Computational and Mathematical Organization Theory
https://doi.org/10.1007/s10588-024-09384-z

MANUSCRIPT

Human emergency behaviour and psychological stress characteristic mining based on large-scale emergencies

Yi Luo[1] · Xiaoping Yang[1] · Xiaoming Li[1] · Zhenzhen Chen[3] · Fangyuan Liu[2]

Accepted: 3 January 2024

Abstract

Human emergency behaviour and psychological stress response in emergencies are important scientific issues in basic emergency management research. The analysis of the dynamic characteristics of large-scale human behaviour based on electronic footprint data provides a new method for quantitative research on this problem. Previous studies usually assumed that human behaviors were randomly distributed in time, but few studies have studied the psychological stress response of human groups under the influence of emergencies and carried out prediction methods through social media data. Based on the data from five emergencies and daily events in the Qzone, this paper explores the statistical characteristics of human communication behaviors such as time, space and social interaction. The research results reveal the psychological evolution of human groups when they encounter public security emergencies by analysing the causes of individual psychological stress responses in the group. We find that the time interval between people's posting behaviour and interactive comment behaviour in mobile QQ space before and after an emergency can be approximately described by a power-law distribution. The time interval distribution of Posting and reply is an obvious heavy-tailed distribution. These behavioural characteristics are consistent with people's psychological stress characteristics. Individual psychological stress responses gradually evolve into social-psychological responses with changes in behavioural characteristics. The greater the social-psychological stress response is, the more panic the public will be, which will cause the outbreak of group irrational behaviour. The research results are theoretically helpful in understanding the impact of emergencies on human communication behaviour patterns and reveal the psychological stress process of mass panic in large-scale emergencies.

Keywords Emergency psychology · Behavioral psychology · Large-scale emergencies · Human emergency behaviour characteristics · Time series analysis · Data mining

Extended author information available on the last page of the article

Published online: 16 February 2024

1 Introduction

A series of human behaviors, such as communication, travel, shopping and socializing, are the direct or indirect driving forces of the typical complex system of human society. How to deeply understand the regularity and internal driving mechanism of human micro behaviour patterns at the macro level and then apply it to the control of the social system has been a wide concern in academic circles. At present, statistical physics methods in the context of big data make this idea possible. In 2009, Baraba's album on Complex Systems and Networks (Barabasi 2009), published in The journal Science, predicted complexity research in the next decade: "From mobile phones to GLOBAL positioning systems and the Internet, there is a rapid increase in the number of electronic devices we use every day to capture everything from our communications to our location. So the first complex system that we are most likely to quantify is probably not a cell or the Internet, but human society." At the same time, 15 internationally renowned scholars headed by Professor Lazer, including Baraba'sii, jointly published a paper entitled "SOCIAL SCIENCE: The Computational Social Science". Article (Lazer et al. 2009) marks the birth of an interdisciplinary field of data-driven computational sociology, which is based on statistical physics and focuses on the study of temporal and spatial dynamics of human behaviour, the characteristics and evolution of social networks, data access and privacy protection, and the cultivation of new academic mechanisms. Subsequently, Castellano et al. (2009), Conte et al. (2012), and Pentland (2014) also reviewed the research issues and methods in this field.

The dynamics of human behaviour, initiated by statistical physicists, have become a branch of computational sociology. It, as a new interdisciplinary research direction, mainly embarks on human behaviour by a large number of individual human behaviours and group behaviours in quantitative statistics, studies its performance in time, space, and social complexity reveals the hidden statistical regularity and explores the mechanism of these laws and the effects on social, economic, technological and ecological external systems. Prior to this, it was generally assumed that human behaviour occurred randomly in time and that the sequence of behaviours was approximately a Poisson process with an exponential distribution of intervals or waiting times. However, Baraba's research on the non-Poisson characteristics of the time distribution of human activities and interpretation work based on the priority queuing mechanism in 2005 (Barabási 2005) and Brockmann et al.'s quantitative research on the spatial scaling law of human movement in 2006 (Brockmann et al. 2006) were successively published in Nature. It has become a historical turning point in the temporal and spatial complexity analysis of human behaviour. The study of human behaviour dynamics has become a hotspot of complexity science research globally. More than 30 papers have been published in top international academic journals, such as Nature (Oliveira and Barabási 2005), Science (Malmgren et al. 2009a) and Proceedings of the National Academy of Sciences (Kenett and Portugali 2012). A series of representative related works have also been published in Physical Review Letters (Iribarren and Moro 2009), Europhysics Letters (Goh and Barabási 2008), Physical Review E (Girardin et al. 2008), New Journal of Physics (Do and

Gatica-Perez 2012) and other physics journals. Meanwhile, relevant research work has also been published in IEEE Pervasive Computing (Malmgren et al. 2009b), ACM UbiComp (Social Networks 2011), SIGKDD (Song et al. 2014), SIGSPATIAL GIS (Traag et al. 2011) and other international journals and conferences in the field of computers. It involves empirical analysis, theoretical modelling, and applying the time and space characteristics of human behavior.

The definition of emergencies is extensive, and the national response plan emergency is defined as emergencies that can cause extremely significant casualties and serious property damage, interfere with people's daily life order, destroy facilities, are bad for the environment and cause the functional disorder of natural or manufactured events. The cause and scope of influence can be divided into four categories: natural disasters, accident disasters, public health events, and social security events.

The public's perception of events is often reduced, as is their perception and judgment of events, leading to panic. When the public's needs cannot be met, there will be a psychological stress response, a physical instinct reaction, mainly manifested in psychological behaviour and physiological and emotional abnormalities. Due to the decline of individual cognition and judgment errors and the spread of rumours, the individual psychological stress response will gradually evolve into the social-psychological stress response. The greater the social-psychological stress response is, the more panic the public is likely to break out of group irrationality. However, there are few studies on the group psychological stress response process under sudden public crisis events, so it is particularly important to study the group psychological stress dynamic process under sudden public crisis events.

To quantitatively understand the dynamic process of group psychological stress, we are the first to integrate human behaviour characteristics into a group stress response, which is used to analyse human group psychology under large-scale emergencies. The main contributions of our work are as follows:

1. To analyse the influence of group behaviour rules behind large-scale emergencies on psychological stress, we achieved effective quantification of group psychology based on the group behaviour dynamics model.
2. To analyse psychological fluctuations under emergencies and establish a group behavioural stress model, the mechanism behind abnormal group psychological behaviours is studied from a microscopic perspective. On this basis, the psychological stress level under different interventions was studied. The paper is organized as follows: Sect. 2 discusses related work; Sect. 3 presents the proposed method; Sect. 4 presents the experimental results; and Sect. 5 concludes the paper.

2 Related work

With the widespread application of social media, human social behaviors can be perceived in real time, which provides a data basis for studying human behavior patterns under emergencies and makes it possible to analyse the impact of emergencies quantitatively. Many scholars have carried out exploratory research on

the quantitative analysis of the impact of emergencies based on research on the dynamics of human behaviour under normal conditions.

2.1 Research on the temporal and spatial characteristics of human communication behaviour

The time-domain model analysis of communication behaviour is used to study the statistical law of human communication behaviour over time. The main statistical indexes include interval time, waiting time, diversity analysis of time series features, array occurrence coefficient and memory coefficient, and array occurrence period division and statistics under different thresholds, such as event number distribution in array occurrence period, interval time during array occurrence period, and waiting time during array occurrence period.

Interval time or wait time analysis is important to study the internal regularity of the occurrence of events. After Barab'asi discovered non-Poisson statistical properties of human email communication behaviour (Barabási 2005), the same phenomenon has been found in many other empirical results of human communication behaviour. Most of the results show that it can be fitted by a power-law distribution (Kan et al. 2013) or exponentially truncated power-law distribution (Jiang et al. 2013) at the population level, but different empirical results are also presented in some literature. The fitted distribution functions include lognormal distribution (Stouffer et al. 2006) and complex three-segment power law (Chun et al. 2008). At the individual level, in addition to obeying the power-law distribution (Li et al. 2008), it also includes the power-law plus exponential two-segment distribution (Bza and Jw 2019), multisegment power-law distribution (Wang et al. 2011), Weibull distribution (Jiang et al. 2013), gamma distribution (Guo et al. 2011) and cascading Poisson process fitting (Anteneodo et al. 2010).

Based on the empirical analysis of the email data set, Barab'asi proposed the original task priority queue model (Barabási 2005) to explain most of the event processing process in daily human life, believing that tasks are limited by the deadline, and we need to arrange our work schedule according to the deadline and waiting time of tasks. The model assumes that human task execution strategies can be divided into three types: first-in, first-out, arbitrary execution, and highest priority execution. The simulation results confirm that the third strategy can generate task execution time series with power-law attenuation intervals. Subsequent scholars gradually improved the model, gave its exact solution and extended it (Gibbs 2014). Wu et al. used the model to reproduce the power-law plus exponential two-segment function characteristics of the probability distribution of the interval time of mobile phone SMS interaction (Bza and Jw 2019).

From the above empirical research results of human spatial movement behaviour, it can be seen that using social media data to study the spatial pattern of human behaviour is an effective means, which is of great significance in understanding the rules of human spatial movement.

