will, thus most people choose to hoard living materials for a period of time to satisfy their daily needs. However, when people see the few commodities on the supermarket shelves and the full shopping carts around them, they will be keenly aware of the crisis of shortages and begin to hoard more than necessary supplies in daily life, resulting in "panic buying behavior" (Tsao et al., 2019). The panic buying phenomenon caused by such major public health incidents can easily lead to large-scale delays or even breaks in the supply chain, which in turn leads to a shortage of supplies for the entire society.

Generally speaking, human behavior is determined by the environment and the inherent characteristics of the individual. In real life, each individual has his own needs. When the needs cannot be met, it will cause people's psychological tension, forcing the individual to take action to eliminate the psychological tension. Especially in the panic buying environment, information about the shortage of materials frequently comes out. Cannon et al. (2019) found that individuals who did not take actions in the face of resource scarcity would lead to expected regret. Compared with the expected consequences of not taking rush purchase and the actual results after taking actions, purchase was regarded as a coping strategy to alleviate the panic caused by scarcity.

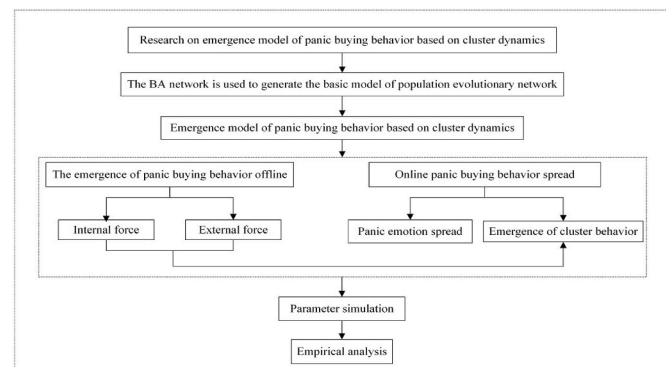


Fig. 1. Framework of this paper.

**Table 2**  
Relevant parameters.

parameter	Description
$P_{part}$	partial update threshold of internal driving force
$P_{full}$	full update threshold of internal driving force
$k_1$	influence weight of individual $i$ 's purchase motivation on the individual's emotional value
$k_2$	influence weight of individual $i$ 's tolerance on the individual's emotional value
$k_3$	adjustment coefficient of environmental impact value
$S_{part}$	partial update threshold of external attractiveness
$S_{full}$	full update threshold of external attractiveness
$C_i$	conformity of individual $i$
$\mu_1$	assimilation parameter
$\mu_2$	repulsive parameter
$d_1$	assimilation threshold
$d_2$	repulsive threshold

**Table 3**  
Relevant variables.

variables	Description
$P_i(t)$	emotional impact value of individual $i$ at time $t$
$M_i(t)$	purchase motivation of individual $i$ at time $t$
$T_i(t)$	tolerance of individual $i$ at time $t$
$E_i(t)$	panic emotion perception of individual $i$ at time $t$
$S_i(t)$	objective environmental impact of individual $i$ at time $t$
$F_i(t)$	joint force received by individual $i$ at time $t$
$Fin_i(t)$	internal force received by individual $i$ at time $t$
$Fout_i(t)$	external force received by individual $i$ at time $t$
$Ni(t)$	number of panic buyers around individual $i$ at time $t$
$N_i(t)$	number of neighbor nodes around individual $i$ at time $t$
$I_n$	information intensity at time $t$
$F_a$	$j$ 's force received by individual $i$ at time $t$
$\varphi$	angle between the position line and the horizontal position of the individual $i$ and $j$ partitions at time $t$
$q_{ij}$	intimacy between individuals $i$ and $j$

Mehta and Zhu (2016) pointed out that consumers' exposure to situational cues made people aware of resource scarcity, which affected their emotions and behaviors. Among them, the most important media was social media. The "hoarding stories" or pictures on empty shelves circulated on social networking websites contributed to individual emotional collapse (Yap and Chen, 2020), which led individuals to take the same purchase behavior (Van Bavel et al., 2020). In addition, panic buying of necessities during a health crisis is considered 'following the crowd' or 'going with the flow' (Cheng, 2004). Some scholars have proposed that group psychology will lead to behavioral control and self-regulation system disorder (Drury et al., 2013), which will promote individuals to observe the reactions of others and form common beliefs with the group (Earl, 2008).

Therefore, this study mainly explores the emergence of group rush buying behavior when individual emotion, herd psychology and external panic information change. The formulas in this study are presented on the basis of consulting data and combining the real simulation evolution. They are different from structural equation and other methods. The applicability of modeling and simulation methods is wider and more diverse, and can carry out the analysis with a large amount of data.

4.1.1.1. Influencing factors of panic buying behavior. There are many factors affecting people's panic buying, which can be summarized into two categories: internal factors and external factors. Internal factors refer to various psychological and physiological factors, such as people's awareness, emotions and needs of panic buying (Sherman et al., 1997), in which individual emotions are the main internal factors that affect people's panic buying. External factors refer to the objectively existing social environment and natural environment, including the out-of-stock

environment and the buying behavior of people around. Under the combined effect of  $P_i(t)$  and  $S_i(t)$ , the individual forms panic buying attitude value  $X_i(t)$ . The calculation is as follows:

$$X_i(t) = P_i(t) + S_i(t) \tag{1}$$

**(1) Emotional impact value  $P_i(t)$**

Affected by needs, which are generated due to the lack of subjective experience of something in the individual's life, individual emotion is a subjective psychological tendency. According to Maslow's need theory, human needs generate motivation, and motivation promotes behavior. In the panic buying environment, the weaker individual's purchase motivation and the stronger their tolerance indicate the weaker perceived panic mood and the lower desire to buy, prompting people not participate in the panic buying. On the contrary, the stronger individual's buying motivation indicates the weaker patience, and the desire to buy will rise sharply, prompting individuals to participate in panic buying. Therefore, the individual emotional impact value  $P_i(t)$  is mainly affected by the individual purchase motivation  $M_i(t)$ , and the individual tolerance  $T_i(t)$ . The specific expression is:

$$P_i(t) = k_1 \cdot \sin\left(\frac{\pi}{2} \cdot M_i(t)\right) + k_2 \cdot \cos\left(\frac{\pi}{2} \cdot T_i(t)\right) \tag{2}$$

where the value range of  $P_i(t)$  is  $[0,1]$ ,  $k_1 + k_2 = 1$ ,  $k_1$  and  $k_2$  represent the influence weight of purchase motivation and individual tolerance on individual emotion, respectively. In the process of the individual demand game, the purchase motive  $M_i(t)$  is affected by the individual's panic perception  $E_i(t)$ , which measures the individual's impact by the epidemic. The larger value means more obvious impact. The formula for the influence of purchase motivation is as follows:

$$M_i(t) = \sin\left(\frac{\pi}{2} \cdot E_i(t)\right) \tag{3}$$

where the greater individual's perception of panic reflects the more sensitive to external shortages, the stronger desire to buy, and the greater motivation to purchase. The individual's panic perception  $E_i(t)$  belongs to  $[0,1]$ . If its value is closer to 1, the individual's panic degree will be stronger, and the value of  $M_i(t)$  belongs to  $[0,1]$ .

The individual tolerance  $T_i(t)$  represents the individual's tolerance for a certain thing, which is also affected by the individual's panic perception  $E_i(t)$ . The higher individual's panic perception indicates the more vulnerable psychology. The lower tolerance to the external out-of-stock environment will encourage the individual to participate in the panic buying, and vice versa. Based on this, the influence of individual panic perception on individual tolerance is as follows:

$$T_i(t) = \cos\left(\frac{\pi}{2} \cdot E_i(t)\right) \tag{4}$$

where  $T_i(t)$  belongs to  $[0, 1]$ , indicating the tolerance influence value of individual  $i$  at time  $t$ .

**(2) Objective environmental impact  $S_i(t)$**

The impact of external factors mainly comes from the objective environment, and the impact of the objective environment in the epidemic is mainly reflected in the epidemic environment and the impact of the number of panic buyers around the individual. When an individual faces a complex and dangerous environment, he/she usually cannot rely on his/her own knowledge to make accurate and reasonable judgments timely. At this time, he/she will seek the "help" of the surrounding individuals and decide his/her next behavior based on the behavior of the surrounding individuals. Based on this, the objective environmental impact  $S_i(t)$  is affected by individual conformity, surrounding buying environment and the intensity of external epidemic information.  $S_i(t)$  belongs to  $[0, 1]$ , and the calculation formula is as

follows:

$$S_i(t) = k_3 \cdot C_i \cdot \frac{NI_i(t)}{N_i(t)} \cdot I_n \tag{5}$$

where  $k_3$  is the adjustment coefficient.  $C_i$  means individual conformity, which is affected by cultural differences, life background and other factors.  $N_i(t)$  means the number of neighbor nodes around individual  $i$  at time  $t$ .  $NI_i(t)$  represents the number of panic buyers around individual  $i$  at time  $t$ .  $NI_i(t)/N_i(t)$  represents the proportion of panic buyers among neighbor nodes of individual  $i$  at time  $t$ . Generally speaking, if there are more panic buyers around individual  $i$ , it is easier for individual to be affected and then participate in the panic buying. In addition, individuals will also be affected by external epidemic information  $I_n$ ,  $I_n \in [0,1]$ . The greater intensity of the external epidemic information indicates that individuals feel more drastic changes, and the corresponding objective environment impact is greater and external attraction is more obvious.

**4.1.1.2. Internal force  $Fin_i(t)$ .** The panic buying behavior is affected by the individual's emotions. After the individual feels the real shortage of goods offline, he/she is impacted and is prone to be panic, and the situation of extreme discomfort appears. At this time, affected by this own subjective emotion, the individual will have a subjective purchase intention; at the same time, he/she will generate a positive or negative internal panic buying motivation, which is called internal driving force here. Under the action of this force, the individual makes decision to participate in panic buying. However, taking the individual's acceptance ability into account, the individual's emotional value will affect individual decision-making only when the individual's emotional value exceeds a certain level. Based on this, under the influence of his emotional value  $P_i(t)$ , the individual's internal force  $Fin_i(t)$  is expressed as follows:

$$Fin_i(t) = \begin{cases} Fin_i(t), & \text{if } 0 \leq P_i(t) < P_{part} \\ Fin_i(t) + P_i(t) \cdot \frac{P_{full} - P_i(t)}{P_{full} - P_{part}}, & \text{if } P_{part} \leq P_i(t) < P_{full} \\ Fin_i(t) + P_i(t), & \text{if } P_{full} \leq P_i(t) \leq 1 \end{cases} \tag{6}$$

where  $Fin_i(t)$  belongs to  $[-1,1]$ , representing the internal force that individual  $i$  receives at time  $t$ . When  $Fin_i(t) \in [-1,0]$ , it means that the individual is affected by the reverse force, showing a silent spiral, and there is no willingness to buy. When  $Fin_i(t) \in [0,1]$ , it means that the individual is affected by the positive force and has a desire to buy;  $P_{part}$  and  $P_{full}$  indicate the partial update threshold and full update threshold of external attractiveness respectively. When  $0 \leq P_i(t) < P_{part}$ , the individual's emotional value is very low and the individual's willingness to buy is not affected, and the internal strength remains unchanged at this time. When  $P_{part} \leq P_i(t) < P_{full}$ , the individual's emotional value is high, but the individual can tolerate it, which will affect the individual panic buying willingness insignificantly, and internal force part updates correspondingly. When  $P_{full} \leq P_i(t) \leq 1$ , the individual's emotional value exceeds its psychological tolerance threshold, the irrational state is obvious, the individual is deeply affected, and the corresponding internal force changes greatly, which is recorded as a complete update of the internal force. The corresponding internal force update interval is shown in Fig. 2.

