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Simulation Research on the Infection of Unsafe Behavior of Employees Based on Social Network

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Abstract: In order to study the characteristics of unsafe behavior contagion, based on the small world network, an unsafe behavior contagion model with behavioral rules such as homogenization aggregation, second-degree relationship distance of infection, influence paradox, and attenuation of behavioral contagion was constructed. The Netlogo platform was used for simulation. According to the results, it is found that the transmission of unsafe behavior has the contagion characteristics of hysteresis, emerging, and progressiveness. Whether the contagion behaviors occur was determined by the average path length of the network. The strong connection relationship in the network structure would trigger the infection of unsafe behavior. There was a significant positive correlation between the node distribution level of the network structure and the time-consuming cycle of unsafe behavior. Through research and exploration of the formation law and diffusion characteristics of unsafe behaviors in social networks, it is expected to provide theoretical support and direction guidance for the prevention and control of unsafe behaviors in social networks, thereby promoting the improvement of individual and organizational safety performance.

1. Introduction

Behavioral contagion originated from the study of group behavior. The existence of behavioral contagion effects was initially pointed out in "The Crowd-A Study of the Popular Mind" by Gustave Le Bon, and he argued that emotions and behaviors in the group were contagious. Wheeler[1] defined behavioral contagion, indicating that when behavioral contagion occurs, the recipient's behavior becomes more like the initiator's behavior. In the process of behavioral contagion, the initiator did not deliberately communicate, trigger, or provoke a change in the recipient's behavior. In the field of domestic research, behavioral contagion was defined as the process of homogenizing the behavior of interacting people through behavior without considering the influence of internal and external factors.

According to the above theory, unsafe behavior should be contagious. And in the process of infection, the influence of individual internal factors and other external factors were not taken into account, and the interaction between individuals was concentrated. The theory of social contagion believes that the behavior of individuals in network relationships not only affected their direct connecting people (one-degree relationship), but also the indirect connecting people' connecting people (second-degree relationship), and even the connecting people' connecting people' connecting people (third-degree relationship). The effect of behavioral contagion determined the distance of infection, which was manifested as the spread of behavior [2].

Based on this, through a variety of experimental methods such as human-computer interaction experiments, random control experiments, online experiments, and computer simulation experiments, the contagion effects of a variety of different behaviors have been confirmed by scholars at home and abroad, namely, offensive behavior, rebellious behavior, self-harm behavior, consumer behavior, new technology adoption behavior, smoking behavior, divorce behavior, voting behavior, helping behavior, financial behavior, suicidal behavior, bank run behavior, and antisocial behavior[3-8],which provided a reference for the verification of the contagion effect of unsafe behavior and the study of the distance of infection. Complex network was characterized in portraying the structure of interpersonal networks in the social system. In the actual social ecosystem, it was more common to find systems with the characteristics of small-world networks. Therefore, it was of more realistic value to explore the contagion and evolution of unsafe behaviors under the structure of small-world networks.

Through the simulation of behavioral contagion in the small-world network, it is found that behavioral contagion depended on the width of the bridge connection, and behavioral contagion had the characteristics of multi-source enhanced network structure[9]. Using complex network modeling and simulation techniques (Agent simulation modeling, etc.), the behavior of micro-individuals was simulated, thus realizing the evolution and analysis of macro-group phenomena [10]. Based on the simulation of Agent simulation modeling technology, the contagion effects of behaviors such as habitual behavior [11] and the network structure characteristics and influence mechanism of behavioral contagion in small-world networks [12]were verified. Agent simulation modeling technology was feasible for behavioral contagion in small-world networks, which could be adopted to analyze the network structure characteristics and influence mechanism of unsafe behavioral contagion.

2. Model Construction

Based on Agent simulation modeling technology, under the small-world network structure, the contagion law of individual unsafe behavior along the network structure was explored. An individual was defined as a single agent, represented by a node. The social relationship between individuals was represented by the small-world network connection. There was behavioral contagion due to the interaction between individual agents with different behavioral attributes.

