Evolutionary Path of Group Safety Behavior of Grass-Roots Employees

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Abstract. To discover the evolution rules of strategy choice for the group safety behavior of grass-roots employees, the payment matrix for the behavioral interaction among employees is constructed by virtue of the evolutionary economics. Through analysis of evolution model for the interactive process of behavior, the influence of strategy choice for the employees' individual behavior on the evolution of group behavior is revealed. Through numerical simulation, the study on the influence of variation in the different initial proportion and different parameters of group on the evolutionary trend. The result shows that it is conducive for grass-roots employees to have their behavior evolve towards the expected direction if business executives strengthen the safety check, fair in meting out rewards or punishments, improve employees' awareness to the cost of safety noncompliance behavior, lower the satisfaction from noncompliance operation, optimize the operation procedure and pre-job safety education and training.

Keywords: Evolutionary path · Grass-roots employees · Group game · Numerical experiment · Safety behavior

1 Introduction

Grass-roots employees' safety behavior exerts a great influence on the healthy and sustainable development of an enterprise as they directly participate in the production and engage in the element tasks. With the perfection of facilities and equipment and increasingly mature technology, the hard environment for the work safety of employees has witnessed a certain improvement, but the support for the soft environment such as encouragement of workmates to supervise others and communicate with each other about safety is ignored, as a result, the noncompliance production of employees still continues despite repeated prohibition and the risk of accident is increased [1]. It is pointed in the social learning theory put forward by Albert Bandura, an American psychologist that human behavior can be acquired through their own direct experience and model behavior of others, and people can form their own behavior through observing that of people around them [2]. As the grass-roots employees and their surrounding workmates are in the same work environment and their living environment and cultural level are similar, one person's behavior will inevitably have an impact on the others' behavior through exchange and communication about the safety and transfer of all information, and the group behavior of work safety or compliance production can

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also be formed [3], which will exert an influence on the employees' choice for their own attitude and behavior. Moreover, employees can judge their workmates' behavior and compare their own behavior with them, once a certain behavior can bring gains to them, other employees will learn such behavior [4].

Grass-roots employees of an enterprise are always in a group consisting of themselves and their workmates during the production process instead of being isolated. It is very easy for grass-roots employees to show the safety attitude and behavior [5] consistent with that of their workmates due to influence of group pressure as most of them have low education level, high labor intensity, weak safety awareness, yearn for integration into the group and being accepted by workmates. The group behavior of grass-roots employees is a stable status which is finally formed from the employees' interaction in the group and constant adjustment of their own strategies, during which employees and their workmates interact with each other, and workmates' safety behavior is a major factor affecting the safety atmosphere of the group. In the literature review by [6] with respect to the safety atmosphere of construction site, it is pointed the workmates' role and influence is an important dimension for the safety atmosphere. Also, there are scholars verifying the workmates' influence and support behavior are the major parts constituting the safety atmosphere of a group [7, 8] through factor analysis. Zohar's (2010) study shows the group atmosphere and workmates' behavior exert a significant influence on the employees' safety behavior, and positive friendship among workmates can reduce the adverse influence of low-level safety atmosphere on the employees' attitude towards safety and safety behavior from the network perspective of employees' friendship [9]. Fugas, Silva and Meliá (2012) discovers the workmates' behavior plays a role of regulating the employees' cognition of standard for safety and attitude towards safety in the study on relations between the safety atmosphere and safety behavior in the transformational leadership organization [10]. Besides, Zhou, Fang and Wang (2008) draw a conclusion from the study that the degree of influence of safety atmosphere (colleague's influence and management commitment) on the safety behavior is greater than that of personal experience thereon according to Bayesian Theory [11].

Thus it can be seen that the grass-roots employees' safety behavior is closely related to their workmates' behavior [12], however, there is few study in the domestic and foreign literatures based on the interaction of their employee' safety behavior. Therefore, this article provides theoretical support and policy suggestion for normalizing the group behavior of grass-roots employees through building game model between employees and their workmates with evolutionary economics theory and discussion about the factor affecting the evolutionary results through analysis of evolution model in the interactive process.