**4.1.1.3. External force  $Fout_i(t)$ .** In addition to the internal driving force, the individual's final decision is also affected by external force. When the external environmental impact value  $S_i(t)$  is larger, the individual is more strongly affected by the external environment, and the value of external force  $Fout_i(t)$  is greater and the desire to buy is stronger. Similar to internal driving forces, individuals are different in sensitivity to the external environment, and will update their  $Fout_i(t)$  based on  $S_i(t)$ . Since

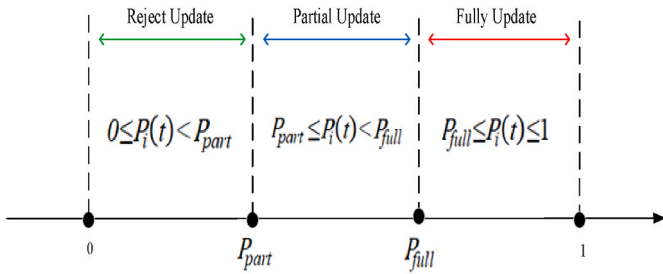


Fig. 2. Internal force update interval.

the internal force update interval is divided into three segments, in order to make the analysis more in line with actual requirements, the external force update interval is set to three segments, as shown in Fig. 3. The calculation formula of  $F_{out_i}(t)$  is as follows:

$$F_{out_i}(t) = \begin{cases} F_{out_i}(t), & \text{if } 0 \leq |S_i(t)| < S_{part} \\ F_{out_i}(t) + S_i(t) \cdot \frac{S_{full} - S_i(t)}{S_{full} - S_{part}}, & \text{if } S_{part} \leq |S_i(t)| < S_{full} \\ F_{out_i}(t) + S_i(t), & \text{if } S_{full} \leq |S_i(t)| \leq 1 \end{cases} \quad (7)$$

where  $F_{out_i}(t) \in [-1,1]$ , representing the external force of individual  $i$  at time  $t$ . When  $F_{out_i}(t) \in [-1,0]$ , it means that the external environment has a negative traction on the individual  $i$ , and the individual will not participate in the panic buying at this time. When  $F_{out_i}(t) \in [0,1]$ , it means that the external environment has a positive attraction to individual  $i$ , which encourages the individual to participate in panic buying.  $S_{part}$  and  $S_{full}$  represent the threshold of partial update and full update of the external force, respectively. When  $0 \leq |S_i(t)| < S_{part}$ , the objective environmental impact value is low, and the impact on the individual is minimal. At this time, the external force remains unchanged. When  $S_{part} \leq |S_i(t)| < S_{full}$ , the objective environmental impact value is greater, which affects the individual decision insignificantly, the corresponding external force is partially updated. When  $S_{full} \leq |S_i(t)| \leq 1$ , the individual is completely affected, the external force changes greatly, and the corresponding external force is fully updated.

**4.1.1.4. Buying behavior zone.** According to the above analysis, the individual produces a behavior under the combined action of external attraction and internal driving force. Combined with the existing research findings, the outcome proved that it is reasonable to divide the whole population into attraction area, synchronous area and free area when the actions of fish and pigeons are unified (Dieck Kattas et al., 2012). Combined with our study, social influence and individual psychological effect will form group dynamics (Moussaïd et al., 2013) and produce group phenomenon. In order to analyze the emergence process of group panic buying behavior, the x-axis represents the change of internal force within the interval  $[-1,1]$ , and the y-axis represents the change of external force within the interval  $[-1,1]$ . At this time, the panic buying behavior can be divided into four areas in the coordinate

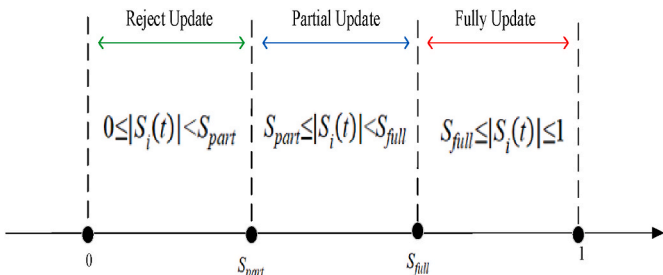


Fig. 3. External force update interval.

system to describe the behavior changes of individual  $i$  under the action of the internal and external forces of the surrounding individuals.

Based on the values of external force and internal force, the four areas formed are defined Not buying Zone, Attraction Zone and Buying Zone, where the first quadrant indicates that the individual's internal and external forces are both positive, and the panic buying is significantly affected. Under the action of the two positive forces, the individual gradually forms Buying Zone. In this area, individuals are determined to participate in panic buying. The second and fourth quadrants are both affected by a positive and negative force, and they are hesitant to panic buying and are in a state of vacillation. This corresponding area is called the Attraction Zone, and individuals in this area are easily affected. The third quadrant indicates that the external and internal forces received by the individual are negative, regardless of the external environment or internal state, the individual is in the insensitive stage without positive reaction, and has extremely low desire to panic buying. This corresponding area is the Not buying Zone, and the individuals in this area are determined not to participate in the buying. The specific partitions are shown in Fig. 4:

According to the buying zone partitions, the specific calculation formula of individual joint force  $F_i(t)$  can be obtained as follows:

$$F_i(t) = \begin{cases} \sqrt{Fin_i(t)^2 + Fout_i(t)^2}, & \text{if } Fin_i(t) \geq 0 \text{ and } Fout_i(t) \geq 0 \\ \frac{Fin_i(t) + Fout_i(t)}{2}, & \text{if } Fin_i(t) \cdot Fout_i(t) < 0 \\ -\sqrt{Fin_i(t)^2 + Fout_i(t)^2}, & \text{if } Fin_i(t) \leq 0 \text{ and } Fout_i(t) \leq 0 \end{cases} \quad (8)$$

where  $F_i(t)$  represents the joint force of individual  $i$  at time  $t$ . According to the calculation rule of joint force,  $F_i(t)$  belongs to  $[-\sqrt{2}, \sqrt{2}]$ .

**4.1.2. The spread of online panic buying behavior**

During the epidemic, offline individuals need to keep social distance, so the process of mutual opinion interaction is limited, and they can only judge the status quo of the environment by what they see and feel. This process is realized through the above-mentioned force update, and the internal and external forces are updated to different degrees according to the different levels of the environment and emotional changes. Individuals make an instinctive response offline based on the stimulus of the surrounding environment, and generate self-driving force under the action of their own behavior rules. At the same time, through online interaction, the movement direction is updated under the action of neighbor individuals to complete the position movement.

Online interaction includes two parts: the spread of individual

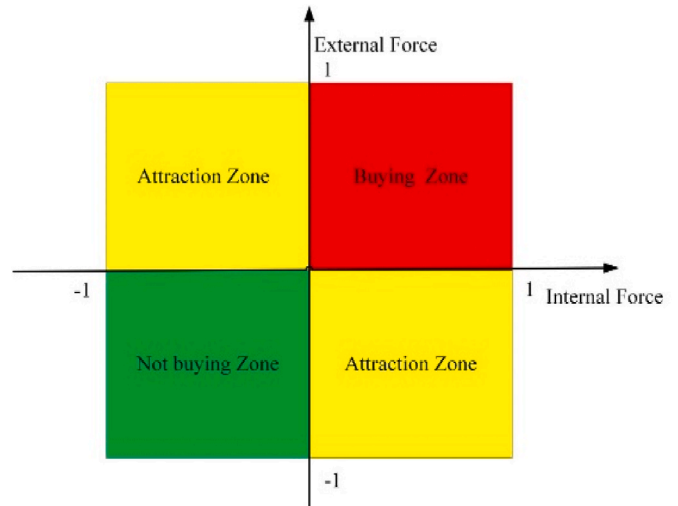


Fig. 4. Buying zone partitions.

emotions and the update of individual forces. Through the interaction, the individual will be affected by the emotion of the other party, so that his own emotional value will change. At the same time, the internal and external forces of the individual will be affected by the traction of the neighbors during the interaction to complete the update of their own forces.

**4.1.2.1. The spread of panic emotion.** The Internet provides a broad communication platform for netizens. In a complex network environment, netizens exist as independent agents and share information with other netizens. In addition, the network has the characteristics of no spatio-temporal restriction, high interaction efficiency, low cost, and fast transmission speed, so it has a huge number of users. Panic emotion spreads rapidly through the Internet, affecting individual's choices of panic buying.

This paper constructs the transmission rules of individual emotions based on the improved J-A model. The specific transmission rules are as follows:

$$P_i(t+1) = \begin{cases} P_i(t) + \mu_1 \cdot (P_j(t) - P_i(t)), & \text{if } |P_j(t) - P_i(t)| < d_1 \\ P_i(t) - \mu_2 \cdot (P_j(t) - P_i(t)), & \text{if } |P_j(t) - P_i(t)| > d_2 \\ P_i(t), & \text{others (9)} \end{cases}$$

where  $\mu_1$  is assimilation parameter,  $d_1$  is assimilation threshold,  $\mu_2$  is repulsion parameter, and  $d_2$  is repulsion threshold.

**4.1.2.2. Force update.** In addition to offline perceptions that have an impact on individual behavior, online opinion interactions will also change the individual's state. Vicsek model in swarm dynamics is used to construct online individual force interaction update rules. The details are as follows: Individual  $i$  selects the average speed of other individuals within a certain radius to update his behavior and obtain a new forward direction and movement speed. This process corresponds to the interaction of individual viewpoints, and generates new viewpoints and new attitudes after the interaction, which changes speed direction. Due to the continuous interaction between individuals and continuous speed update, a unified opinion is finally formed, and the phenomenon of group synchronization occurs.

For cyberspace, the physical distance has no practical meaning, and individuals cannot update their opinions by obtaining the opinions of other individuals within their actual radius. In order to describe the process of viewpoint interaction between individuals, this paper simulates the connection between individuals by constructing a network of relationships, and defines that individuals who are connected to each other can interact and obtain the opinions of each other, so as to update themselves. The coordinate system constructed above is equivalent to a large force field space. In this space, individuals are squeezed, collided, and attracted by neighboring nodes, so as to continuously update their

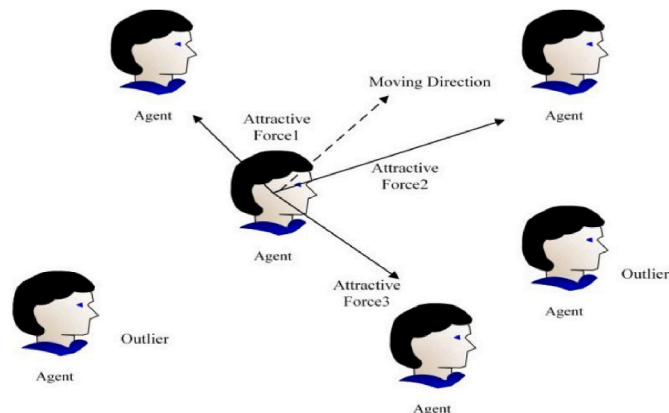


Fig. 5. Analysis of individual force.

behaviors until the emergence of group behaviors, as shown in Fig. 5.