Here are rules of behavior for an individual's unsafe behavior. First of all, multiple individuals with unsafe behavior characteristics are connected through relationships and show aggregation. Secondly, individual unsafe behaviors are affected by their social networks. There is behavioral contagion between individuals-colleagues-colleagues, that is, unsafe behavioral contagion within the second-degree relationship connection. Thirdly, the contagion influence of unsafe behavior shows an exponential attenuation characteristic according to the distance of infection. The influence index is the greatest in the first-degree relationship, it decays in the second-degree relationship, and the influence is no longer significant in the third-degree relationship[13-14]. Fourthly, under the network structure, the greater the strength of the relationship connection, the closer the relationship between the individual and the adjacent individual will be, and the stronger the interaction. Fifthly, in the network connection structure, the degree of centrality is selected as an indicator of the influence of individual behavior. The greater the centrality of an individual, the less affected the individual is by the smaller the centrality of the adjacency relationship, that is, the greater the difficulty (threshold) of changing its behavioral state. Sixthly, the behavioral contagion threshold refers to the threshold value of an individual's behavioral state change after being affected by the contagion of the unsafe behavior of the adjacency. If the comprehensive force of the individual's behavior after interaction is not greater than this threshold value, the original behavior will be maintained; after interaction, if the individual's behavioral force is greater than the threshold value, the behavioral state changes, showing the phenomenon of behavioral contagion. In this study, the threshold value of behavioral state change in the existing research results of Klein et al. is used to define the infection threshold value of unsafe behavior[15].

The model of unsafe behavior infection under the small world network includes both individual behavior attributes and the connection of relationships between individuals. In this study, based on reference to previous research results, the Christakis-Fowler model proposed by Gonzalez-Pardo, Cajias and Camacho was used as a basic model, combined with the characteristics of unsafe behavior infection, the model was constructed[16].

- A small world network with n nodes is constructed, and the (unsafe) behavioral force Y value of n nodes should obey the normal distribution at time t_0, Yt_0~(0.5,0.166).
- Drawing on the equation of behavioral state change in the research results of Klein et al., the threshold value θ of behavioral contagion was affected by the “number of relational connections W, the strength of relational connections b, and the initial behavioral force Y” of the individual agent. θ and b showed a reverse trend change. The number of connections between θ and the relationship W showed a positive trend change, the formula was as follows:

$$\theta = \frac{1}{1 + e^{\frac{1}{W}(b-Y)}}, b \sim N(0,1)$$

- In the second-degree relationship, the force of individual unsafe behavior was affected by the behavior of adjacent individuals, and the influence of behavioral contagion showed exponential attenuation characteristics. β was used to indicate the degree of influence of adjacent individuals on the Agent in the first degree relationship. (1-β) indicated the degree of influence of adjacent individuals in the second degree relationship on the Agent. And β=N×(1–β), N≥1, then the Agent individual i is affected by the behavior of the agent individual j in the adjacency second-degree relationship at time t0 Yjt0 was:

$$Y_{j,t_0} = \sum_{j=1}^{2} [(j-1)(1-\beta) + (2-j)\beta] \frac{\sum jY_{i,j,t_0}}{W_{i,j}}$$

- When the Agent individual i interacts with other connected individuals at time t0, it was affected by the behavior of other adjacent Agent individuals j within the second-degree relationship. Relational connection strength b was used to measure the degree of influence of adjacent individuals on Agent individuals; Then, the behavioral force Yit0+1 of the individual agent at the moment of t0+1 was:

$$Y_i t_{0+1} = (1+b)[Y_i t_0 + Rand(0,0.05)] + b\left[Y_{j,t_0} + Rand(0,0.05)\right], j = 1,2$$

- The values of the behavioral force Yit0+1 of the individual Agent at the time of t0+1 and the threshold value θ of the individual Agent's behavioral contagion were compared. When the value of the former was greater than the latter, the behavior state S of the individual Agent changed, resulting in unsafe behavior contagion.

$$S = \begin{cases} 1\ if Y_i t_{0+1} > \theta \\ 0\ if Y_i t_{0+1} \leq \theta \end{cases}$$

▪ All Agent individuals with state S of 0 were performed in Step d. Cycle in turns until the state S of all agents was 1, and the cycle would be stopped.