2.2 Research on behaviour rules in emergencies

Researchers have also used many other types of social media data to conduct in-depth analyses of the impact of emergencies. Analysing the impact of Hurricane Sandy on social communication based on Flicker data (Preis et al. 2013) or Twitter data (Wang and Taylor 2014) and the impact of the Boston Marathon bombing on social communication based on Twitter data (Lin and Margolin 2014), data analysis using a variety of network media sports, a presidential election or large storms and other mass incidents caused by the impact on social communication (Szell et al. 2014), using GPS data analysis of the nuclear accident impact on personnel emergency evacuation behaviour (Pentland 2014) 36, use of flight 911, volcanic eruption events such as data analysis of the impact of human movement mode (Woolley-Meza et al. 2013), etc. In terms of emergency detection, Candia et al. studied the spatiotemporal regularity of group communication behaviour by using the communication data of 6 million mobile phone users in a European country for one month and provided a quantitative method for the activity and volatility of call volume, which has potential application value in emergency detection (CandiaJ, et al. 2008). Altshuler et al. proposed a method to detect emergencies based on social network data (Altshuler et al. 2013). Based on simulation experiments, various types of emergency information given by Bagrow et al. (Bagrow et al. 2011) were used to verify the entire network. Traag et al. analysed the movement track information formed by approximately 900 million SMS messages and call records of 5.75 million mobile phone users in a European country over 14 months. The detection and participant identification method of social group gathering events based on the Bayesian location reasoning framework is presented (Traag et al. 2011). Baker et al. analysed mobile phone users' three-month travel trajectory data in Los Angeles, San Francisco, and New York. They gave the results of regional participation in a mass event, etc., pointing out that mobile phone data have broad application prospects in mobile computing, urban planning, social-ecological analysis and epidemic transmission (Becker et al. 2013).

2.3 Research on stress in emergencies

Selye (1956) believed that stress refers to a biological reaction phenomenon of human or animal organisms to environmental stimuli, which can be caused by many different demands imposed on the body and is nonspecific. Peleg et al. (2002) found significant differences in psychological stress responses between on-site rescue workers and disaster victims after disaster events. Clauw et al. (2003) showed that irrational emotions appear in early public psychological stress responses, with anxiety, hypochondria and panic being the most common. Scientific prevention and effective response. Ariane Keitel (2011) tested people's physiological and psychological changes in an emergency state by setting emergency scenes. The research results confirmed that people's physiological and psychological parameters in an emergency state would change differently, resulting in anxiety and fear. AHBro

(2015) used a computer to simulate the influence of social support on people's emotions in the agent model and found that social support can relieve emotional pressure and that different types of social support have different effects on different types of people. It can be found from the above studies that qualitative analysis methods are mostly used in the study of group psychological behaviours in emergencies, which are dominated by negative emotions such as fear, anxiety and blind obedience, and lack quantitative analysis.

Generally, the research method of psychological stress is mainly empirical research to find the factors related to stress, but there is a lack of visual analysis of the specific process of psychological stress, and there are still many gaps and deficiencies in the research in this field at home and abroad. Group behaviour dynamics can effectively study group psychological stress responses and analyse the specific process of group psychological stress under public crisis emergencies from the group's perspective, making quantitative analysis possible.

3 Excavating the characteristics of human emergency behaviour and group psychological stress in large-scale emergencies

3.1 Data set

In the monopoly era of mobile Qzone communication, the data of mobile Qzone communication can better explain the behaviour of human beings in network communication. However, few studies have been conducted on the impact of emergencies and prediction methods based on social media data. According to the latest user tracking data, in October 2012, the average daily coverage of Tencent QQ reached 180 million people, and the arrival rate of Internet users reached 66.9%. Alitwangwang has 37.47 million daily subscribers and 13.8 Internet users. The average daily coverage of Fexin.com reached 16.95 million people, ranking third with 6.3 Internet users.

Our data are collected from the long-term monitoring data of 400 000 homes and offices (excluding public Internet access places) of Xoangben's network behaviour in October 2012. Details are provided in Table 1.

Internet users' average daily arrival rate is the quotient of the average daily coverage of all websites compared to the total daily coverage.

According to the latest data from the user tracker, in October 2012, Tencent QQ was used for 3.3 billion hours, accounting for 87.1 of the total time, ranking first among instant messaging software. Ali WantWant's effective use time reached 200 million hours, accounting for 5.4% of adequate use time. The effective use time of skew reached 69.77 million hours, accounting for 1.8 of the sufficient use time, and the three together accounted for 94.3 of the total adequate use time. The effective usage time rate is shown in Table 2.

Table 2 is from the long-term monitoring data of online behaviour of 400 000 households and offices (excluding public Internet access places) in October 2012. The monthly valuable time ratio in Table 2 is the ratio of the reasonable monthly time of the software to the sum of the reasonable monthly time of all the

Table 1 Daily coverage of real communication software in October 2012

ranking	Software	Average daily coverage	The average daily arrival rate of Internet users	Ranking change
		ten thousand people	%	
1	Tencent QQ	18,103	66.9%	→
2	Ali Wangwang	3747	13.8%	→
3	Feixin	1695	6.3%	→
4	Crooked	741	2.7%	→
5	MSN	645	2.4%	→
6	Renren desktop	491	1.8%	→
7	Microblog desktop	318	1.2%	→
8	Tencent RTX	254	0.9%	→
9	Tencent TM	211	0.8%	→
10	Skype	179	0.7%	→

Table 2 Statistical table of daily active use events of real-time communication software in October 2012

Ranking	Software	Monthly effective use time	The monthly effective use time ratio	Ranking change
		ten thousand hours	%	
1	Tencent QQ	330,258	87.1%	→
2	Ali Wangwang	20,341	5.4%	→
3	Feixin	6977	1.8%	↑
4	Crooked	6210	1.6%	↓
5	MSN	2806	0.7%	→
6	Renren desktop	2540	0.7%	↑
7	Microblog desktop	2350	0.6%	↓
8	Tencent RTX	2276	0.6%	→
9	Tencent TM	1821	0.5%	→
10	Skype	1234	0.3%	→

software in this category. As mentioned above, in 2012, people's communication behaviour patterns and online opinion expression tools were relatively simple. Since Tencent QQ in 1999, QQ has gradually evolved into the most important communication and chat software.

Similarly, when a particular event happens, people mainly publish some events in mobile QQ space to obtain friends' comments to know friends' views on the event. Therefore, we choose mobile QQ space data to analyse emergencies and routine events over the years in the social media data. Since the mobile Qzone was the main way for people to express their opinions on the Internet, our research can verify different events and people's group behaviours through a single communication behaviour (posting and replying on the mobile Qzone).

In this chapter, we analyse and compare the time interval of posting comments in the mobile QQ space of four different types of emergencies and one typical event and conclude the influence of emergencies on human communication behaviour patterns.

3.2 Statistical description of data

The data analysed in this paper are from the mobile QQ space data of 571 volunteers, including the complete data of 468 friends' mobile QQ space after removing invalid users. The period is from July 2005 to August 2014. As the most successful instant chat software in China and the related application of QQ, mobile Qzone also has a large number of active users. People can post messages, logs, and other interactive replies in the mobile Qzone. Furthermore, every behaviour of the user in the space (active initiator, passive initiator, time, content) will be recorded. In data cleaning, the crawling program is used to simulate the mobile QQ space of the browser login users for information crawling. This paper mainly analyses the time interval of users' three typical posting behaviours in the mobile QQ space: talk, log and message. The accurate time of the data can be real to the second. The data details are shown in Table 3.

In data cleaning, we remove some abnormal data; for example, the time is 1970-01–01 00:00:00 or null. In the actual experiment, we try to calculate statistics on the time interval in days, hours, minutes and seconds. The experimental results show that fitting time in seconds is more consistent with people's normal work and rest time, so we choose seconds as the unit for time interval analysis.

3.3 Model of the task priority queue

Barabasi et al. proposed and improved the task priority queue-based model, which uses task queues to explain most event processing in daily human life. They believe that tasks are limited by the deadline, and they need to arrange their work schedule according to the deadline and waiting time of functions. For a task in a queue, the length of its waiting time depends on the policy that people choose and execute it, and there are three main types:

1. The most straightforward execution strategy is the first-in, first-out approach, which is common in many service processes(Song et al. 2014). The waiting time is the sum of the execution time of all previous charges. If the execution time of each lesson is a bounded distribution, the wait time distribution will form an exponential tail, indicating that the wait time of most tasks is almost the same.

Table 3 Data summary table

Type	Log	Message	Board	Summary
Post	140,996	40,809	91,599	273,404
Reply	630,111	202,790	87,718	920,619

2. The random execution policy randomly selects tasks to be executed next regardless of task priorities and waiting time in queues. The distribution of task wait time is also exponential (Woolley-Meza et al. 2013).
3. Performing the task of top priority strategy is the most common method in human activities. At this point, the high-priority study shortly after joining the queue was soon implemented, and the low priority task requires its high priority of tasks geometrically to be executed, which may wait a long time. Perhaps this is observed in human behaviour characteristics of the thick tail.

At each step of the model, the task with the highest priority is executed with probability P, and a task is randomly selected with probability 1 − P. When P approaches 1, the model describes strategy (III), and the distribution.

of waiting time predicted by the model presents a power-law feature with a power index of -1. When P approaches 0, the model describes strategy (II), and the distribution of waiting time predicted by the model shows exponential decay.

We use the task priority queue model to analyse and explain the impact of emergencies on human behaviour.