It can be seen from Fig. 5 that individual  $i$  is simultaneously affected by the traction of multiple individuals in the group that are related to it. For example, for individual  $i$  ( $Fin_i(t), Fout_i(t)$ ), it is affected by neighbor node  $j$  ( $Fin_j(t), Fout_j(t)$ ). The force change and angle update formula for the next step of individual  $i$  are as follows:

$$\begin{cases} Fin_i(t+1) = Fin_i(t) + F_a \cdot \cos \varphi \\ Fout_i(t+1) = Fout_i(t) + F_a \cdot \sin \varphi \end{cases} \quad (10)$$

$$\varphi = \begin{cases} \arctan \frac{Fin_i(t) - Fin_j(t)}{Fout_i(t) - Fout_j(t)}, \\ \text{if } Fout_i(t) - Fout_j(t) \neq 0 \\ 0, & \text{if } Fout_i(t) - Fout_j(t) = 0 \end{cases} \quad (11)$$

where the angle  $\varphi$  refers to the angle between the line of the corresponding positions of the individual  $i$  and  $j$  in the panic buying behavior zone and the horizontal direction, reflecting the next forward direction of the individual  $i$ .  $F_a$  means that the individual  $i$  receives the force of the individual  $j$ , and the calculation formula is:

$$F_a = q_{ij} \cdot \sqrt{(Fin_i(t) - Fin_j(t))^2 + (Fout_i(t) - Fout_j(t))^2} \quad (12)$$

where  $q_{ij}$  represents the intimacy between individuals  $i$  and  $j$ , which is used to measure the degree to which individual  $i$  is affected by individual  $j$ . Generally speaking, individual  $i$  will not completely change its behavior according to the behavior of individual  $j$ . In this process, if the individual is more intimate with the individual  $j$ , he/she is more convinced of the views of the individual  $j$ , and is easier to move in the direction of the individual  $j$ , and the traction is greater, as shown in Fig. 6.

The simulation steps of the model are as follows:

- Step 1 : At the initial moment,  $N$  two-dimensional arrays are randomly generated, each corresponding to the coordinates  $(x,y)$ , where  $x$ -axis represents the internal driving force received by the individual, and  $y$ -axis represents the external attraction received by the individual. According to the quadrant of the coordinates, determine the individuals who participate in panic buying, those who do not participate in panic buying, and those who are hesitating. According to formulas (2)-(5), the individual's influence values suffering from internal and external factors are calculated.
- Step 2 : At any time, taking individual's acceptance ability into account, the degree of influence will be different. Set a partial and full influence threshold. When it is greater than the corresponding threshold, the individual's internal and external forces change are updated according to formulas (6)-(7).
- Step 3 : At any time, the individual  $i$  randomly selects its neighbor individual  $j$  as the interaction object, and performs panic emotion interaction according to formula (9), and updates its own emotional value. At the same time, judge the intimacy between individuals  $i$  and  $j$ . The higher the intimacy is, the greater the attraction will be. According to formulas (10)-(12), the internal and external forces are updated and moved to the corresponding position in the coordinate system. With the continuous progress of evolution, the number of individuals in the Buying zone continues to rise.
- Step 4 : Repeat the update of internal and external forces until the end of the evolution time. It can be obtained from the above evolution steps that at time  $t$ , there is a relational expression for the number of individuals in the network:

$$N(t) = NB(t) + NA(t) + NN(t) \quad (13)$$

where  $N_B(t)$  represents the number of individuals in the Buying Zone,  $N_A(t)$  represents the number of individuals in the Attraction Zone, and



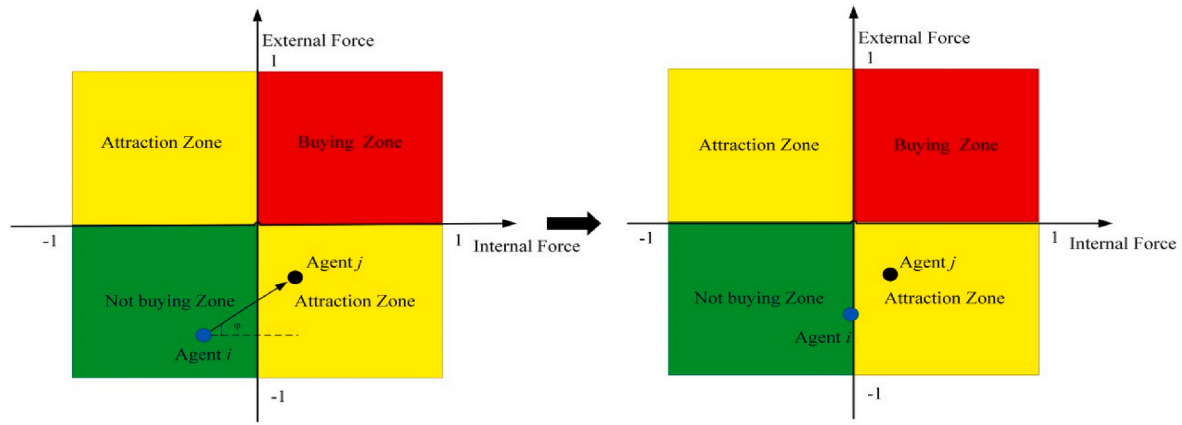


Fig. 6. Individual force movement.

$N_N(t)$  represents the number of individuals in the Not buying Zone. The density of individuals participating in the panic buying in the entire network at time  $t$  is:

$$\Delta_B(t) = \frac{N_B(t)}{N} \quad (14)$$

Based on the above analysis, the evolution flow chart of group panic buying behavior is shown in Fig. 7.

#### 4.2. Analysis

This section uses MATLAB software to simulate the emergence model of group panic buying behavior built above, and explores the influence of individual panic perception, individual conformity degree, epidemic information intensity, number of interactions, network structure, etc. on group panic buying behavior so as to reveal its internal evolution mechanism.

First, the initial parameters are set. The BA scale-free network is selected as the initial network of the simulation experiment with the node size of 1000. Our simulation sets the initial internal driving force  $Fin_i$  and external attraction  $Fout_i$  of the individual  $i$ , representing the individual's perception of the panic buying behavior that has occurred, and both obey the normal distribution of  $N(0,0.5)$ , and are mapped to  $[-1,1]$  interval, i.e. the value less than  $-1$  is set to  $-1$ , and the value greater than  $1$  is set to  $1$ , to ensure that individuals are scattered in the four quadrants. The individual conformity degree  $C_i$  obeys the normal distribution of  $N(0.5,0.15)$ , and maps to the interval  $[0,1]$ , the value greater than  $1$  is set to  $1$ , and the value less than  $0$  is set to  $0$ . The mean

value of  $0.5$  means that the conformity of most individuals in the group is in the middle, and the variance is set to  $0.15$  to make all the numbers in the range of  $[0,1]$  get the probability value. In addition, since purchase motivation has a more direct impact on individual purchase desire, and tolerance as an individual characteristic, the reaction is relatively slow, thus the purchase motivation influence coefficient  $k_1 = 0.6$ , and the tolerance influence coefficient  $k_2 = 0.4$ . In addition, the parameters of the J-A model are set as:  $\mu_1 = 0.2, \mu_2 = 0.2, d_1 = 0.3, d_2 = 0.8$ . For comprehensive visualization considerations, other parameters are set as:  $S_{part} = 0.2, S_{full} = 0.4, P_{part} = 0.4, P_{full} = 0.6, k_3 = 0.8$ .

#### 4.2.1. The influence of individual panic perception and individual conformity degree on the emergence of panic buying behavior

Due to the large differences in life background and personality characteristics among individuals, the degree of response to changes in the external environment will be different, which directly affects the individual's final decision-making. Individual factors not only affect their internal emotions (Sharma and Alter, 2012), but also determine the degree to which the individual is affected by the external environment. Therefore, the following will study its influence on the emergence of panic buying behavior from the perspective of individual panic perception and individual conformity.

#### 4.2.1.1. The influence of individual panic perception on the emergence of panic buying behavior.

The individual's panic perception indicates the individual's panic perception level, which directly affects the individual's panic mood. The epidemic is fierce, and individuals perceive that their survival is threatened, and the dual pressures of physical and

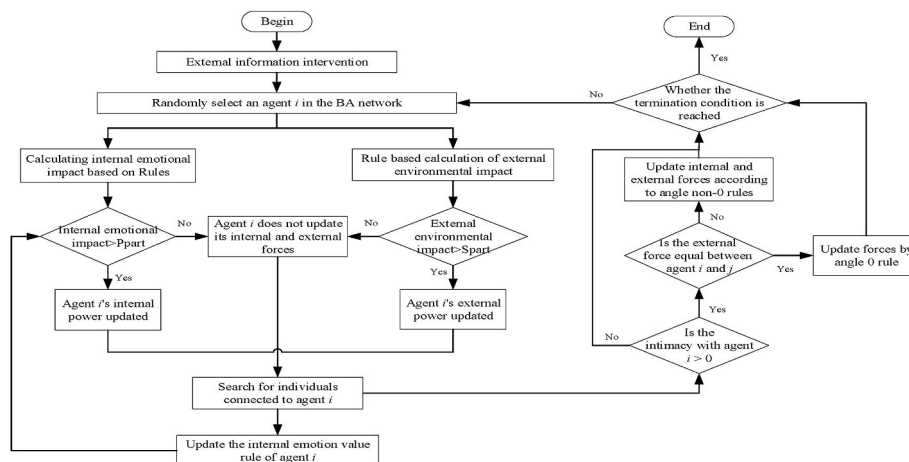


Fig. 7. Evolution flow chart of group panic buying behavior.

psychological causes them to be scared. When the panic exceeds the individual's psychological tolerance limit, he/she will have a desire to buy to ease his/her anxiety. In order to observe the influence of different individual panic perception on the emergence of panic buying behavior,  $E_i(t)$  is set to obey  $N(0.1,0.15)$  and map to  $[0,1]$ , so that the panic perception of most individuals in the network is 0.1, indicating that individual network nodes are generally less sensitive to panic perception.  $E_i(t)$  is set to obey  $N(0.5,0.15)$  and is mapped to  $[0,1]$ , indicating that individual network nodes have general panic perception. Later,  $E_i(t)$  is set to obey  $N(0.9,0.15)$  and is mapped to  $[0,1]$ , indicating that individual network nodes are more sensitive to panic perception. The simulation result is shown in Fig. 8.

Fig. 8 shows the number of people in each area over time under three different panic levels. It can be seen from Fig. 8 that the scale of panic buying enlarges with the increase of the individual's panic perception. The reason is that the greater individual's panic perception brings the more significant panic emotion, the individual's internal driving force, the stronger desire to buy, easier participation of panic buying, and forms larger scale of panic buying. In addition, from Fig. 8(a)–(c), it can be seen that with the increase of individual panic perception, the growth rate of the curve in the buying zone becomes larger, i.e. the emergence of group panic buying behavior becomes faster, indicating that the greater degree of perception, the greater impact of the epidemic, and the easier formation of a group panic buying phenomenon.

**4.2.1.2. The influence of individual conformity degree on the emergence of panic buying behavior.** In real life, people often feel nervous, fearful, anxious and other negative emotions while facing an epidemic. Especially under the constraints of limited resources and time, and limited by knowledge, experience, and cognitive abilities, they tend to lose their normal judgment and rational thinking; instead, they often imitate other people's behaviors. In this process, individual conformity plays a pivotal role. Generally speaking, the higher the individual's conformity is, the more likely he/she is influenced by the opinions of others. In order to compare the influence of different conformity degrees on the emergence of panic buying behaviors, three different levels of conformity degrees are set for simulations, and the results are shown in Fig. 9.