3. Simulation Experiment and Results

In this study, the Netlogo platform was used to simulate and run the unsafe behavior infection model based on the small-world network. First of all, the small world network was built. The nodes of the small world network were configured with behavioral attributes, and the Agents with specific attributes were connected in a small range to meet the homogenized aggregation state between insecure actors. Secondly, the interaction between Agents was activated. If the behavioral force of the interacting Agent was greater than the threshold value of the behavioral contagion, the behavioral state of a single Agent was updated; otherwise the behavioral force attributes were updated to participate in the next round of Agent interaction. Finally, after multiple rounds of interaction, until all Agents had achieved behavioral state changes, the entire simulation process would be terminated.

▪ Num-nodes were used to describe the number of nodes in the small world network, that is, the number of individual Agents in the small world network, with a value from 10 to 300.

▪ Rewiring-probability was used to control the average path length and clustering level of the formation of a small world network, with values between 0 to1. 0 represented a regular network, 1 represented a random network, and greater than 0 and less than 1 represented the small world network structure.

▪ Rewire-all was applied to complete the conversion from a regular network to a small world network. The constructed small-world network structure (node degree distribution level) was generated based on the size of the Rewiring-probability value.

▪ Num-red was applied to indicate the number of nodes with a behavior state S of 1 when building a small world network, which referred to the number of randomly generated Agent with unsafe behavior.

▪ Homogenization was used to perform small-scale local interconnection of Agent individuals with behavior state S of 1, so as to configure the homogenized aggregation state of Agent unsafe behavior individuals under initial conditions.

▪ β represented the degree of influence of adjacent individuals on the Agent in the first degree relationship. (1-β) represented adjacent individuals in the second-degree relationship. The degree of influence of all adjacent individuals on a single agent was set as 1, and based on the research results of Christakis &Fowler, β was set as 0.75.

▪ b was utilized to represent the connection strength of the relationship between Agents, with the value from 0 to1. The value indicated the intensity of the influence of adjacent individuals on the Agent; The greater the b value, the more the relationship connection tended to be a strong connection, and the stronger the influence would be; the smaller the b value, the more the relational connection tended to be a weak connection, and the weaker the influence would be.

▪ Interaction was applied to control the interaction effects of unsafe behaviors on Agent groups under the small world network. According to the behavioral infection threshold, whether a single agent changes its behavioral state S should be determined.

▪ Through Average-path-length, the average path length of the entire small world network was calculated, which referred to the average of the shortest path length (or distance) between the two Agent nodes in the small-world network. The shortest path referred to the shortest path that starts from one node i, passes through the node connected to it, and gradually "reach" another node J.

3.1. Characteristics of Hysteresis, Emergence, and Progressiveness

In the process of interaction between individual agents, after many experiments, at the level of connection strength and clustering coefficient of different relationships, the phenomenon that the number of unsafe actors in the early stage was common. And then, the number of unsafe actors gradually increased, and the number of safe actors gradually decreased. In the early stage of Agent interaction, there was a behavioral contagion effect between different types of actors; however, this contagion effect did not cause an increase in the number of unsafe actors until the end of the "steady-state phenomenon", reflecting the "hysteresis" characteristic of behavioral contagion, which was different from the instantaneous characteristic of information dissemination.

In the meantime, the interaction between individuals of unsafe actors and individuals of safe actors has triggered more and wider spread of unsafe behaviors, which was the feature that single-type cooperative behavior groups or single-type safe behavior groups did not perform. It was a feature that could not be presented by a simple combination of "single-type unsafe behavior groups" and "single-type safe behavior groups". Consequently, the phenomenon of the spread of unsafe behavior generated by the overall effect of the relationship network structure was endowed with a functional nature that was not possessed by the "isolated part and its aggregated part", which was a kind of "emergence" of the spread of unsafe behavior. Finally, after the hysteresis and emergence of multiple infections were superimposed together, the progressive characteristics of the spread of unsafe behaviors were revealed.

3.2. Restriction Analysis of Average Path Length

Under the premise of controlling the connection strength b of the relationship (the b value was 0.5), with the help of the Behavior-space tool, the small world network simulation experiment was carried out 500 times. Through the averaging of 10 behavioral infection experiment steps at the level of a single average path length, the time-consuming (steps) level of the agent set to complete unsafe behavioral infection was obtained.