3.4 Characteristics of human behaviour during high-risk events

The (M, B) phase diagram used here can be used to quantify the memorization and paroxysms of complex systems such as human behaviour and natural phenomena. The horizontal and vertical coordinates of the phase diagram are the memory coefficient (M) and the matrix coefficient (B), respectively. The memory coefficient M consists of the interval time series τ_i (i = 1, 2…). It is derived from the autocorrelation function, which is defined as:

$$M = \frac{1}{n-1}\sum_{i=1}^{n-1}\frac{(\tau_i - m_1)(\tau_{i+1} - m_2)}{\sigma_1\sigma_2}$$

The (M, B) phase diagram used here can be used to quantify the memorization and paroxysms of complex systems such as human behaviour and natural phenomena. The horizontal and vertical coordinates of the phase diagram are the memory coefficient (M) and the matrix coefficient (B), respectively. The memory coefficient M consists of the interval time series τ_i (i = 1, 2…). It is derived from the autocorrelation function, which is defined as:

$$\mathrm{B} = \frac{\sigma^{\tau} - \mathrm{m}^{\tau}}{\sigma^{\tau} + \mathrm{m}^{\tau}}$$

where m^{τ} and σ^{τ} are the sample mean and standard deviation of the mobile QQ space posting interval τ, respectively.

If M > 0 and tends to 1, the time series has strong memorization, that is, strong predictability; if M = 0, it means neutral; if M < 0 and tends to − 1, it means that the time series has anti-memorization. If B > 0 and tends to 1, it means that the time series has strong parturients; if B = 0, it means that the parturient is neutral; the time

series is a Poisson process with random behaviour; if $B < 0$ and tends to -1, it means that the time series tends to rule and has periodic characteristics.

3.5 CPT theory of psychological stress

The CPT model of psychological stress is a cognitive-phenomenology-interaction model of stress, which is a psychological model. This model is mainly elaborated from three aspects, as shown in Fig. 1.

The first is the cognitive view. This view emphasizes the direct motivation and mediating factors of the individual's psychological stress response determined by the individual's experiential thoughts and ideas of events experienced. Whether stress occurs and how psychological stress occurs depends on the individual's evaluation and interaction with the environment. The evaluation mainly consists of primary evaluation and secondary evaluation. The primary evaluation evaluates the harmfulness and severity of pressure events, while the secondary evaluation evaluates its coping resources and methods. If the individual evaluation is within their cognitive range, the degree of psychological stress of the individual will be very low, and there will even be no psychological stress response. However, psychological stress will occur when individuals think they cannot cope with the event after evaluation.

The second is the phenomenological view. The phenomenological view mainly refers to the specific events, time, place, environment and people related to the experience of psychological stress. When, where and what kind of event happened. Who was involved, how much was at stake, and what was the impact on individuals and society? The main thing here is to externalize all the information about the event.

The third is the interactive view. This view emphasizes that the individual's psychological stress experience is mainly generated through the interaction between the individual and the environment. When the individual cannot cope with events, psychological stress will occur. At the same time, it pays attention to the interaction between individuals and the environment, emphasizing the subjective initiative of individuals in the environment. They can actively change their behaviour according to feedback and changes in information to adapt to changes in the environment.

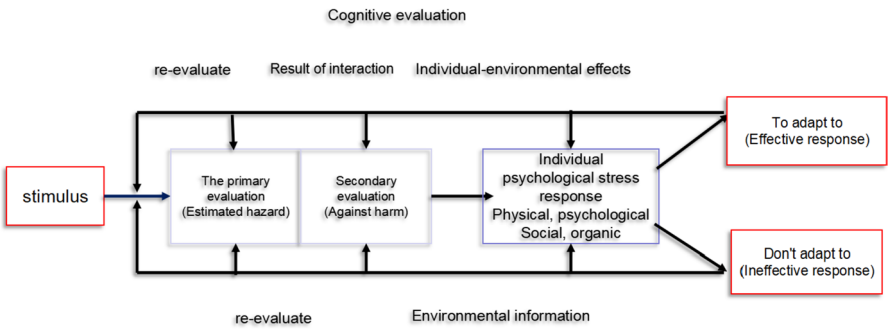

Fig. 1 Individual-environmental effect drawing

Cognitive psychological stress—phenomenology—can be seen in the interaction theory model, the typical psychology model, which pays attention to the role of the person's psychology and behaviour, according to the definition of psychological stress of the relationship between individual and environment, emphasizing individual initiative and the differences between individuals, different individuals, because of their difference, degree of psychological stress reaction. They are all different. This model focuses not only on both ends of the model but also on the process in the middle. The model points out the whole process of psychological stress, including stressors, stress mediators and psychological stress responses. The individual initiative believes that people are not mechanically manipulated in the face of stressful events, nor are they negative organisms. While being affected by environmental stress, individuals should deal with stressful events through their efforts to reduce and eliminate psychological stress levels.

We use the task priority queue model and the CPT theory of psychological stress to analyse and explain the impact of emergencies on human behaviour.

4 Experimental results

4.1 Experimental setup

Power law fitting experiment: The power law package in MATLAB was used to carry out a power law fitting experiment on the comment time interval data. The specific steps are as follows:

1. Call the plfit function in the powerlaw package to fit the comment interval data and obtain the powerlaw index and constant term.
2. Use the plplot function in the powerlaw package to visualize the fitting results.

Paroxysmal experiment: For paroxysmal comment intervals, we can study the following experiment:

1. The review time interval data were grouped according to different time windows, and the unit of this experiment was seconds.
2. Paroxysmal: For the comment interval data within each time window, calculate its mean and standard deviation, and store the results in an array.
3. Memorability: For the comment interval data in each time window, its correlation with the comment interval data in the previous time window is calculated, and the results are stored in an array.
4. Use the diagram tool in MATLAB to visually display the results to observe the aggregation phenomenon and memory phenomenon of the comment time interval.

4.2 Distribution of human posting time interval in case of emergencies

When analysing the distribution of human posting time intervals in the case of emergencies, we chose the Hailstorm event in Gansu. We considered four kinds of

posting behavior: posting time interval distribution, talk posting time interval distribution, log posting time interval distribution, and message posting time interval distribution. Interval time is the interval between two posts, expressed by the power rate and representing its probability distribution. The logarithmic binning method is used in the statistical analysis to observe the damping trend.

4.2.1 Distribution of human posting time interval in case of emergencies

Emergencies often trigger panic and disrupt the daily lives of individuals involved in crisis events, particularly those with significant interests at stake. The urgency and uncertainty surrounding such events often limit the public's understanding and judgment of the situation, leading to heightened panic. When the public's needs are not met during emergencies, individuals may experience psychological stress responses characterized by physiological, emotional, and behavioral abnormalities.

Figure 2 illustrates the distribution of various posting time intervals, which exhibits heavy-tailed characteristics to varying degrees. These posting behaviors demonstrate a pattern of alternating between long periods of silence and short periods of activity. Our experimental findings align with previous research on users' posting behaviors on platforms such as blogs, microblogs, mobile phone messaging, and QQ chat. However, MsgFeed posts exhibit a more pronounced heavy-tailed pattern. This can be attributed to the fact that individuals prioritize taking immediate countermeasures and resolving natural disasters before posting on MsgFeed to share their experiences or provide assistance. Consequently, a significant heavy-tailed feature and long periods of silence are observed in the data.

In contrast, blog posts tend to be less frequent and characterized by longer periods of silence. This can be attributed to the nature of blogs, which often serve as platforms for individuals to summarize their recent experiences, such as annual

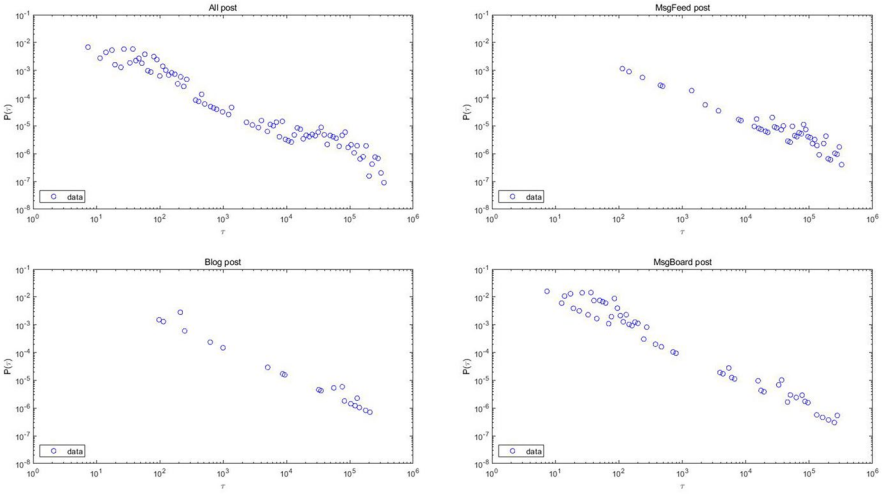

Fig. 2 Distribution of human Posting time intervals in the case of emergencies

summaries. During emergencies, people tend to focus solely on the event at hand, leading to fewer blog posts as their attention is diverted from personal experiences.

4.2.2 Time interval distribution of human comments in case of emergencies

The comment record and time interval of a different type of post reflect the impact of the corresponding post in an emergency to show the impact of various kinds of correspondence. The life cycle of talk, log, and the message is analysed in seconds in the double logarithm coordinate system (Fig. 3).