2 Methodology

A. *Model assumption*

In the same group (such as a team), the grass-roots employees' and their workmates' choice for safety behavior is interactive and is a dynamic adjustment process. It is

assumed that the employees' attitude towards safety and safety behavior in the group are different, some have strong safety consciousness, while some have weak safety consciousness, therefore, employees in the group are divided into Group A and Group B, two game players with bounded rationality, from which one employee is randomly selected respectively each time to play the game. Behavior abiding by the provisions for work safety is called safety compliance behavior, while the behavior inconsistent with the provisions for work safety is called safety noncompliance behavior [13].

The second it is assumed that employees need to contribute extra labor L in case of choice for work safety behavior, coefficient of gains from work safety behavior is α_1, coefficient of gains from production is α_2, the potential loss to be borne by employees in case of choice for safety noncompliance behavior is S_Z; as the safety compliance behavior may cause injury and death to workmates, the potential loss to be borne by workmates is λS_Z ($\lambda > 0$). The psychological satisfaction obtained by employees who choose safety compliance behavior due to puppyism or follow of their workmates' behavior is called puppyish gains V, and such behavior can bring negative demonstration effect (D) to the workmates. The probability that employees choose safety noncompliance behavior are discovered by enterprise executives is P_{C1}, once being discovered, those will be imposed upon a punishment B (fine and deduction of bonus), and all the workmates in the team getting involved will be also imposed upon a punishment εB ($\varepsilon > 0$) and will complain, as a result, the workmates' words and deeds will bring a certain psychological blow E to the noncompliance employees. If all the selected employees choose the safety noncompliance behavior, the probability for the discovery of noncompliance behavior will rise to P_{C2}, which, together with P_{C1}, reflects the enterprise's strength for supervision over its employees' work safety. Table 1 shows the payment matrix built for the game of grass-roots employees' choice for work safety behavior model.

Table 1. Payment matrix

	Employee A	Employee B
Safety compliance	$a = \alpha_1 L$, $e = \alpha_1 L$	$c = \alpha_1 L - \lambda S_Z - P_{C1}\varepsilon B - D$, $g = \alpha_2 L - S_Z - P_{C1}B + V - P_{C1}E$
Safety noncompliance	$b = \alpha_2 L - S_Z - P_{C1}B + V - P_{C1}E$, $f = \alpha_1 L - \lambda S_Z - P_{C1}\varepsilon B - D$	$d = \alpha_2 L - S_Z - P_{C2}B + V$, $h = \alpha_2 L - S_Z - P_{C2}B + V$

B. *Model evolution*

To build the replicated dynamic equation for the grass-roots employees' choice for work safety behavior model according to the game relationship above, and simulate the replicated game process of these two groups with bounded rationality with such replicated dynamic equation. It is assumed that, at the initial time of the game, proportion of employees in the Group A that choose safety compliance behavior strategy is p, and that choose safety noncompliance behavior strategy is $1 - p$; while proportion of employees in the Group B that choose safety compliance behavior strategy is q, and that choose safety noncompliance behavior strategy is $1 - q$.

Gains U_1 and U_2 respectively from employees' choice for safety compliance behavior and safety noncompliance behavior strategy in Group A is:

$$U_1 = qa + (1-q)c \tag{1}$$

$$U_2 = qb + (1-q)d \tag{2}$$

The replicated dynamic equation for employees' choice for safety compliance behavior in Group A is as follows:

$$F(p) = \frac{dp}{dt} = p(1-p)(U_1 - U_2) = p(1-p)[q(a-b-c+d)+c-d] \tag{3}$$

Gains V_1 and V_2 respectively from employees' choice for safety compliance behavior and safety noncompliance behavior strategy in Group B is:

$$V_1 = pe + (1-p)f \tag{4}$$

$$V_2 = pg + (1-p)h \tag{5}$$

The replicated dynamic equation for employees' choice for safety compliance behavior in Group B is as follows:

$$F(q) = \frac{dq}{dt} = q(1-q)(V_1 - V_2) = q(1-q)[p(e-g-f+h)+f-h] \tag{6}$$

Jacobian Matrix of the equation obtained therefrom is:

$$J = \begin{bmatrix} \frac{dF(p)}{dp} & \frac{dF(p)}{dq} \\ \frac{dF(q)}{dp} & \frac{dF(q)}{dq} \end{bmatrix} = \begin{bmatrix} (1-2p)[q(a-b-c+d)+c-d] & p(1-p)(a-b-c+d) \\ q(1-q)(e-g-f+h) & (1-2q)[p(e-g-f+h)+f-h] \end{bmatrix} \tag{7}$$