Fig. 9 reflects the number of people in each zone over time under different conformity levels. From Fig. 9(b) and (c), it can be seen that when the degree of conformity is at medium and high levels, the final group panic buying scales are both larger, and exceeds 950. From Fig. 9 (a), it can be seen that conformity obeys  $N(0.1,0.15)$ , i.e. when it is at a low level, the scale of group panic buying is significantly smaller, and becomes stable at around 615. The above shows that when the individual's conformity degree is at a low level, the individual can still become sober and make rational decisions, and will not follow others to participate in panic buying. When the individual's conformity degree in the group is at a medium or higher level, individual cannot be rational and is easy to blindly participate in panic buying. In general, the scale of panic buying enlarges with the increase of individual conformity.

**4.2.2. The influence of epidemic information intensity on the emergence of panic buying behavior**

The epidemic information intensity  $I_n$  refers to the intensity of external information formed in the context of the epidemic that has a negative impact on people's lives. The most significant information is out of stock and home isolation. These are main cause for panic buying. Once the public feels out of stock, they will inevitably take quick action to participate in the panic buying. Therefore, the intensity of external epidemic information will affect the speed and scale of the emergence of group panic buying. The closer the  $I_n$  value is to 1, the harsher the external environment is and the stronger the people's willingness is to buy. In practice, government intervention can ease people's panic and reduce their enthusiasm for buying. In order to compare the effects of government intervention, the discussion will be carried out separately

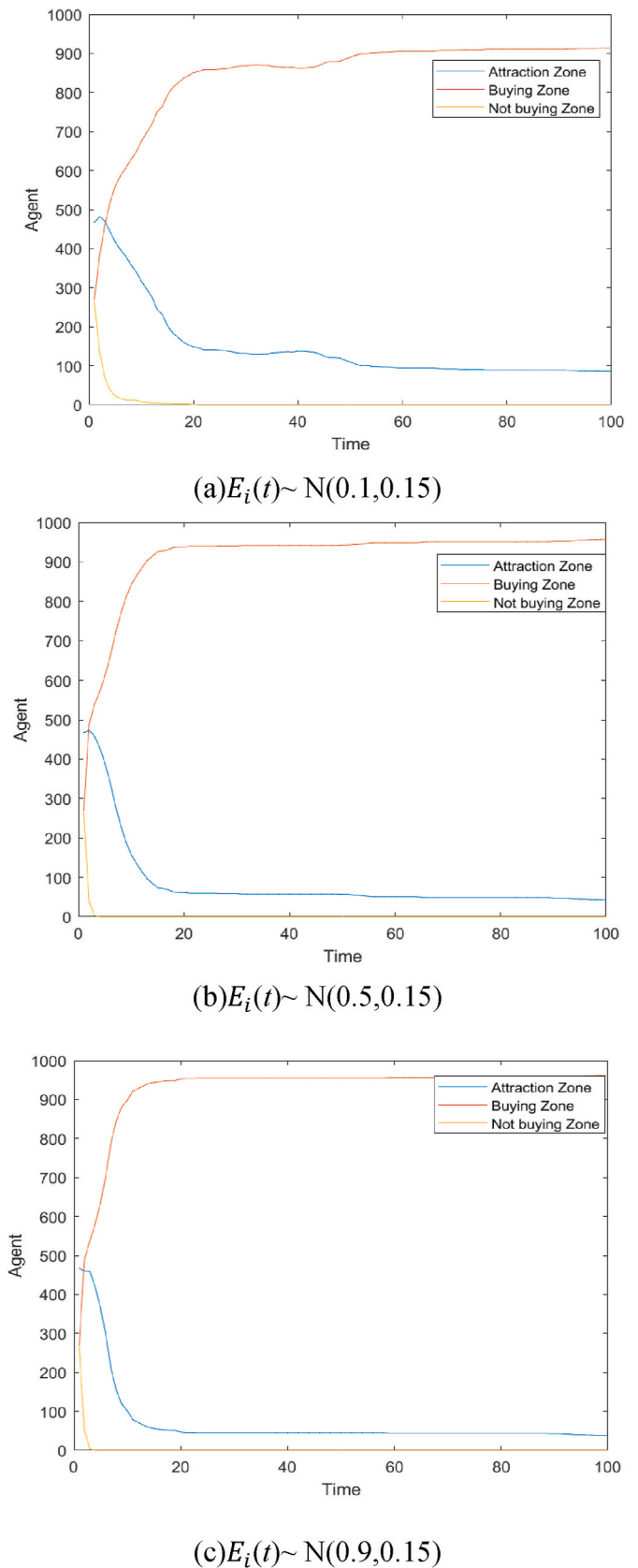
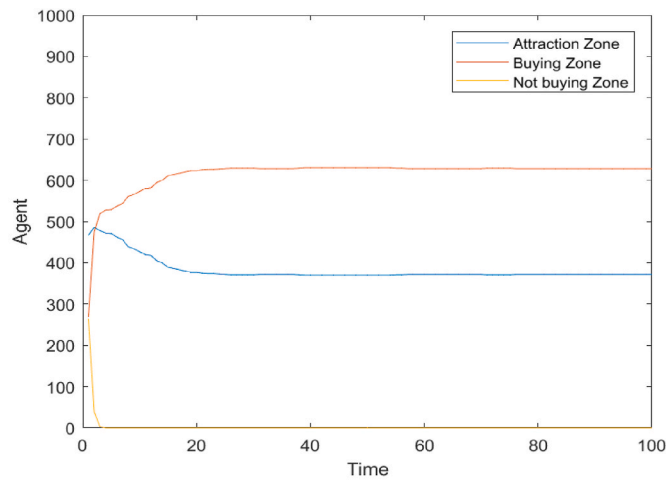
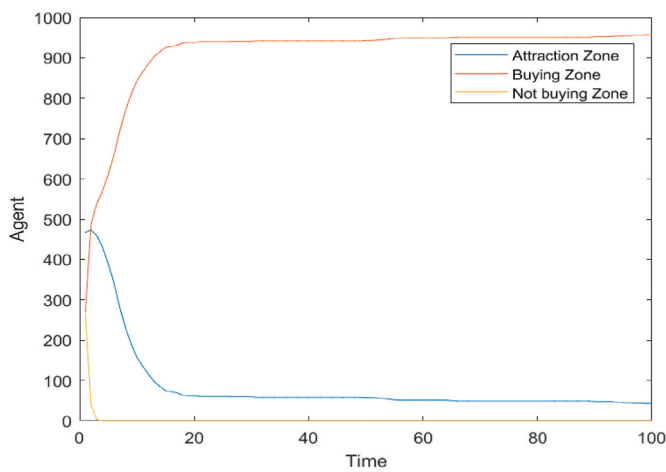


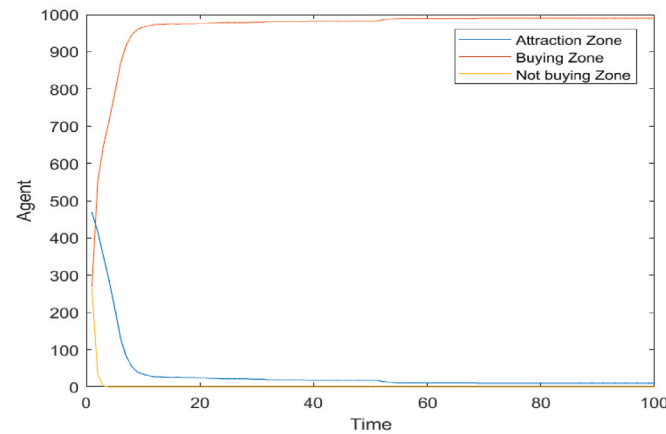
Fig. 8. The number of people in each zone over time under different individual panic perception.



(a)  $C_i \sim N(0.1, 0.15)$



(b)  $C_i \sim N(0.5, 0.15)$



(c)  $C_i \sim N(0.9, 0.15)$

**Fig. 9.** The number of people in each zone over time under different conformity levels.

from the presence or absence of government intervention. First, our study simulates the situation without government intervention, and then sets the external out-of-stock information intensity  $I_n$  as 0.2, 0.4, 0.5, 0.6, 0.8, respectively. The simulation results are shown in Fig. 10.

Fig. 10 shows the number of people in each zone over time under different intensities of epidemic information when there is no government intervention. It can be seen from Fig. 10 that as the intensity of information on the epidemic continues to increase, the scale of people participating in panic buying has also enlarged, but it has not enlarged at a constant rate. In addition, people who do not participate in buying under different epidemic information intensities all disappear at Time = 4. From Fig. 10(a)–(b), it can be seen that when  $I_n$  increases from 0.2 to 0.4, the number of panic buyers increases by about 40, and the final buying scale is also smaller. At this time, the management is less difficult and the social harm is relatively weak. From Fig. 10(b)–(d), it can be seen that with the increase of  $I_n$ , the number of panic buyers increases significantly. When  $I_n$  increases from 0.4 to 0.6, the number of panic buyers increases by more than 100 for every 0.1 increase of  $I_n$ . It can be seen from Fig. 10(d)–(e) that when  $I_n$  increases from 0.6 to 0.8, the growth rate of the number of panic buyers becomes smaller, increasing by about 50. Overall, with the increase in the information intensity about the epidemic, the growth rate of panic buying goes up first and then goes down. The reason is that in the early stage of the epidemic, the public’s perception of external dangers is weak, and the enthusiasm for buying is low, thus the scale of buying is small. With the continuous development of the epidemic, the public’s sense of crisis has risen sharply, and the desire to buy is strong, thus the number of buyers is rapidly increasing. When the number of panic buyers increases to a certain extent, the group is close to saturation, and its growth rate decreases.

In addition, after major public health incidents, government intervention (Prentice et al., 2020) has played an extremely important role in alleviating people’s anxiety and reducing their motivation to buy. Among them, the time of intervention has a crucial impact on the effect of intervention. Therefore, the following analysis of the influence of government intervention on the emergence of panic buying behavior at different time will help the government explore the best time for the good intervention effect. From Fig. 10, when there is no government intervention, the panic buying scale of the group is basically stable around Time = 20. At this time, the slope of the corresponding curve of the Attraction Zone at each time is close to 0, i.e. the growth rate of the number of people in the Buying Zone is close to 0, and thereafter the scale of panic buying basically remains the same. When Time = 4, the group who does not participate in panic buying disappears. Therefore, using Time = 4 and 20 as anchor points, our simulation sets the intervention time points as 3, 10, 15, 20, 25 to observe the changes in the panic buying scale. Then, our study sets the intensity of external epidemic information before the intervention to 0.8, and the simulation results are shown in Fig. 11.

Fig. 11 shows the number of panic buyers before and after the intervention at different intervention time points. It can be seen from Fig. 11 that if the intervention takes place before Time = 20, the earlier the intervention time is, the smaller the panic buying scale will be. If the intervention takes place after Time = 20, the panic buying scale will no longer change and remain at a higher level. The difference is very small, and the intervention effect is not obvious. This shows that the sooner the government intervenes, the better intervention effect will be. It is best to intervene before panic buyers disappear since there are still fully rational individuals in the group. However, the intervention has little effect after the population growth rate in the buying zone that tends to zero.