Because of time constraints and the uncertainty of emergencies, the public tends to reduce their activities accordingly. Recognition and judgment are also reduced, leading to panic. The main reason is that such an emergency will trigger the psychological stress response of the public and cannot meet the needs of the public. As shown in Fig. 2, human comments after an emergency are more active than those posted on the mobile QQ space because posting is an individual behavior, while comments are a many-to-one behavior. Comments on MsgFeed show two power-law distributions, the first steeper than the second, in line with a user posting pattern based on waning user interest. When people see others' posts about natural disasters on MsgFeed, they actively discuss them. Over time, however, interest in the event first drops sharply, then slowly, and eventually calms down. Blogs and message boards generally do not post information about natural disasters (emergencies), so they are not affected by events.

The characteristics of emergency behaviour and psychological stress are people's behaviours and psychological states in emergency situations. In emergency situations, the public often feels time pressure and uncertainty, which causes them to reduce their activities accordingly. In addition, due to the suddenness of the

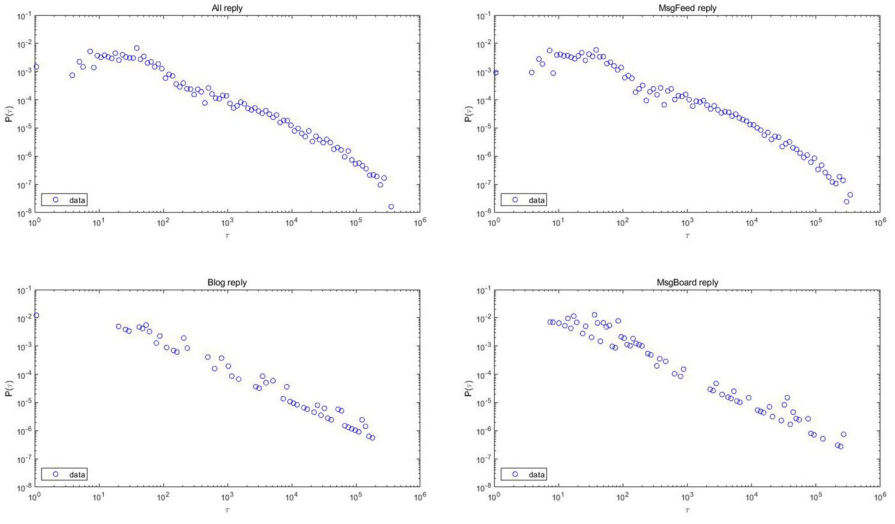

Fig. 3 Time interval distribution of human comments in case of emergencies

emergency, the public's ability to recognize and judge will also be reduced, making panic more likely. Emergency events trigger the public's psychological stress response, which is a physical and psychological coping mechanism. When the public's needs are not met, they face stress and anxiety. This psychological stress response can lead to a decline in the public's attention and thinking skills, thus affecting their ability to respond to emergencies and make decisions.

In emergency situations, public behavior and response are often influenced by time constraints and uncertainty. They may fall into a state of panic and confusion and be unable to make rational decisions. This feature of psychological stress makes the public more vulnerable to emergency situations, leading them to reduce their corresponding activities and reduce their cognition and judgment of events. In addition, the psychological stress response in emergency situations also affects the level of public interest and attention to the event. In the aftermath of an emergency, the public may show intense interest and discussion of the event, but this interest tends to wane over time. This is because the public experiences a wave of emotions in the face of an emergency, with the initial intense interest fading and eventually calming down.

4.2.3 Empirical analysis under different emergencies

After a sudden public crisis, individuals often struggle to make accurate judgments and evaluations due to the limited time and information available. The lack of rational cognition, combined with external pressure and personal needs, leads to a psychological stress response, which is a natural human instinct. In a state of stress, the presence of effective stress can enhance people's crisis awareness and alertness, thus enabling them to respond actively to the crisis. However, as a sudden public crisis persists, psychological pressure and stress on individuals tend to increase. When stress surpasses an individual's cognitive capacity, it can result in psychological trauma, disrupt daily life, and have detrimental effects on physical health.

Emergencies elicit various behavioral responses and psychological stress characteristics. During a crisis, individuals may exhibit emergency behaviors such as seeking safety, mobilizing resources, and assisting others. These emergency behaviors are driven by the instinct to survive and protect oneself and others. Moreover, individuals may experience heightened levels of anxiety, fear, and uncertainty, which can lead to increased vigilance and hyperarousal. This heightened state of alertness allows individuals to stay attuned to potential threats and take necessary actions to ensure their safety.

Additionally, individuals may also display cognitive and emotional responses during a crisis. The cognitive responses involve a rapid assessment of the situation, including the evaluation of available resources and potential risks. These evaluations are influenced by the individual's prior knowledge, experiences, and beliefs. Emotional responses, on the other hand, can range from feelings of shock and disbelief to anger, sadness, and grief. These emotional reactions are normal and can vary depending on the severity of the crisis and its impact on individuals' lives.

Furthermore, individuals' coping mechanisms and resilience play a significant role in their response to a sudden public crisis. Coping mechanisms refer to the

strategies individuals employ to manage and adapt to the stressors they encounter. These can include problem-solving, seeking social support, or engaging in self-care activities. Resilience, on the other hand, refers to an individual's ability to bounce back and recover from adversity. Resilient individuals are better equipped to cope with the psychological stressors associated with a crisis and are more likely to adapt and restore normalcy in their lives.

In conclusion, during a sudden public crisis, individuals face difficulties in making accurate judgments and evaluations due to limited time and information. The resulting psychological stress response can have both beneficial and detrimental effects. While effective stress can enhance crisis awareness and prompt active responses, prolonged stress can lead to psychological trauma and disrupt individuals' lives. Understanding emergency behaviors and psychological stress characteristics can help in developing effective crisis management strategies and support systems to assist individuals in coping with the challenges posed by a sudden public crisis.

We use the mobile QQ space posting time interval to reveal the impact of emergencies on human behaviour to conduct an analysis experiment. According to four types of emergencies and one recurring event, we divided the data of the mobile QQ space into five groups, as shown in Table 4.

4.2.4 Impact of natural disasters on human behavior

In the given figure, the X-axis represents the time interval of people's posting in the mobile QQ space, while the Y-axis represents the probability of occurrence under the time interval of posting on the X-axis. Let us consider the occurrence of natural disasters as an example. On May 10, a massive hailstorm struck Min County, Gansu Province, resulting in mountain floods and the unfortunate loss of 37 lives. When examining the time distribution of mobile QQ space posts during natural disasters, it is observed that the corresponding five-day time interval distribution exhibits a negative correlation with the power index value (Fig. 4).

Major natural disasters not only lead to casualties and property losses but also inflict severe psychological trauma upon individuals, families, and communities

Table 4 Event grouping table

Category	Group1	Group2	Group 3	Group 4	Group 5
Event type	Natural disasters	Disaster	Public health	Social security	Ordinary events
Event	Hail	Fire	Anthrax	Hijacking	Events
At the time of the incident	282	254	121	429	333
The day before the incident	230	202	156	350	310
Two days before the event	381	261	152	361	265
One day after the incident	356	253	135	285	484
Two days after the event	316	267	129	280	300

affected by the disaster. As evident from the figure, people's activities were relatively high on the day when the hailstorm occurred in Gansu Province. However, as time progressed, the activity decreased significantly compared to the preceding days. This decline can be attributed to the fact that during natural disasters or emergencies, individuals experience immense pressure, disrupting their equilibrium and causing a deviation in their adaptability to the environment. Consequently, people tend to prioritize information related to the disaster, leading to increased attention towards such incidents.

During emergencies, characterized by sudden, uncertain, and urgent events that stimulate individuals mentally, people tend to have higher visibility. As a result, they first disseminate and exchange information about the incident on the internet, dedicating considerable time to supporting the victims of the disaster or assisting in the affected area. The figure demonstrates that in the case of natural disasters, people engage in rescue and relief efforts as early as possible after disseminating relevant information. The interval of the posttime silence period begins earlier than that of ordinary events and continues for a longer duration.

During natural disasters, individuals enter a state of active discussion, as indicated by several discrete power rates towards the end of the data points. This phenomenon primarily arises due to the psychological response of most individuals to natural disasters, although some individuals may have a weaker ability to cope with

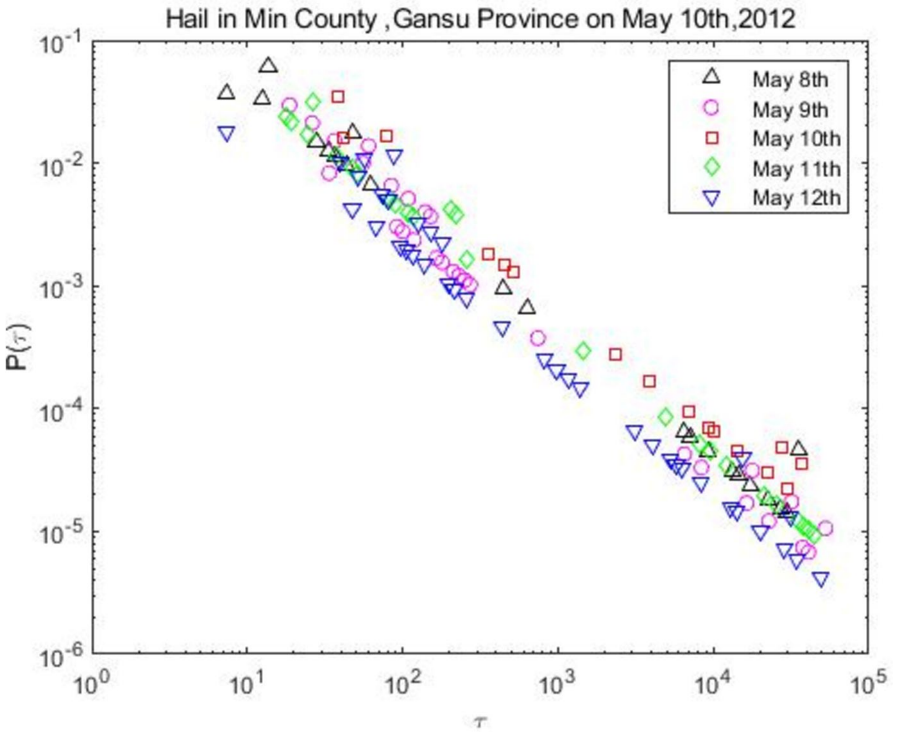

Fig. 4 Distribution of human post time intervals under the influence of natural disasters

such situations. Therefore, it is crucial to not only focus on the mental health of individuals in disaster-stricken areas but also pay attention to the psychological well-being of these individuals.