In the first 90 experiments, the small-world network had a higher level of average path length, and its agent set took more time to complete unsafe behavioral infection, revealing that the high level of average path length constrained the speed of behavioral infection; In other words, the time it takes for unsafe behavior transmission to occur between agent individuals was related to the length of the shortest path between them. In 90-500 times of experiments, the average path length change of the small world network has maintained a relatively stable level. The level of time it takes for the Agent set to complete the infection of unsafe behavior maintained in the "upper and lower fluctuation range of 8.2 steps". On the one hand, the characteristics of the average path length that restricts the time-consuming transmission of behavior have been revealed. On the other hand, in terms of fluctuations in infection time, the explanation of this study was as follows: Because behavioral contagion had the characteristics of a multi-source enhanced network structure, it was on a small-world network with differentiated node distribution levels. That is, different small-world networks had different node degree distribution kurtosis and skewness, and the number of agent individual relationship connections had different degrees (different multi-source levels). Accordingly, on a small-world network with the same average path length, differences in the distribution level of nodes, such as differences in peak levels, caused differences in the time-consuming behavior of infection. (Under the constraints of the average path length, the difference fluctuated up and down at a level centered on 8.2 steps).

3.3. Analysis of the Impact of Relationship Strength

Relational connection strength b and Rewiring-probability were taken at different levels. Using the Behavior-space tool in Netlogo, the influence of relational connection strength b and average path length of the small world network on the time-consuming transmission of agent unsafe behavior was explored. In Behavior-space, simulation experiments were conducted 650 times.

There was a reverse trend of change between the relationship connection strength (b) and the transmission time (steps); when the connection strength of the relationship between Agents increased in the interval from 0 to 1, the time-consuming infection tended to decrease. Conversely, when the strength of the relationship between agents gradually decreased, the time-consuming infection tended to increase; When the strength of the relational connection was greater than 0.2, the contagion rate began to decrease at an accelerated rate, and increased with the strength of the relational connection. Especially when the strength of the relationship connection was greater than 0.4, the time-consuming infection suddenly decreased drastically; It was revealed that the strength of the relationship connection directly affected the rate of transmission of unsafe behaviors. Under the strong relationship connection, the time-consuming transmission of unsafe behaviors between individual actors was quite short. In other words, behavioral contagion was more likely to occur and complete；On the contrary, under the weak relationship connection, the transmission of unsafe behaviors between actors took a longer time, making it more difficult for behavioral transmission to occur and complete, which was different from the weak connection theory in information dissemination. That is, under a strong connection, behavioral contagion could be triggered easily. Under weak connections, the diffusion and dissemination of information could be promoted. Based on the same average path length level, although the level of relationship connection strength was different, there were differences in the level of node degree distribution of different network structures. Under the influence of multi-source reinforcement, the time-consuming difference in the completion behavior of the agent set was triggered, which was reflected in the fluctuation of up and down within a certain interval; That is, there was the coexistence of light-colored line clusters and curved surfaces.

4. Conclusions

The law and diffusion characteristics of the formation of unsafe behaviors in social networks have explored in this study, revealing the law of the spread of unsafe behaviors among employees in the organization. When few members in the organization have unsafe behavior and the majority is not inclined to unsafe behavior, the infection of unsafe behavior starts from colleagues who are closely connected to few members, and then gradually spreads to colleagues' colleagues according to the network connection path. However, when a certain number of members are infected with - unsafe behavior, the unsafe behavior characteristics of more members will be emerged, forming the unsafe behavior characteristics of the organization. The conclusion of this research is of great significance for the prevention and control of unsafe behaviors in social networks. To intervene in unsafe behaviors in the organization, it is recommended to analyze the relationship structure between members in the organization and adjust the relationship connection to narrow the average relationship path. Through the application of external means to weaken the relationship connection, to prevent the emergence of unsafe behaviors in the organization, thereby promoting the improvement of individual and organizational safety performance. There are still some shortcomings in this research. In further research, it is essential to explore and expand the unsafe behavior of other degree distribution characteristic networks to explore the impact of differences in degree distribution characteristics on the spread of unsafe behaviors.

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