4.2.3. The influence of combined factors on the emergence of panic buying behavior

Through the above analysis, the factors that affect the emergence of panic buying behavior include individual panic perception, individual conformity degree and epidemic information intensity. A single factor has a relatively simple influence on the emergence of group panic buying behavior. In reality, there are often multiple factors that work together. In order to simulate the emergence of group panic buying

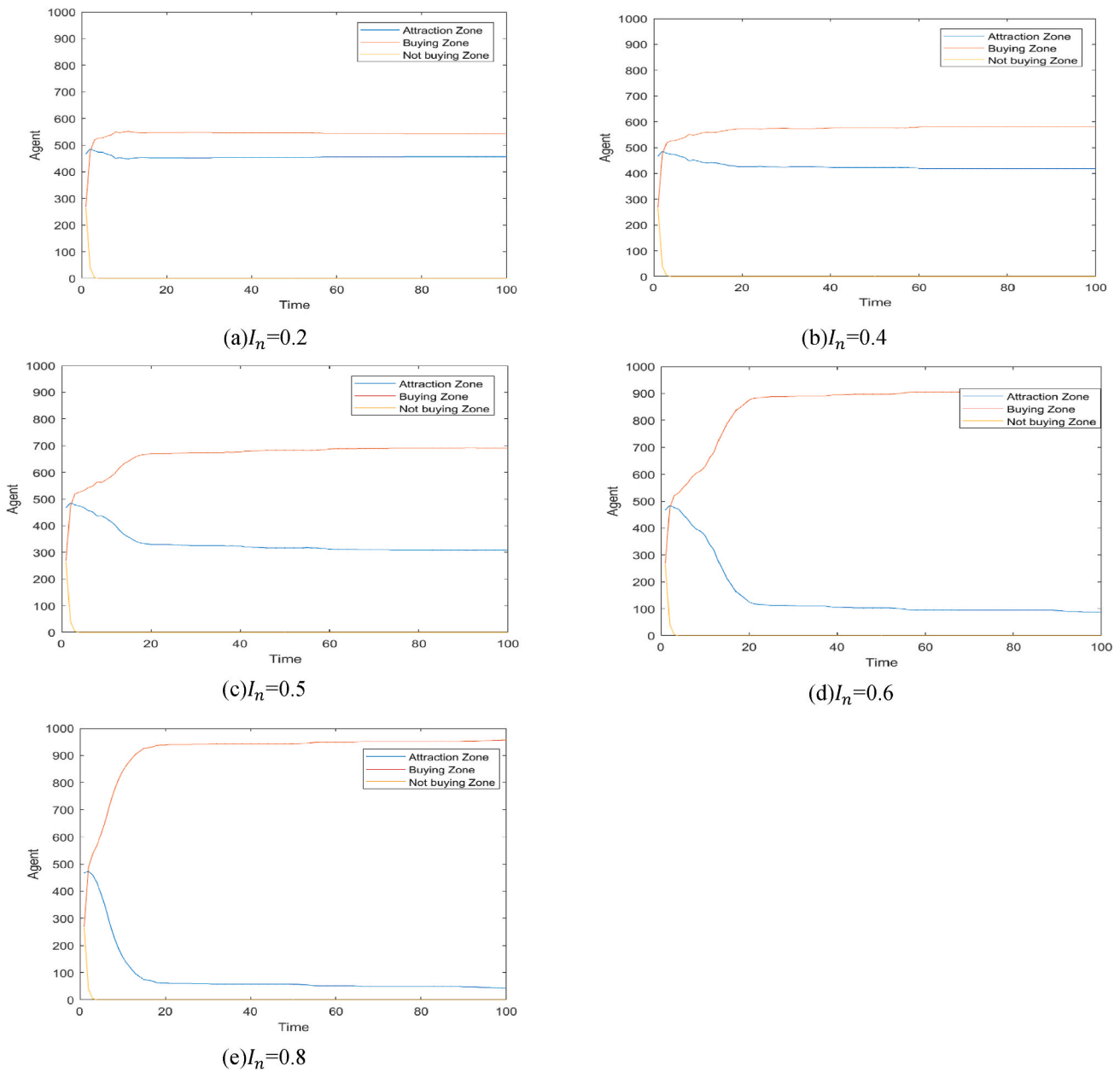


Fig. 10. The number of people in each zone over time under different intensities of epidemic information when there is no government intervention.

behavior, the influence of the combination of factors on the emergence of panic buying behavior is analyzed. Therefore, this section analyzes the combination of various factors that affect panic buying behavior to find out the key factors that affect the emergence of panic buying behavior. Set these three variables to simulate at different levels and observe the changes in the panic buying scale. The simulation results are shown in Figs. 12–14.

Fig. 12 shows the number of panic buyers under different epidemic information intensity and individual conformity. It can be seen from Fig. 12 that the higher the individual conformity is, the greater the intensity of the epidemic information will be, and the more people will participate in the panic buying. However, when the information intensity of the epidemic is equal to 0.2, the number of panic buyers remains unchanged under different conformity degrees. When the information intensity of the epidemic is higher than 0.2, the number of panic buyers increases with the increment of individual conformity, indicating that the impact of individual conformity becomes apparent only when the intensity of the epidemic information is higher than a

certain level. Overall, the scale of panic buying is more affected by the intensity of the epidemic information.

Fig. 13 shows the number of panic buyers under different information intensity and individual panic perception. It can be seen from Fig. 13 that the greater intensity of the epidemic information represents the higher individual's panic perception and larger scale of panic buying. Under the same level of information intensity, the scale of panic buying increases with the increment of individual panic perception, but the increment is small and the change is not obvious. While at the same level of panic perception, the scale of panic buying increases with the intensity of the epidemic information obviously and the positive correlation is significant. It shows that the intensity of epidemic information has a greater impact on the emergence of panic buying behavior.

Fig. 14 shows the number of panic buyers under different individual panic perception and individual conformity. It can be seen from Fig. 14 that with the gradual increase of individual panic perception and individual conformity, the number of panic buyers has increased significantly. In addition, when the individual conformity degree is very low,

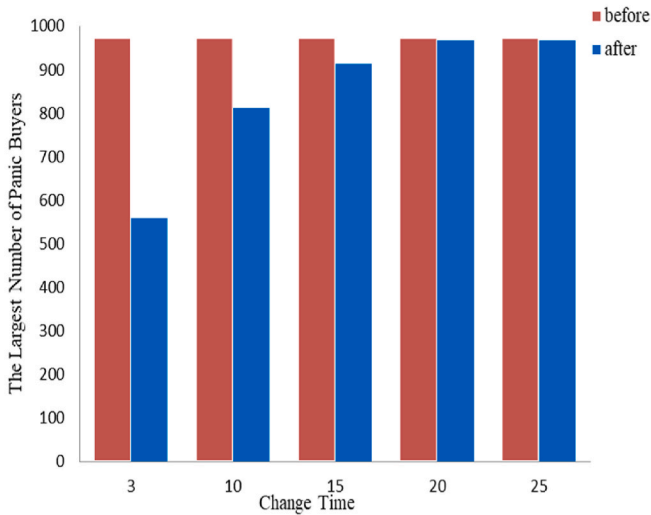


Fig. 11. The number of panic buyers before and after the intervention at different intervention time points.

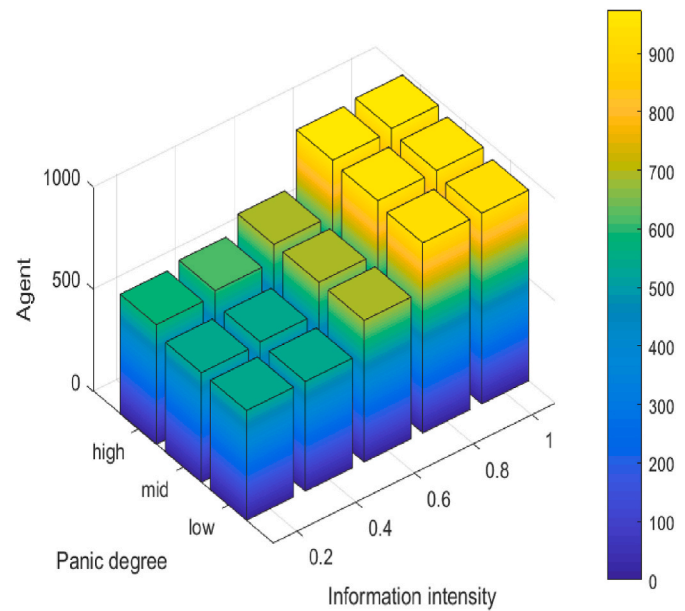


Fig. 13. The number of panic buyers under different information intensity and individual panic perception.

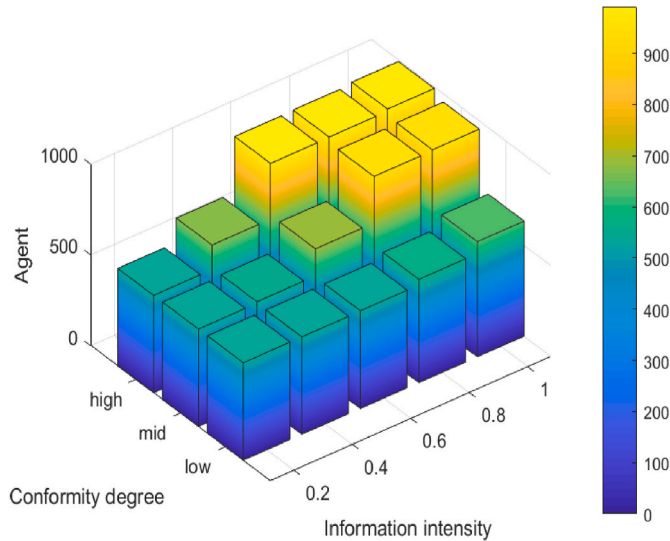


Fig. 12. The number of panic buyers under different epidemic information intensity and conformity.

no matter how much individual panic perception is, the number of panic buyers will not reach a very high level, at most around 560; while the number of panic buyers will increase significantly with the increment of the individual's conformity degree. Therefore, individual conformity degree has a more significant impact on the emergence of panic buying behavior.

In summary, the comprehensive simulation with the three variables that affect the emergence of panic buying behavior from a micro perspective shows that the intensity of epidemic information has the greatest impact on the emergence of panic buying behavior, followed by individual conformity, and then individual panic perception. From a macro perspective, the combined effect of internal emotions and external environment determines the individual's choices of panic buying behavior, which in turn affects the emergence of group panic buying behaviors. Therefore, analyzing the effect of environment and emotions on the emergence of panic buying behavior has important practical significance. Here set different levels of emotional and environmental impact values, and compare the changes in the scale of group panic buying. The simulation results are shown in Fig. 15.

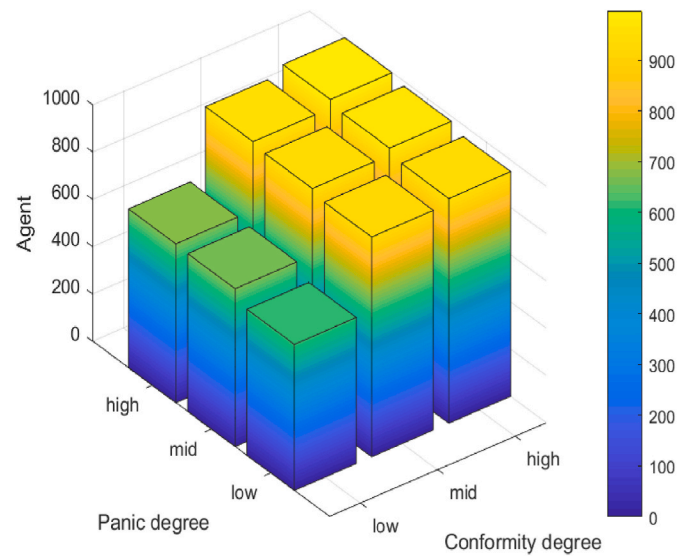


Fig. 14. The number of panic buyers under different individual panic perception and individual conformity.