However, as circumstances evolve, people's interest diminishes, leading to periods of silence, eventually returning to normalcy. It is important to acknowledge the cyclical nature of people's engagement and response during and after emergencies. By understanding emergency behaviors and psychological stress characteristics in depth, we can better address the needs of individuals affected by natural disasters and provide appropriate support. The usage of more academic language is recommended to enhance the scholarly tone of the article.

4.2.5 Impact of sudden accidents and disasters on human behavior

Taking the fire incident at the Guangdong underwear factory on December 5, 2012, as a case study, it is evident that there exists a negative correlation between the power index values of the five user groups in the time distribution of mobile QQ space posts during accidents and disasters. Similar to natural disasters, there is a prolonged period of silence following such incidents. However, unlike natural disasters, people tend to exhibit heightened attention towards their immediate surroundings when confronted with a fire incident at a factory, leading to intense social discussions. During such events, individuals experience elevated psychological stress levels, which consequently results in a higher level of activity on December 5 compared to the other two days. People actively engage in comments and posts, leading to shorter time intervals between their contributions. This observation suggests that during periods when a single online expression tool is available, individuals prioritize their attention towards accidents occurring in their vicinity and express their opinions more frequently (Fig. 5).

In the face of accidents and disasters, emergency response behaviors and psychological stress characteristics play a crucial role. It is essential to provide individuals with rational risk cognition and evaluation to effectively deal with emergencies. This enables people to actively respond to accidents and disasters, ensuring their safety and raising awareness. It is noteworthy to highlight the emergency response behaviors exhibited by individuals during such incidents. People tend to be more alert and cautious, seeking information and updates regarding the accident. This behavior is driven by the need to protect themselves and their loved ones, as well as to stay informed about the situation. Additionally, individuals may engage in discussions and express their concerns, aiming to raise awareness and encourage collective action.

Furthermore, the psychological stress characteristics observed during accidents and disasters are worth exploring. The occurrence of a significant incident such as a factory fire triggers a range of emotions and stress responses in individuals. These may include fear, anxiety, and a heightened sense of vulnerability. Consequently, individuals may exhibit a greater sense of urgency in their responses, actively participating in discussions and seeking ways to mitigate the impact of the incident.

In conclusion, during accidents and disasters, individuals demonstrate emergency response behaviors and experience psychological stress characteristics that influence

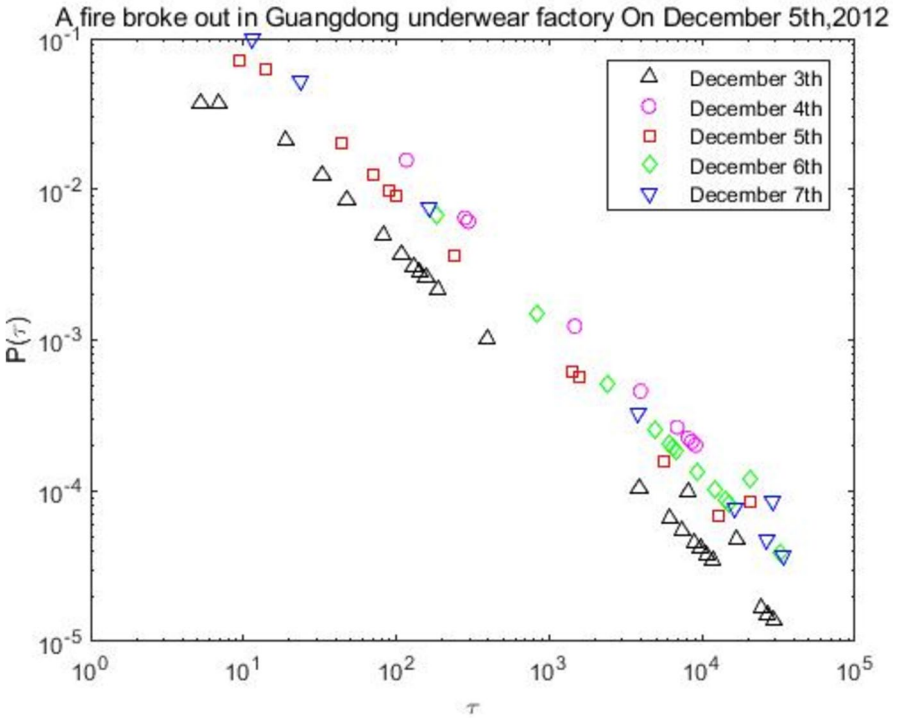

Fig. 5 Time interval distribution of human Posting under the influence of accidents and disasters

their online activities. The availability of a single online expression tool allows people to focus their attention on local accidents, leading to increased engagement and more frequent comments. Understanding these emergency behaviors and stress responses is crucial for effective emergency management and fostering a collective response to such incidents.

4.2.6 Impact of public health events on human behaviour

The analysis of the anthrax outbreak on August 13, 2009, reveals several important findings regarding people's emergency response during public health events. First, there is a negative correlation between the power index values of different user groups in the time distribution of mobile QQ space posting. This suggests that certain user groups are more active in sharing information during emergencies, while others are less active. However, after the anthrax outbreak, there was no significant difference in the power rate of people's comments on social media. This can be attributed to the limited information available on that day, as well as the lack of interaction and delayed dissemination of information. Nevertheless, people responded more promptly to the news on subsequent days, particularly on August 14 and 15. Public health security events have a wide-ranging impact, and individuals' psychological stress levels are significantly

lower during such events compared to other days. This indicates that people are sensitive to public health events and that their psychological stress levels fluctuate based on the impact of these events on individuals (Fig. 6).

During public health events, data are continuously updated, and people pay close attention to the latest trends, frequently using communication tools to stay informed about the current situation. The small number of posts with intervals of more than one day suggests that these intervals may represent individuals experiencing different emergencies within the data set. The imbalance estrangement and reduced personal social-psychological endurance observed during public health events affect both individuals and society as a whole. This imbalance negatively impacts people's cognition, emergency response capacity, compression ability, and overall balance. It is crucial to address these issues and find effective methods to rebalance and stabilize morale.

When dealing with public health events, it is important to improve emergency record-keeping, establish a people-oriented response mechanism, and prevent the spread of rumours and panic on the internet. These measures can help ensure a more effective and informed response to public health emergencies.

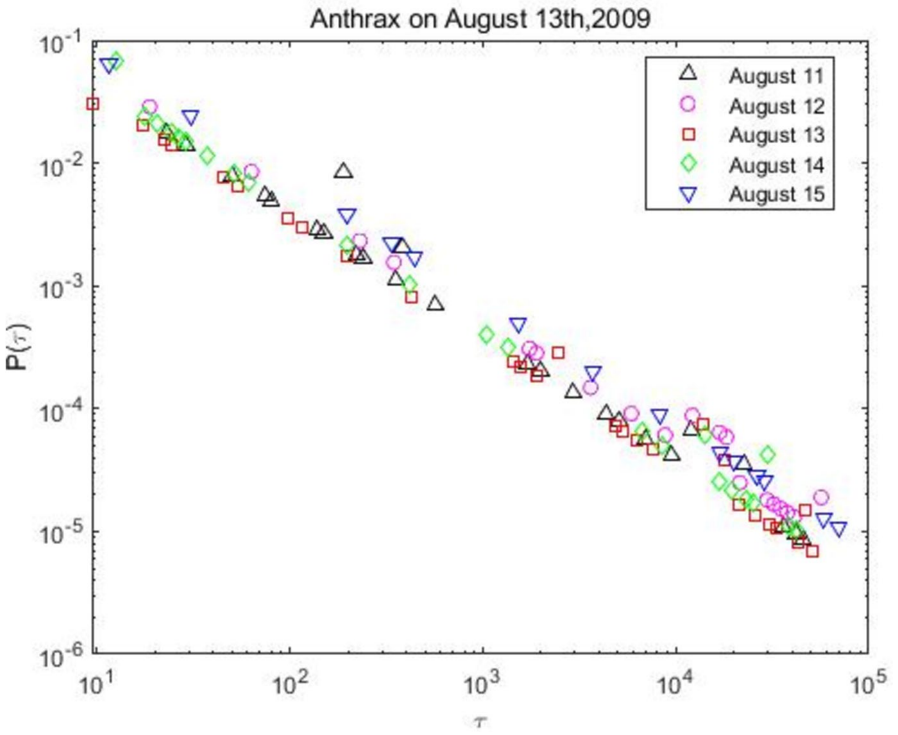

Fig. 6 Distribution of human post time intervals under the influence of public health events

4.2.7 Impact of social security incidents on human behaviour

Taking the hijacking incident of June 29, 2012, as an example, the time distribution of mobile QQ space posts during social security incidents revealed a negative correlation in the power index value among five user groups. These findings highlight the detrimental impact of social security incidents on the coordination of social relations and the organization of social activities within a specific timeframe and geographical area. Such incidents result in significant losses to human life, property, and well-being, posing a serious threat to normal social order, public security, and even triggering economic recession, social chaos, and political turmoil. On July 22, the day of the hijacking incident, there was no significant difference in the power of people's comments on social media. However, on July 23, a significant difference emerged due to the limited reporting of detailed social security incidents on that day. News media outlets received accurate information through alternative channels and subsequently compiled a comprehensive report, which was disseminated the following day. This led to a surge in public discussions and debates on social platforms two days after the social security incident. Such events often generate a sense of public insecurity and anxiety (Fig. 7).