Fig. 15 shows the number of panic buyers under different individual emotions and surrounding effect. It can be seen from Fig. 15 that, on the whole, the number of panic buyers increases with the increment of emotion effect and surrounding effect. The difference is that with the increase of emotion value, the increment of the number of panic buyers is smaller. However, the number of panic buyers increases obviously with the increment of the surrounding effect. Therefore, surrounding effect has a greater impact on the emergence of panic buying behavior, that is, external attractiveness has a more significant impact on panic buying behavior. It can be seen that when a public health incident occurs, policy intervention by relevant departments is more effective in mitigating the adverse effects of disasters than expert psychological counseling.

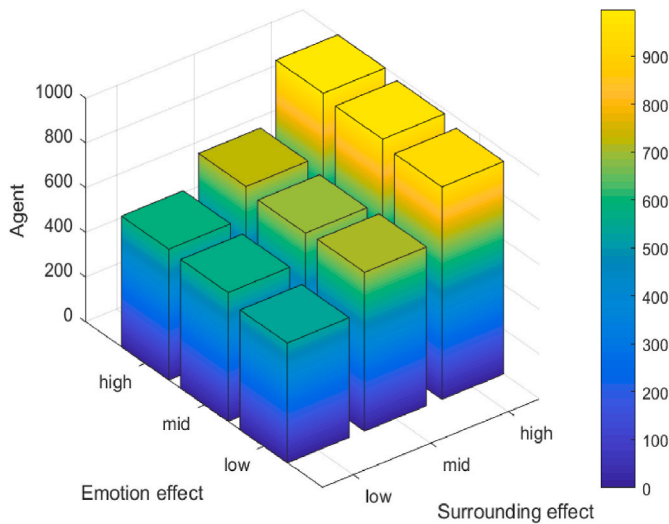


Fig. 15. The number of panic buyers under different individual emotions and surrounding effect.

4.2.4. The influence of interacted numbers on the emergence of panic buying behavior

Generally, individuals tend to listen to their friends and follow their actions while making decisions (Frank and Schvaneveldt, 2016). In this process, in addition to the influence of conformity, individuals may also be affected by the number of friends around them. Generally, the larger individual's social circle indicates more opportunities they have to interact with other individuals, and greater probability of being affected by negative emotions, which directly affects the individual's panic buying enthusiasm. Therefore, by changing the number of people interacting with individuals, this paper explores its relationship with the emergence of panic buying behavior. Firstly, BA scale-free networks with different number of edges are set up, and then the changes of panic buying behavior under different number of edges are simulated. BA scale-free network is based on the network generated by growth mechanism and priority connection mechanism. By changing the increased number of edges  $m$  each time, such network is able to explore the impact of the number of interactions on the emergence of panic buying behavior.

Fig. 16 shows the BA scale-free network diagram under different numbers of edges. Due to the large number of nodes and complex relationships in the real network, only the connection relationships between 100 individuals are displayed here for visualization. In Fig. 16, the red dot indicates the individual, and the edge of the connecting dot indicates that there is a connection relationship between individuals, and thus viewpoint interaction can occur. The blue line indicates new contacts. Generally, more connected sides indicate that the scale of interaction among individuals is larger, the speed of information spread

is faster, and the promotion effect on the emergence of panic buying behavior is more obvious. In order to verify the authenticity and promotion effect of the promotion effect, the emergence process of panic buying behavior under different number of edges is simulated, and the results are shown in Fig. 17.

Fig. 17 shows the number of buyers over time under different number of edges. As can be seen from Fig. 17, the number of node connections has a significant impact on the emergence of panic buying behavior. With the increase of the number of node connections, the final group buying scale also enlarges gradually, and the time required to achieve stability gradually shortens. When  $m = 1$  and Time = 60, the population is completely stable. When  $m = 3$  and Time = 30, the population reaches completely stable status. When  $m = 6$  and Time = 18, the population size is completely stable. This is because: on the one hand, when the number of node connections is large, panic spreads quickly and widely, and there are many affected individuals, so there are more individuals participating in panic buying; On the other hand, the more nodes are connected, the fewer isolated individuals exist in the network, and the connections between nodes are closer. Individuals can unify their opinions in a short time. Therefore, the time required for the group to achieve stability is relatively short.

4.2.5. The influence of network structure on the emergence of panic buying behavior

Because the real network structure is extremely complex, it is difficult to reproduce the real scene by using a certain network. Therefore, in order to more scientifically analyze the impact of network topology on the emergence of group buying behavior, this section simulates the

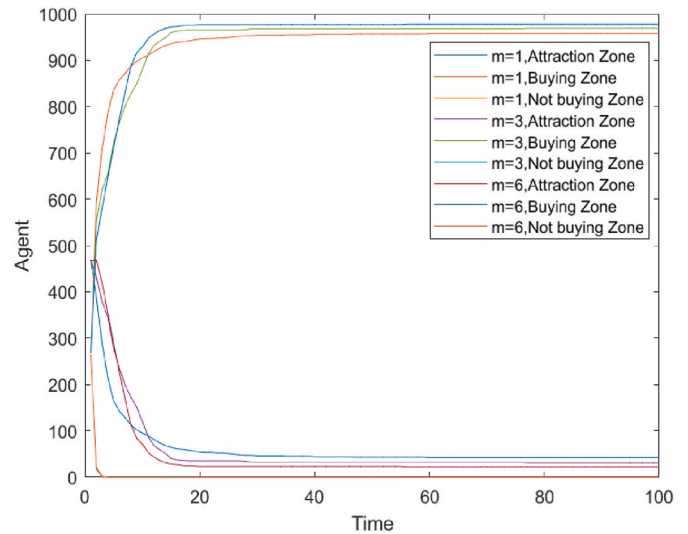


Fig. 17. The number of buyers over time under different number of edges.

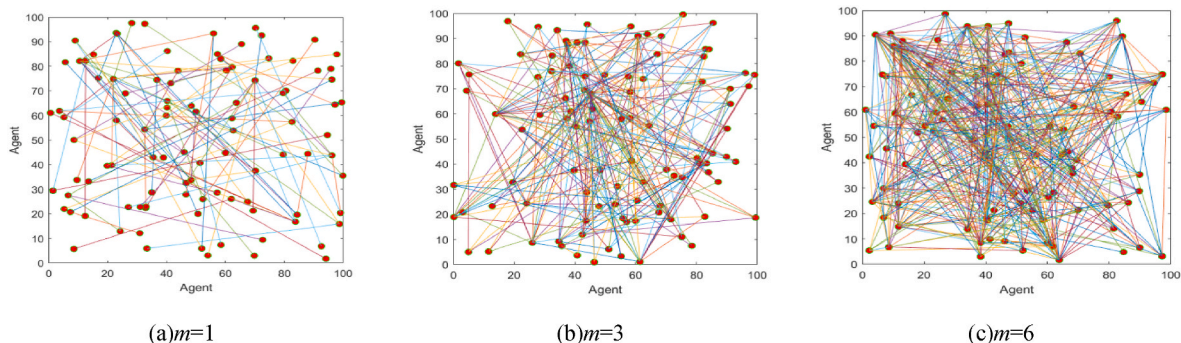


Fig. 16. BA scale-free network diagram under different number of edges.

impact of BA scale free network, WS small world network, ER random network and fully connected network on group buying behavior. According to the above analysis, the epidemic information intensity has the most significant impact on panic buying behavior, and it can reflect the changes of the external environment. Therefore, this section mainly discusses whether the impact of network structure on the emergence of panic buying behavior is different under diverse epidemic information intensity. For more intuitive observation, the epidemic information intensity is set to a higher level  $I_n = 0.8$  and lower level  $I_n = 0.2$ , individual panic perception and conformity are at a medium level, distributed around 0.5. Our study conducts simulation respectively to observe the number of panic buyers. The parameters of different network structures are shown in Table 4, and the simulation results are shown in Fig. 18.

Fig. 18 shows the number of panic buyers over time under different network structures and epidemic information intensities. As can be seen from Fig. 18, the network structure has a significant impact on the emergence of panic buying behavior. Under the same epidemic information intensity, BA network and ER random network have an obvious inhibitory effect on the emergence of group panic buying behavior, the scale of panic buying is small, and can accurately reflect the impact of epidemic changes. Compared with the number of panic buyers under BA network, the number of panic buyers under other network structures has changed to different degrees. The evolution trend of ER network under different information intensity is not far from that of BA network, and their panic buying scale is at a low level when the epidemic information intensity is small. In the fully connected network, the scale of group panic buying under different information intensity is large, and the gap is not obvious. The reason is that there are few isolated nodes in the network, the nodes are closely connected, deeply affected by the emotions of individuals, and weakly affected by the external environment, which cannot accurately reflect the impact of changes in external factors on panic buying behavior. WS network can reflect the impact of the change of epidemic information on the emergence of panic buying behavior to a certain extent, but the effect is worse than BA network. Overall, when the external information changes, panic buying behavior has emerged on different scales in the four network structures, which shows that the network structure will have a certain impact on the group buying behavior.

### 5. Empirical analysis

This section selects the panic buying of rice, noodles, grain and oil in Shijiazhuang, Hebei Province, caused by the rebound of the epidemic in January 2021, to verify the model built in this paper.

Since the outbreak of the COVID-19 epidemic, through the efforts of all parties to prevent and control the epidemic, initial results have been achieved in epidemic control, and various localities have begun to resume normal social and economic activities in an organized manner. However, on January 3, 2021, Shijiazhuang, Hebei, reported new local cases and 12 cases of asymptomatic infection for the first time. The Secretary of Shijiazhuang Municipal Party Committee emphasized that Shijiazhuang would quickly enter a wartime state to deal with the epidemic, and people began to concentrate on purchasing supplies. On January 6, relevant departments issued a notice on the prevention and

**Table 4**  
Topology parameters of different network.

Name	Average Path Length	Clustering Coefficient	Average Degree
BA scale free network	2.6405	0.0305	19.3
ER random network	2.3088	0.0179	20.113
Fully connected network	1	1	799
WS small world network	2.6405	0.3511	25

control of the epidemic and notified the initial implementation of the “city closure”. At this time, people rushed to supermarkets to buy daily necessities such as rice, noodles, grain and oil, and the enthusiasm for buying was high. Starting from January 8th, with official release of relevant news about the availability of materials through Shijiazhuang Daily, and the fact that the price of storage-resistant vegetables stopped rising, public’s enthusiasm for panic buying reduced.

In order to analyze the whole development process of the incident of “the residents of Shijiazhuang, Hebei Province participate in panic buying for rice, flour, grain and oil”, according to the actual development trend of the epidemic, the whole event is divided into three stages. The first stage was the initial period of the epidemic rebound: from January 3, 2021 to January 5, 2021, during this stage, people’s enthusiasm for buying was increasing. The stage was the large-scale outbreak period of the epidemic: from January 6, 2021 to January 7, 2021, people were enthusiastic about buying at this stage very much. The third stage was the period when the epidemic subsides after the release of the positive news that “relevant materials are sufficient”: i.e. from January 8, 2021 to January 9, 2021, people’s enthusiasm for panic buying gradually declined at this stage.

Focused on the incident of “residents in Shijiazhuang, Hebei panic buying for rice, noodles, grain and oil”, the 14669 Weibo comment data of relevant panic buying news in Shijiazhuang at Hebei was crawled in the corresponding time period. The form of crawling fields is shown in Fig. 19.

After cleaning the crawled comment data and removing invalid comments with incomplete meaning and irrelevant to the topic, a total of 12,610 Weibo comments were screened out. According to the six-degree separation theory in interpersonal relationships, the statistical results of these data can reflect the general applicability of user behavior to a large extent. Then perform emotion analysis on the cleaned data, adopt the Chinese emotion dictionary on Zhinet and the stopped words of Harbin Institute of Technology, make appropriate adjustments in conjunction with the crawled content, and add vocabulary with implicit negative attitudes similar to “buy” into the negative emotion dictionary. Use emotion analysis tools such as JIEBA word segmentation to perform emotion analysis based on Python, and obtain the emotion value of each comment through quantitative scoring. The emotional scores of the three stages of preliminary analysis are shown in Fig. 20.

According to the emotion analysis results of the three stages, from the initial period to the outbreak period, people’s positive and negative emotion scores decreased, and the total emotion score decreased significantly with the decrement from 0 to -0.5. It shows that on the whole, people are greatly hit by the epidemic and have serious negative emotions. However, the government intervention and the release of news with sufficient materials thereafter have played a certain role, making people’s negative emotions eased and the total emotional score increased.

The analysis of the external environment here is mainly to measure the impact of epidemic information intensity on group panic buying behavior, so it is necessary to quantify the epidemic information intensity within the time of panic buying in the case. Since the browsing data of Weibo topics is the cumulative value that changes continuously from the date of topic release, only the daily data change within one month can be obtained, and some data earlier than one month cannot be obtained. In order to reflect its change trend more accurately, Baidu, which is equivalent to the number of Weibo users, is selected to obtain daily data. As of December 2020, the number of monthly active users of Baidu and Weibo has reached 544 million and 521 million, respectively. It is persuasive to use Baidu Index to reflect information changes. At the same time, Baidu Index integrates the search data of PC and mobile terminals, which is more comprehensive and objective. Take # Shijiazhuang epidemic situation # as the topic to search and obtain Baidu index data, as shown in Fig. 21.

In addition to the search trend of related topics in the Baidu Index as an indicator to reflect the intensity of epidemic information, the number

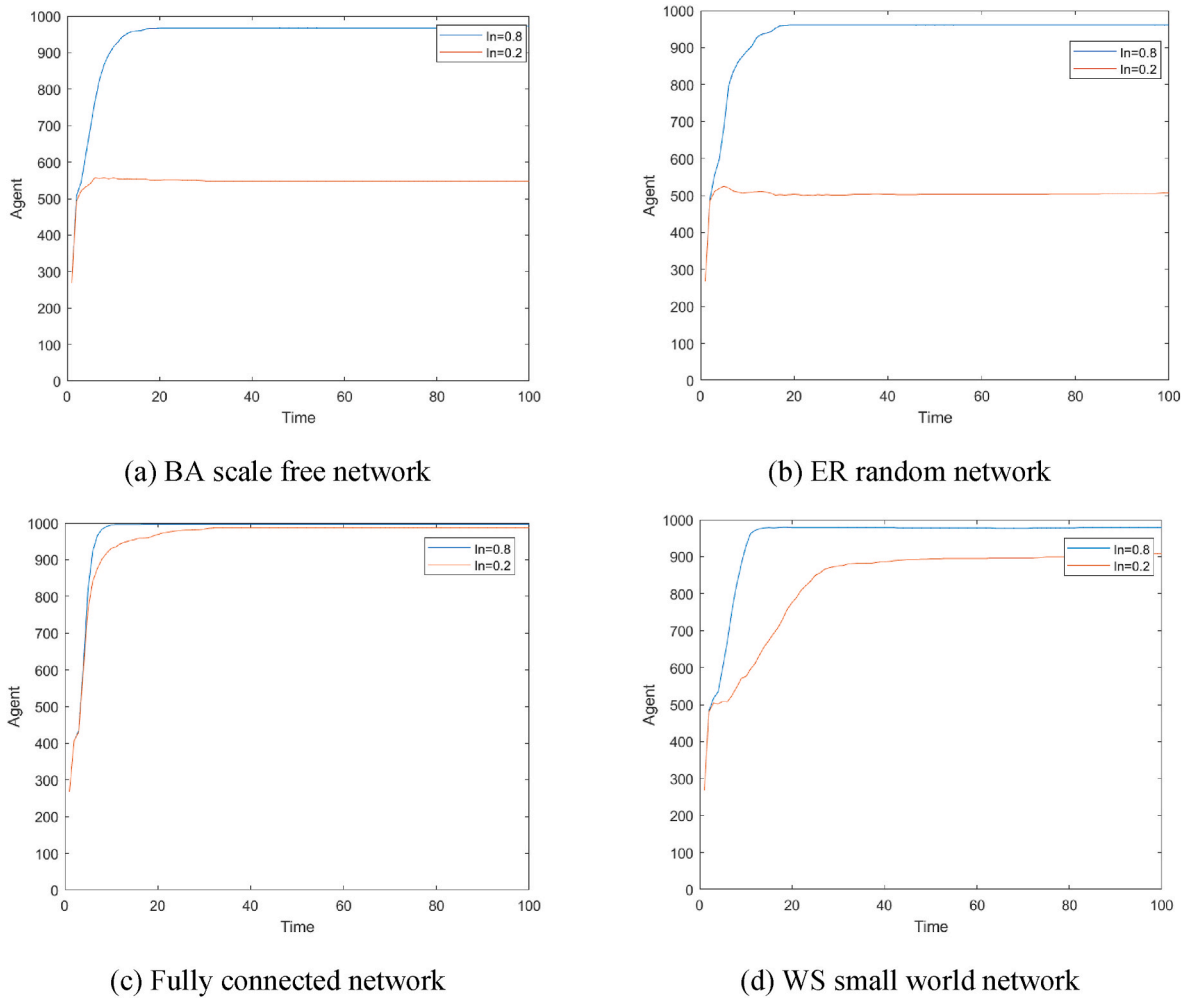


Fig. 18. The number of panic buyers over time under different network structure and epidemic information intensity.

A	B	C	D	E	F	G	H
Microblog publisher	Microblog publisher link	Release time	Publish content	Publishing device	Forwarding number	Number of comment	Number of likes
1							
2	About Shiji	https://weibo.com/17CJanuary 9th	Can you go shopping now? 2 Shijiazhuang, can you	Things arom21	123	5145	
3	Sugar free	https://weibo.com/517January 9th	Today's third nucleic acid test, the things order	iPhone clien	1		
4	S. S of S	https://weibo.com/115January 9th	#Shijiazhuang shopping # Carrefour can place orde	Phone clien		1	
5	Bart can't	https://weibo.com/66CJanuary 9th	We can't say we have everything, we can also say vivo X30 Pro				
6	User 70503	https://weibo.com/70CJanuary 9th	Where to buy vegetables! I'm willing to pay threeMillet flag			1	
7	East uncle	https://weibo.com/634January 9th	#Shijiazhuang epidemic ## Shijiazhuang buy # thisVivo 26 5g 1		1		
8	Drunken 22	https://weibo.com/60CJanuary 9th	I saw the online store open at more than four o'clockovaipro you				
9	Zhang Meng	https://weibo.com/194January 9th	This is what a person in his 20s should look likeiPhone 11 Pro		42	11	
10	Uncle's thi	https://weibo.com/75CJanuary 9th	I bought a lot of vegetables, eggs, fruits and snDoggy's iPho		15	3	
11	A sweet a	https://weibo.com/54CJanuary 9th	Be sure to select goods in advance, add them to tiPhone clien		3	9	
12	October - S	https://weibo.com/574January 9th	I bought a dish today, 65 a set meal! Some peopleGlory V9 1 i		8	3	
13	Two Dongd	https://weibo.com/57CJanuary 9th	Why can't I place an order	Glory 30 Pro	5	1	
14	Yan Zheng	https://weibo.com/17CJanuary 9th	Online sales is like make news. Tmall supermarketMicroblog In2		4	17	
15	Wx policy	https://weibo.com/52CJanuary 9th	Late night shopping 2 Shijiazhuang	Millet 6 mal	33	5	
16	Make progr	https://weibo.com/215January 9th	After the closure of the city, I can't get out atMicroblog In3		6	45	
17	_Renew	https://weibo.com/191January 9th	Report to you: the news is completely opposite toIqoo neo3 i:18		198	697	
18	Fifteen he	https://weibo.com/52CJanuary 9th	Is there a vegetable group near dongsanzhuang, XiiPhone clien		4	1	
19	Ren Ye 945	https://weibo.com/58CJanuary 9th	Is there anything you can buy near Chengjiao streiPhone clien		14	3	
20	Rouze kou	https://weibo.com/35CJanuary 9th	Wow, there are only two baby dishes, two taros anGlory 10 AI		4		

Fig. 19. #Panic buying in Hebei# Weibo comments.

of newly diagnosed people each day can also reflect the changes in the epidemic, which can be used as another indicator to measure the epidemic information intensity. Our study integrates the two indicators to calculate the intensity in the three stages, and summarizes the calculation results in Table 5.

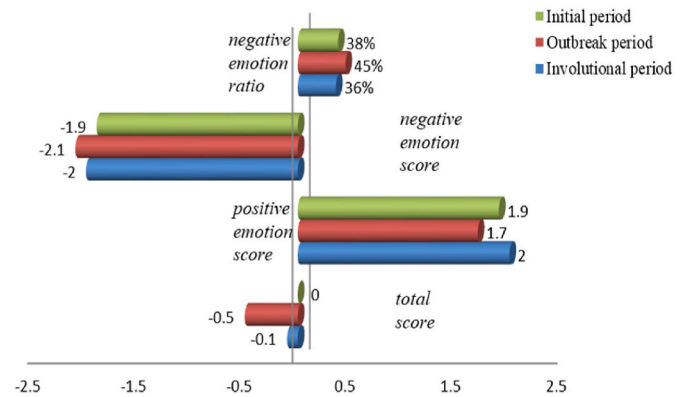


Fig. 20. Emotion analysis.

The data of daily related topic search from Baidu index was obtained as shown in the (Baidu index) column. Due to the huge amount of data, direct analysis is more complicated. Therefore, the data is simply processed to map it to the range of [0,1]. Here, set the information intensity of the highest search volume in a single day 310981 to 1, calculate the daily information intensity, and then calculate the weighted average of the information intensity of the corresponding period. The calculation results are shown in the column named Information intensity 1 in Table 4. Our research conducts the same method for the number of



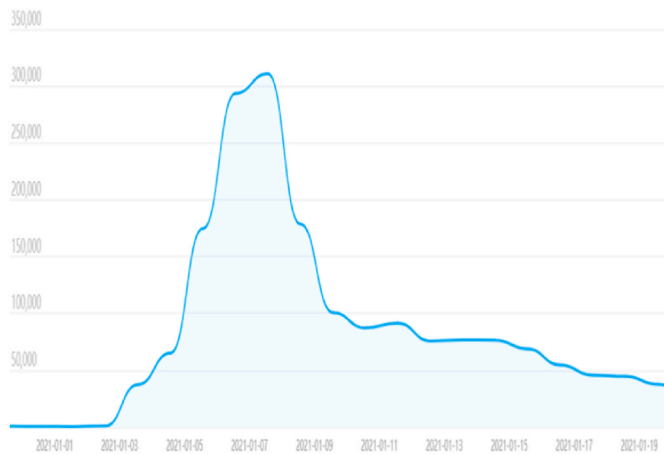


Fig. 21. # Shijiazhuang epidemic situation # Baidu index.

newly diagnosed people in another indicator, sets the information intensity of the maximum number of newly-increased people of 50 in a single day to 1, and calculates it as shown in the column named Information intensity 2 in Table 4.