In response to these challenges, it is crucial to implement effective emergency measures and address the psychological stressors experienced by individuals. Emergency actions should include prompt and accurate dissemination of information, enhanced security measures, and effective crisis management strategies. Additionally, it is essential to provide psychological support and counselling services to affected individuals and communities. This helps stabilize people's psychology and alleviate the negative psychological impacts caused by social security incidents.

In conclusion, social security incidents, such as the hijacking incident of June 29, 2012, have far-reaching consequences on various aspects of society. They disrupt social relations, hinder social activities, and pose threats to public security and normalcy. It is imperative to address the emergency response and psychological stressors associated with such incidents through effective measures, including timely information dissemination, enhanced security measures, crisis management strategies, and psychological support. Strengthening ideological development and social management is also crucial in maintaining public security and stability.

4.2.8 Impact of ordinary events on human behaviour

During emergency events, there were clear indications of human behavior following the law of "long silence, short burst." People were initially in a state of shock and disbelief, leading to a prolonged period of silence. However, as time passed, the intensity of their emotions intensified, resulting in a short burst of activity (Fig. 8).

In contrast, during ordinary events, people did not exhibit this pattern of behavior. Instead, their behavior remained stable and consistent, indicating a state of equilibrium in their minds. This suggests that people are more likely to exhibit fluctuating behavior during emergency situations, where their emotions and stress levels are heightened. Furthermore, during emergency situations, people tend to exhibit certain psychological stress responses, such as increased anxiety, fear, and panic. These

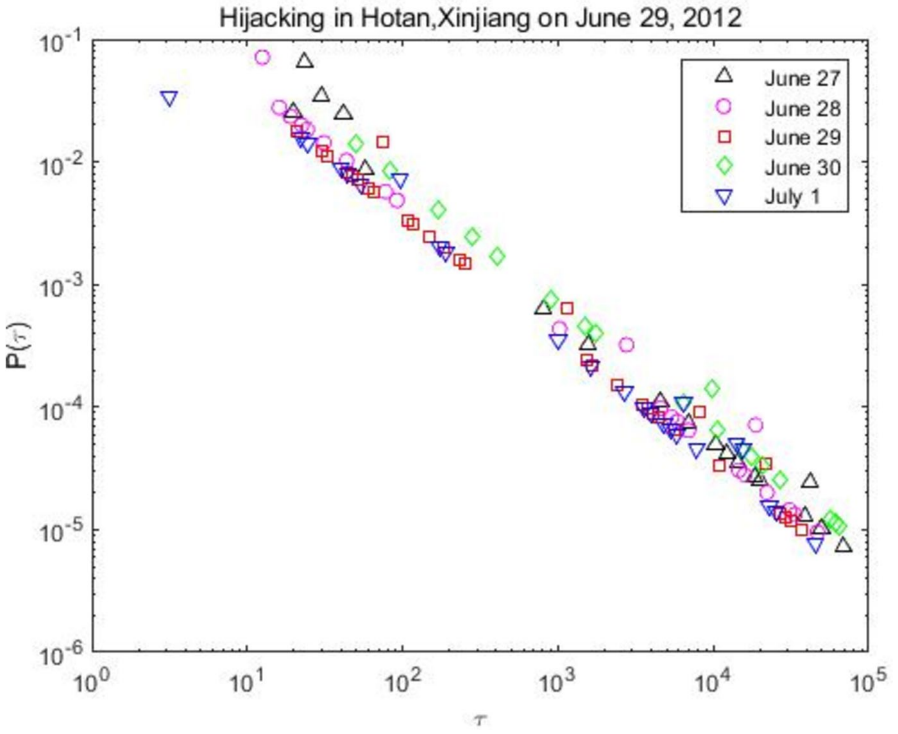

Fig. 7 Distribution of human posting time intervals under the influence of social security events

responses are often a result of the perceived threat to one's safety or well-being, leading to a fight or flight response.

The comparison between ordinary events and emergency situations highlights the significant impact of stress and emotions on human behavior. Understanding these responses can help individuals and organizations better prepare for and respond to emergency situations.

4.3 Comparative analysis of human communication behaviour in emergencies

As seen from this figure, the silent period of mobile QQ space posting in the case of emergencies is longer than that of ordinary events. It may be a process of a human responding to emergencies, and in the part of the array, the time interval of mobile QQ Space Posting is closer than that of ordinary events, and it has the characteristics of a fat tail. This means that at this time, all people, regardless of whether their conformity is high or low or how much they have experienced, will have a psychological stress response, and the group will appear to panic and anxiety. In the figure, the time interval between human posts and replies in the Qzone under emergencies is different from that in ozone under ordinary events. Compared with the time interval between human posts and replies in a zone under emergencies, the general power

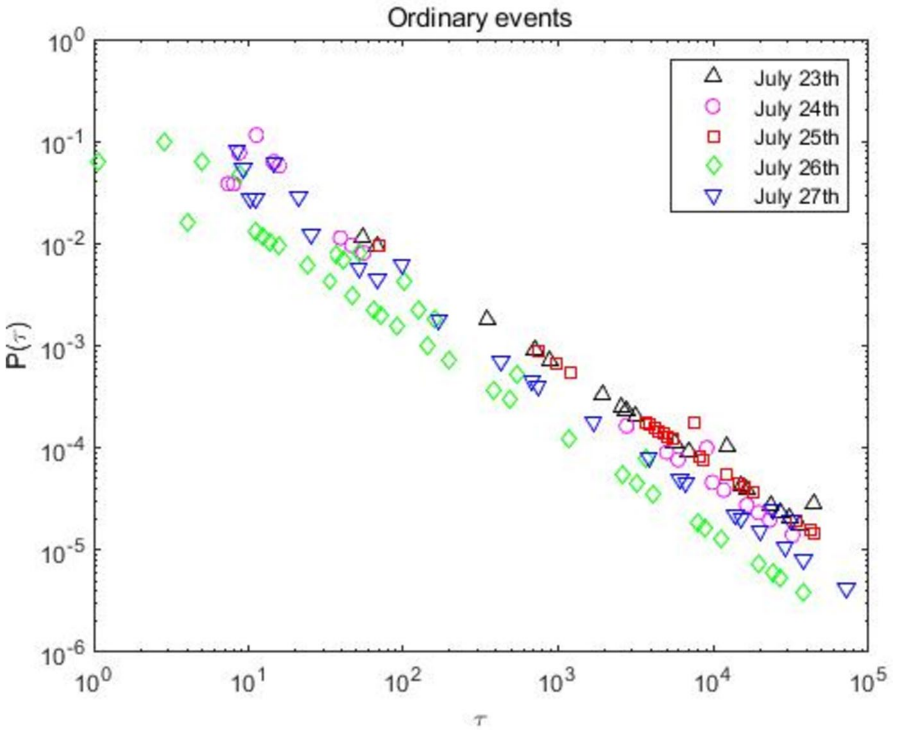

Fig. 8 Human posttime interval distribution under ordinary events

law is low. The overall tendency of the crowd's environmental attitude is negative, and the negative crowd size is much larger than the positive crowd size. The public is worried about emergencies, leading to negative behaviours. The simulation diagram shows that the psychological stress of different emergencies experienced by the group is different, and the psychological stress level of the group that experienced less stressful events is higher. In the public health security event (anthrax), due to the spread of infectious diseases, in the face of the crisis, compared with the narrow spread of social security events, the degree of psychological stress is high, and after the end of the crisis, the time of psychological recovery is also late.

Under sudden public crises, individual experience plays a key role in psychological stress. The individual experience here refers to the number of emergencies that an individual has experienced. She or Ine can, the richer an index, the richer an individual is. However, those who have little experience of crisis tend to feel flustered and helpless in such a sudden situation because they have no or little experience in crises. In a sudden public crisis, inexperienced individuals are most susceptible to environmental influences because they have no judgment. A sudden public crisis influences everyone's psychology when people are under pressure. However, the level of stress in an emergency was the same. The same stress level has a great difference in the psychological impact on different people, but the difference mainly depends on what kind of way the individual takes. In general, copying is considered

a complex process of attitude and behaviour. First, individuals evaluate sudden public crisis events. Some people regard pressure as a challenge and actively solve difficulties, while others regard pressure events as a burden and retreat from difficulties and avoid them negatively. Such differences in individual cognition lead to differences in coping styles in the face of crisis events. Generally, such differences mainly divide people's coping styles into positive and negative styles. The discrete power-law points at the tail of the power-law graph are some people with poor psychological stress levels in emergencies, and we should pay more attention to these groups.