Finally, the average information intensity is calculated as the epidemic information intensity in the corresponding period by integrating the information intensity 1 and information intensity 2 obtained by Baidu search index and the number of newly diagnosed people.

According to the model in this paper, this case is simulated. Due to the large amount of case data and comprehensive visualization consideration, the network scale is set to 1000. It is set that the panic buying is caused by the change of external epidemic information, so the epidemic information intensity in the initial period is set according to the above calculation results of epidemic information intensity of actual cases  $I_n = 0.255$ , epidemic information intensity in outbreak period  $I_n = 0.891$ , epidemic information intensity in involtional period  $I_n = 0.515$ . In addition, negative emotions can reflect the degree of panic perception to a certain extent. The higher the proportion of negative emotions is, the deeper the degree of panic perception will be. According to the results of emotion analysis, the panic perception  $E_i(t)$  in the initial stage obeys  $N(0.38, 0.15)$ ,  $E_i(t)$  in the outbreak stage obeys  $N(0.45, 0.15)$ , and  $E_i(t)$  in the recession stage obeys  $N(0.36, 0.15)$ . Other parameters are set as follows: individual conformity  $C_i$  obeys  $N(0.5, 0.15)$  and maps to  $[0, 1]$ , indicating that most individuals have moderate conformity; The influence coefficient of purchase motivation is  $k_1 = 0.6$ , the influence coefficient of tolerance is  $k_2 = 0.4$ . It indicates that it has a keen response to changes in the external epidemic situation.  $\mu_1 = 0.2$ ,  $\mu_2 = 0.2$ ,  $d_1 = 0.3$ ,  $d_2 = 0.8$ ,  $S_{part} = 0.2$ ,  $S_{full} = 0.4$ ,  $P_{part} = 0.4$ ,  $P_{full} = 0.6$ ,  $k_3 = 0.8$ . The interaction time is time = 100 and the simulation results are shown in Fig. 22.

It can be seen from Fig. 22 that in the initial period, people's negative emotions were low and their panic buying enthusiasm was not high. When the group reached stability, the maximum panic buying scale was about 550. With the development of epidemic situation in the outside world, the emergence of panic buying news, and the interaction between

individuals, the scale of participating in panic buying has gradually become larger. In the outbreak stage, the number of people involved in panic buying is close to 1000. In the recession stage, the government took intervention measures and released news with sufficient materials, which alleviated the panic and anxiety of the people. Some individuals were able to make rational judgments, and the number of people involved in panic buying decreased significantly, which was still more than in the initial period. This shows that the government intervention measures have played a role. If the intervention intensity is appropriately increased, it may achieve better dredging effect. By analyzing the phenomenon of panic buying in three different stages, it is found that the number of panic buying in each stage is basically consistent with the development trend of the epidemic situation. This shows that the emergence model of group buying behavior proposed in this paper can better simulate the real buying events, and has a certain practical significance.

## 6. Discussions and implications

This study explores the formation and influencing factors of group panic buying behavior. In this section, we mainly discuss the theoretical significance and management contributions of this study.

### 6.1. Theoretical contributions

This paper makes some theoretical contributions to the study of panic buying. According to our observation, in previous studies, many scholars conducted analysis with psychological factors for panic buying behavior, and some of them discussed the impact of social media on panic buying separately, but there was short of quantitative analysis of panic buying by combining social media and psychological factors. In addition to taking psychological factors into account, this study also

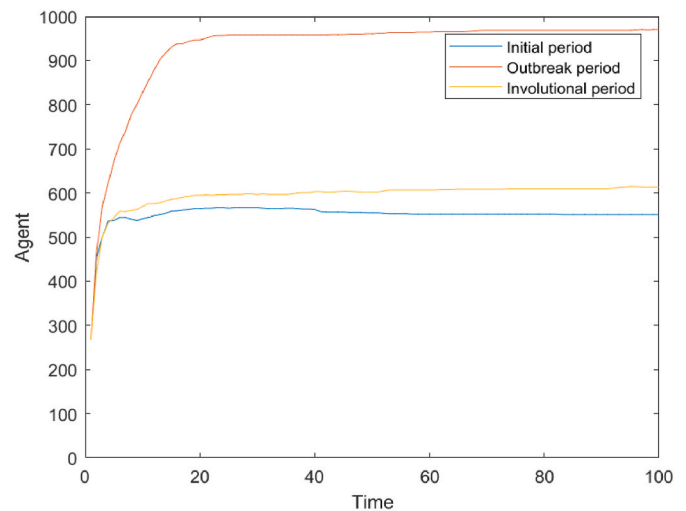


Fig. 22. The number of panic buyers in different periods over time.

Table 5  
Epidemic information intensity.

Period	Time	Baidu index	Conversion results	Information intensity 1	Daily Cases	Conversion results	Information intensity 2	Average information intensity
Initial period	1.3	37470	0.120	0.298	2	0.04	0.213	0.255
	1.4	65264	0.210		11	0.22		
	1.5	174821	0.562		19	0.38		
Outbreak period	1.6	293476	0.944	0.972	50	1	0.81	0.891
	1.7	310981	1		31	0.62		
Involtional period	1.8	178718	0.575	0.449	14	0.28	0.58	0.515
	1.9	100709	0.324		44	0.88		

consider the impact of external environment, including online and offline communications, on the spread of rush buying behavior. Some studies have shown that excessive use of social media (Lee et al., 2012) will affect consumer behavior. Therefore, in theory, the research results obtained from the online and offline two-tier communication model are more consistent with the actual situation.

In addition, this study combines the concept of mechanics into the model, and proposes to quantify the internal driving force and external attraction that affect individual rush purchase decision. They jointly determine the individual's final behavior and the blessing of physics, making this research innovative and more scientific.

Finally, we use the idea of cluster dynamics to simulate the formation of group panic buying behavior. At present, this method is mostly used to study the motion unity of fish, pigeons and micro particles. Few have applied it to the field of group panic buying. Therefore, this is a new originality of our study.

## 6.2. Managerial implications

This study has a certain impact on decision makers, government administration, and managers in non-governmental organizations. First, our study finds that the positive correlation between the external epidemic information and the group buying scale is very strong, but not linear. When the information intensity is low, the group buying scale changes little with the epidemic information intensity, but the information intensity exceeds a certain threshold, and the group forms rapidly and has a large scale. Therefore, in order to reduce the scale of panic buying groups, after the crisis, the government and the media should timely convey real positive information to the people, ensure sufficient materials and reduce the people's sense of panic. They should transmit positive information to the people's ears through multiple channels as much as possible. At the same time, they should pay attention to ensuring the consistency of information and do a good job in information monitoring at the same time, clarify the false information in time and respond to the demands of the people in time. When the epidemic fermentation scale is small, timely preparation can effectively reduce the impact of panic buying.

Second, the public panic caused by the epidemic is obviously different from other emergencies. In the face of such a major serious and unknown infectious disease, coupled with the opacity of information, the public panic develops rapidly at once, and the appeasement of people's emotions should be different from other emergencies. In addition to the timely disclosure of information, we should pay more attention to the appeasement of people after the crisis. It is essential to restore the state before the epidemic. More importantly, we should regain people's confidence in the government. The epidemic is a long term war. The government should timely track and "treat" the psychology of the people after the epidemic. When facing the crisis, the importance of commodities is obvious. Excessive hoarding may not only paralyze the market, but also make the people in real need unable to get timely assistance.

Third, panic buying behavior caused by novel coronavirus pneumonia has a close relationship with public psychology. During the epidemic period, the phenomenon of mass buying still occurred when there was no sign that panic buying would result in material shortage. This is because the herd mentality of the public is causing trouble. When they see articles on the hoarding of various materials in the circle of friends and images of empty store shelves, they will have a sense of crisis and think that they can't live without hoarding. Participate in rush buying under the "suggestions" of relatives and friends and hoard a large number of goods. Even some businesses will make the decision to raise prices at this time. The concept that scarcity is expensive also helps them make the decision to hoard. In addition to government intervention, the management of this phenomenon needs the consciousness of businesses and the consciousness of the people.

## 7. Conclusions

In order to reveal the mechanism of the emergence of group buying behavior, this paper analyzes the internal driving force and external attraction of individuals, constructs the emergence model of group buying behaviors online and offline, and simulates and analyzes the effects of individual panic perception, individual conformity, epidemic information intensity, interaction number and network structure on the emergence process of group buying behavior. Finally, the effectiveness of the model is verified by an actual case.

The following conclusions are obtained through simulation experiments:

- (1) The intensity of epidemic information has the most significant impact on the emergence of group rush buying behavior. This is consistent with the findings of Arafat et al. (2020). In addition, we also find that the scale of mass rush buying increases with the increase of epidemic information intensity; also, the growth rate of the number of group buying first increased and then decreased with the enhancement of the epidemic information intensity. This finding is of great significance for the government to select the intervention time point. At the same time, we find that herd mentality and panic have great impacts on the emergence of group rush buying behavior. Jia et al. (2021) and Mary et al. (2020) have also studied this aspect, but they are different from this research method, and their research is mostly aimed at phenomena, pay attention to results, and do not consider the formation process of groups.
- (2) Government intervention plays a significant role in reducing the scale of group buying. Prentice et al. (2020) focused on the importance and timing of timed intervention. This study find that the intervention is effective before the group reached the maximum rush buying scale, especially before the non rush buying group disappears.
- (3) The emergence of group panic buying behavior is obviously affected by the external attraction and less affected by the internal driving force, indicating that the effect of government policy intervention is better than that of expert psychological counseling. This is mainly because sudden public crisis events have the characteristics of rapidity, urgency and severity, and the effect of psychological counseling (Jun, 2004) has no immediate effect. Arafat et al. (2021) also analyzed the intervention measures and found that media and materials were very important. Combined with this study, it is found that the best intervention is government intervention, supplemented by psychological intervention.

The current research investigated the formation and influencing factors of group panic buying behavior during COVID-19, which contributed to the analysis of panic buying behavior. However, it has to be said that this study has some limitations. Firstly, the formation mechanism of cluster panic buying behavior established in this paper is relatively simple, and the rules of group synchronization behavior are more complex and changeable. Future research can further refine the evolution rules of group synchronization and get more and more novel findings. Secondly, the offline communication mode in this paper does not consider the influence of regional culture and management level. The management level in different regions is different, and there are differences in the speed and ways of panic transmission. In the follow-up, we can carry out classified management from this point of view to observe the communication situation in different regions and the speed of group rush buying. Thirdly, the spread process of panic buying behavior caused by social public health events is actually a dynamic change process. With the continuous change of external epidemic information, the network nodes participating in rush buying will increase and retreat. Therefore, it is necessary to consider the increase and retreat

mechanism of nodes in the network to better reflect the phenomenon of group rush buying. This problem can be considered in more detail in future study and it can be realized by combining the knowledge of other disciplines.

#### Data availability statement

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

#### Declaration of competing interest

The authors declare no conflicts of interest.

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