4.4 Paroxysmal and periodic human communication behaviour in emergencies

This paper uses the (m, b) phase diagram to measure the paroxysm and memory of posting behavior in mobile QQ space. Figure 9 shows the (m, b) phase diagram of the individual posting behaviour sequence with daily posting volume in $1 <= CI <= 50$ from 2006 to 2011. Almost all values are in the first two quadrants of the phase diagram, and their mean values are 0607 MB = (0.060, 0.211), 0809 MB = (0.148, 0.284), 1011 MB = (0.157, 0.229), and 1213 bm = (0.104, 0.278), indicating that the time series of mobile QQ space posting behaviour has significant paroxysmal and weak memory. B = 0.284, indicating that the probability distribution of the interval

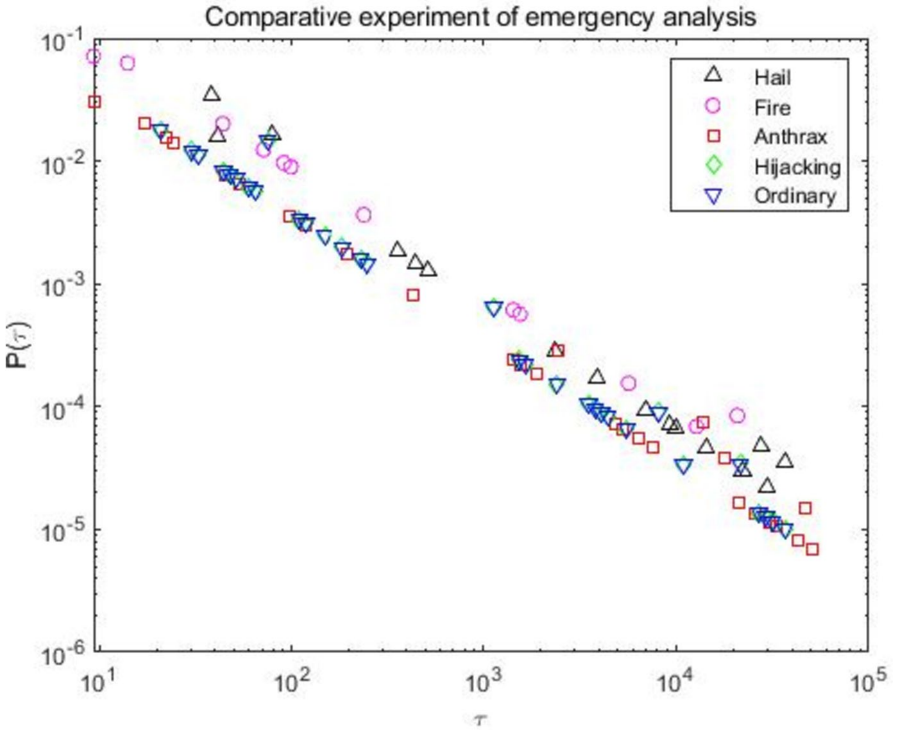

Fig. 9 Comparison of human posting time interval distribution under different emergencies

time of alarm behaviour is more paroxysmal than the exponential distribution (B ≈ 0) characterizing the Poisson process. M = 0.148 indicates that alarm behaviour time series memory characteristics show a medium level (Fig. 10).

To compare the paroxysmal and memory of the posting time sequence of mobile QQpace in the years with more emergencies with the posting behaviour characteristics of mobile QQpace with younger emergencies, Fig. 9 shows the analysis results of several other real data sets, including the posting time interval of mobile QQpace in 06 and 07 (red) and the posting time interval of mobile QQQspace in 08 and 09 (blue) 10. 11-year mobile QQspace posting interval (blue), 12- and 13-year mobile QQspace posting interval (plum red). It can be seen that the time series of mobile QQ space posting behavior in 0809 and 1213 (two years with more emergencies) show stronger paroxysm compared with other behaviors, which is higher than the mobile QQ space data in the other four years. In addition, the average memory is similar to the results of mobile QQpace posting in 10 and 11 years because they have similar handling methods for emergencies, but there are some differences in the urgency and response needs of emergency driving users' string behaviour. A crowded environment is a group attitude and emotional tendency formed by individuals. The attitude tendency of the crowd is divided into positive.

Emotions and negative emotions. A positive emotional attitude means that although individuals face the pressure of a sudden public crisis, negative crowd emotions are mainly reflected in people of confidence and public depression. At the same time, in the further development of psychological stress, with the

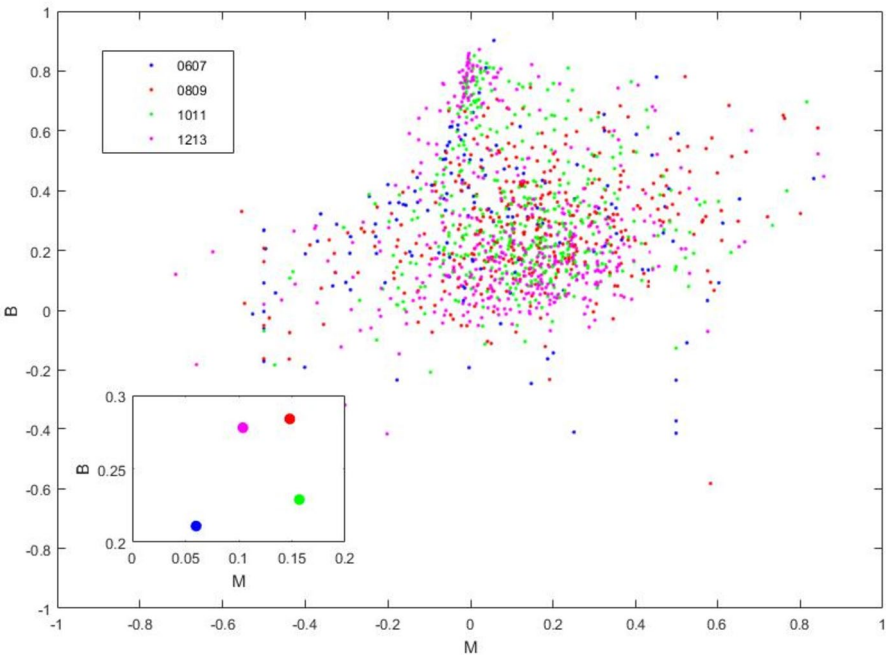

Fig. 10 Paroxysmal and memory QQQQQpace posts from 2006 to 2014

corresponding changes in physiological indicators, psychological reactions and physiological reactions, the two transform and influence each other, resulting in the emergence of abnormal behaviour. In turn, the abnormal behaviour of the public further aggravates the level of psychological stress. The figure shows that the psychological stress suitable for people who experience more crisis events is low, while the psychological stress level is high when the group experiences fewer stressful events.

When we studied the previous chapter, we selected the emergencies in 12 or 2009. We then selected the day and two days before and after these emergencies to make a paroxysmal and memory analysis chart (Fig. 11).

This figure presents an (M, B) phase diagram to assess the paroxysmal and memorability aspects of mobile QQ space posting behavior during four emergency situations. The mean point of the (M, B) phase diagram is (-0.176, 0.326), indicating strong paroxysmal behaviour and weak anti-memory tendencies. Empirical research suggests that human behavior exhibits both strong and weak memory characteristics. However, during emergencies, the bursts of human posting behavior are more pronounced compared to ordinary events and even display anti-memory features.

The intensification of paroxysms can be attributed to the fact that emergencies provoke strong discussions and activities among individuals, leading to abnormal human behavior. The occurrence of anti-memory can be attributed to people's varying response measures based on their judgment of the urgency and response requirements during emergencies. This distinct decision-making process during emergencies, unlike in ordinary events, results in weaker memory retention.

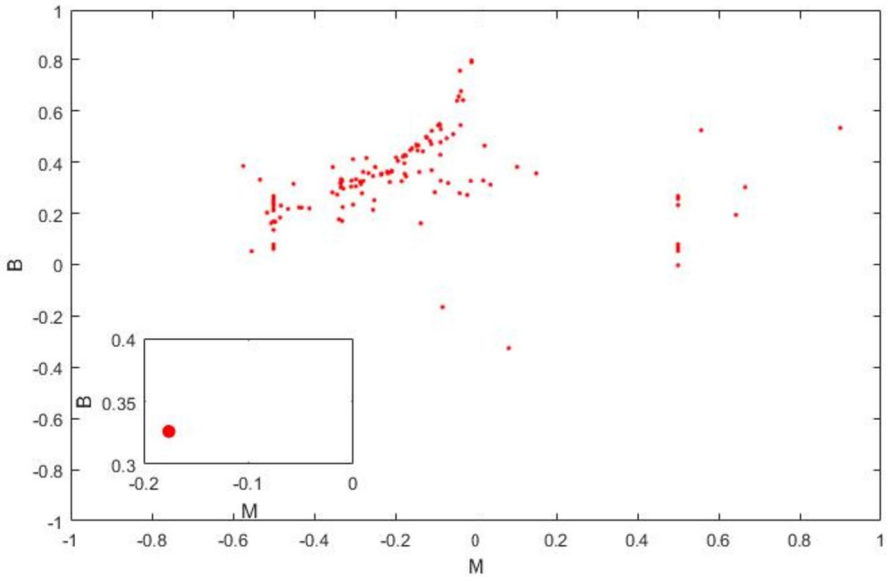

Fig. 11 Paroxysmal and memorable emergencies

5 Results and discussion

By studying the post behavior and comment behavior of mobile Qzone users, we found that the time interval between people's post behavior and interactive comment behavior can be described by a power law distribution in emergency situations. In particular, the time interval distribution of posts and replies showed a significant heavy tail distribution and showed a power rate decay trend over time. We have verified that the end of individual psychological pressure refers to the disappearance of psychological pressure, people's mental state is restored to health, emotions are restored to normal, and anxiety, tension and panic psychology no longer appear. After the public crisis, the intervention measures effectively control the harm caused by the public crisis. With the help of self-regulation and the external social world, psychological pressure gradually disappears, and the psychological state tends to ease. In the face of emergencies, human emotional responses will be stronger than before, and in terms of memory, humans will even have reverse memory and ultimately cannot predict that human post behavior is due to different stress responses in the face of different emergencies.

These findings provide evidence and a reference for further research to truly understand the characteristics of human behavior in emergency situations. In terms of predictive intervention for group psychological stress, there are no specific aspects that can reduce and alleviate the group stress response. Therefore, it is necessary to further explore the influence of social attitudes on group psychological stress in future studies.

References

Altshuler Y, Fire M, Shmueli E et al (2013) The social amplifier—reaction of human communities to emergencies. J Stat Phys 152(3):399–418

Anteneodo C, Malmgren RD, Chialvo DR (2010) Poissonian bursts in email correspondence. Eur Phys J B 75(3):389–394

Bagrow JP, Wang D, Barabási A-L (2011) Collective response of human populations to large-scale emergencies. PLoS ONE 6(3):e17680

Barabási A-L (2005) The origin of bursts and heavy tails in human dynamics. Nature 435(7039):207–211

Barabasi A-L (2009) Scale-free networks: a decade and beyond. Science 325(5939):412–413

Becker R, Volinsky C, Cáceres R et al (2013) Human mobility characterization from cellular net-work data. Commun ACM 56(1):74

Brockmann D, Hufnagel L, Geisel T (2006) The scaling laws of human travel. Nature 439(7075):462–465

Bza B, Jw A (2019) Topography analysis of particle velocity distribution function in gas-solid flow. Chem Eng Sci 197:69–73

Candia J, González MC, Wang P et al (2008) Uncovering individual and collective human dynamics from mobile phone records. J Phys A: Math Theor 41(22):224015

Castellano C, Fortunato S, Loreto V (2009) Statistical physics of social dynamics. Rev Mod Phys 81(2):591–646

Chun H, Kwak H, Eom YH et al (2008) Comparison of online social relations in volume vs inter-action: a case study of Cyworld. In: Proceedings of the 8th ACM SIGCOMM conference on Internet measurement, New York, pp 57–70

Clauw DJ, Engel C Jr, Aronowitz R et al (2003) Unexplained symptoms after terrorism and warn expert consensus statement. J Occup Environ Med 45(10):1040–1048

Conte R, Gilbert N, Bonelli G et al (2012) Manifesto of computational social science. Eur Phys J Special Top 214(1):325–346

Do TMT, Gatica-Perez D (2012) Contextual conditional models for smartphone-based human mobility prediction. In: Proceedings of the 2012 ACM conference on ubiquitous computing, New York, pp163–172

Gibbs JW (2014) Elementary principles in statistical mechanics. elementary principles in statistical mechanics, ii(1):A55–A59

Girardin F, Calabrese F, Fiore FD et al (2008) Digital footprinting: uncovering tourists with user-generated content. IEEE Pervasive Comput 7(4):36–43

Goh K-I, Barabási A-L (2008) Burstiness and memory in complex systems. EPL (Europhysics Letters) 81(4):48002

Guo JL, Fan C, Guo ZH (2011) Weblog patterns and human dynamics with decreasing interest. Eur Phys J B 81(3):341–344

Iribarren JL, Moro E (2009) Impact of human activity patterns on the dynamics of information diffusion. Phys Rev Lett 103(3):038702

Jiang Z-Q, Xie W-J, Li M-X et al (2013) Calling patterns in human communication dynamics. Proc Natl Acad Sci 110(5):1600–1605

Kan A, Chan J, Hayes C et al (2013) A time decoupling approach for studying forum dynamics. World Wide Web 16(5–6):595–620

Keitel A, Ringleb M, Schwartges L (2011) Endocrine and psychological stress responsesin a simulated emergency situation. Psychoneuroendocrinology 36:98–108

Kenett DY, Portugali J (2012) Population movement under extreme events. Proc Natl Acad Sci 109(29):11472–11473

Lazer D, Pentland A, Adamic L et al (2009) Social science: computational social science. Science 323(5915):721–723

Li N-N, Zhang N, Zhou T (2008) Empirical analysis on temporal statistics of human correspondence patterns. Physica A 387(25):6391–6394

Lin Y-R, Margolin D (2014) The ripple of fear, sympathy and solidarity during the Boston bombings. EPJ Data Science 3(1):31

Malmgren RD, Stouffer DB, Campanharo ASLO et al (2009a) On Universality in Human Correspondence Activity. Science 325(5948):1696–1700

Malmgren RD, Hofman JM, Amaral LA et al (2009) Characterizing individual communication patterns. In: Proceedings of the 15th ACM SIGKDD international conference on knowledge discovery and data mining, New York, pp 607–616

Oliveira JG, Barabási A-L (2005) Human dynamics: Darwin and Einstein correspondence patterns. Nature 437(7063):1251–1251

Peleg-Popko O (2002) Bowen theory: a study of differentiation of self, social anxiety, and physiological symptoms. Contemp Fam Ther 24:355–369

Pentland A (2014) Social physics: how good ideas spread-the lessons from a new science. Penguin

Preis T, Moat H S, Bishop SR et al (2013) Quantifying the digital traces of hurricane sandy on Flickr. Scientific Rep 3

Selye H (1956) The stress of life. McGraw-Hill, New York, pp 1–10

Social Networks (2011) In Proceedings of the 17th ACM SIGKDD international conference on knowledge discovery and data Mining, New York, pp 1082–1090

Song X, Zhang Q, Sekimoto Y et al (2014) Prediction of human emergency behaviour and their mobility following large-scale disaster. In Proceedings of the 20th ACM SIGKDD international conference on knowledge discovery and data mining, New York, pp 5–14

Stouffer DB, Malmgren RD, Amaral LA (2006) Log-normal statistics in e-mail communication patterns. arXiv preprint physics/0605027

Szell M, Grauwin S, Ratti C (2014) Contraction of online response to major events. PLoS One 9(2):e89052

Traag VA, Browet A, Calabrese F et al (2011) Social event detection in massive mobile phone data using probabilistic location inference. In: Privacy, Security, Risk and Trust (PAS- SAT) and 2011 IEEE third international conference on social computing (SocialCom), 2011 IEEE third international conference on, Oct 2011, pp 625–628

Wang Q, Taylor JE (2014) Quantifying human mobility perturbation and resilience in Hurricane Sandy. PLoS One 9(11):e112608

Wang P, Lei T, Yeung CH et al (2011) Heterogenous human dynamics in intra- and inter-day timescales. EPL (Europhysics Letters) 94(1):18005

O Woolley-Meza D Grady C Thiemann et al 2013 Eyjafjallajökull and 9/11: the impact of large-scale disasters on worldwide mobility PLoS One 8 8 e69829

Yi Luo An undergraduate student in Zhejiang Yuexiu University. His major is big data analysis, and research interests include big data analysis, and human behaviour dynamics. Now he is submitting three papers and preparing four papers.

Xiaoping Yang Ph. D, Professor, Dean of School of International Business, Lead researcher of Institute of Modern Economics and Management, Zhejiang Yuexiu University of Foreign Languages. Main research interests include business big data, corporate finance and governance.

Xiaoming Li PhD and Associate Professor, College of International Business, Zhejiang Yuexiu UniversityDeputy Director of Shaoxing Key Laboratory of Intelligent Monitoring and Prevention of Smart City. He received his PhD degree from Tianjin University in March 2020. Before that, he received his Master's degree from Xinjiang University in 2008. His research interests include human behaviour dynamics, Multi-layer network local community detection and data mining.

Zhenzhen Chen Research Assistant in Institute of Big Data at Fudan university. Before that, she served as a lecturer in department of big data analysis at Zhejiang Yuexiu University. She earned her master's degree in statistics from Iowa state university, Iowa, United States in 2019. Her research interests include big data analysis and survey analysis.

Fangyuan Liu She received the B.S. degree in international economics and trades from East China University of science and technology, Shanghai, China, in 2018 and the M.S. degree in international accounting and finance from University of Birmingham, Birmingham, UK, in 2019. She is currently pursuing the Ph.D. degree in business and management at UCSI University, Kuala Lumpur, Malaysia.

Authors and Affiliations

Yi Luo[1] · Xiaoping Yang[1] · Xiaoming Li[1] · Zhenzhen Chen[3] · Fangyuan Liu[2]

✉ Zhenzhen Chen
20192057@zyufl.edu.cn

[1] International Business School, Zhejiang Yuexiu University, Shaoxing, China

[2] UCSI University, Kuala Lumpur, Malaysia

[3] Present Address: Fudan University, Shanghai, China