By recording the determinant of Jacobian Matrix as Det J and its trace as Tr, we can get:

$$\begin{aligned} \text{Det J} = {} & (1-2p)(1-2q)[q(a-b-c+d)+c-d][p(e-g-f+h)+f-h] \\ & -pq(1-p)(1-q)(a-b-c+d)(e-g-f+h) \end{aligned} \tag{8}$$

$$Tr = (1-2p)[q(a-b-c+d)+c-d] + (1-2q)[p(e-g-f+h)+f-h] \tag{9}$$

3 Analysis

The symbols p and q respectively represent the proportion of individuals in Group A and B that choose the compliance behavior strategy in such group, so $0 \leq p \leq 1$ and $0 \leq q \leq 1$, and equilibrium and stability of the system will be discussed about on the plane $M^* = \{(p, q) | 0 \leq p, q \leq 1\}$.

Case 1: When $a - b > 0$ (or $e - g > 0$) and $c - d > 0$ (or $f - h > 0$), the system has four equilibriums, among which (0,0) is source point, (1,1) is stable point, while (0,1) and (1,0) are saddle point, and see Fig. 1 for the dynamic interactive process. No matter what kind of strategy the other player chooses, gains from safety compliance behavior strategy are greater than those from safety noncompliance behavior strategy. Therefore, increase the employees' understanding of the importance of work safety, have them fully realize the safety gains and the potential loss from noncompliance behavior; reinforce the strength for the inspection of and punishment upon employees' safety noncompliance behavior; strengthen the construction of safety atmosphere and reduce puppyish gains from employees' safety noncompliance behavior and cut off their adverse demonstration effect to make the system evolve into the mode of (compliance, compliance).

Case 2: When $a - b < 0$ (or $e - g < 0$) and $c - d < 0$ (or $f - h < 0$), the system has four equilibriums, among which (1,1) is source point, (0,0) is stable point, while (0,1) and (1,0) are saddle point, and see Fig. 2 for the dynamic interactive process. In this case, the system will evolve into the mode of (noncompliance, noncompliance), and no matter what kind of strategy one player chooses, gains from safety compliance behavior strategy by the other player are less than those from safety noncompliance behavior strategy. The accident is caused by many factors including safety noncompliance behavior, therefore, employees' noncompliance may not cause accident, in this state, their workmates may even imitate their safety noncompliance behavior due to gains-seeking and fluke mind instead of stopping the same, as a result, the safety noncompliance behavior exerts a further influence on the workmates around and causes the whole system to fall into an "adverse" locking mode.

Case 3: When $a - b < 0$ (or $e - g < 0$) and $c - d > 0$ (or $f - h > 0$), the system has five equilibriums, among which (0,0) and (1,1) are source point, (0,1) and (1,0) are stable point, while (p^*, q^*) is saddle point, and see Fig. 3 for the dynamic interactive process. In this case, the system will evolve into the mode of (compliance, noncompliance) or (noncompliance, compliance).

In such case, the game player can obtain higher gains as long as he or she chooses the strategy different from that of the other players, which means when employees of one player choose compliance behavior, those of the other that choose the safety noncompliance behavior will obtain higher gains and vice versa. Strategy chosen employees will witness adjustment according to the status of whole behavior of the group. If the safety noncompliance behavior in the group is relatively serious, employees therein will be inclined to the safety compliance strategy in the new round of the game, and vice versa as it is easy for an enterprise to relax the safety inspection when the safety compliance is better, and employees will be inclined to the safety

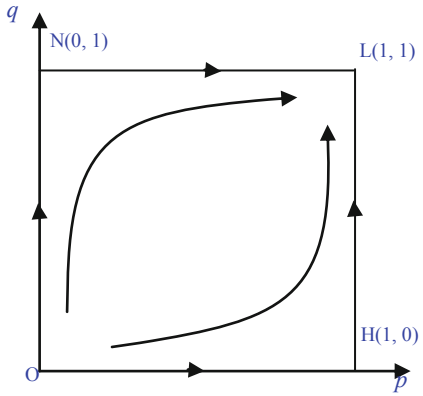

Fig. 1. Dynamic interactive process of case 1

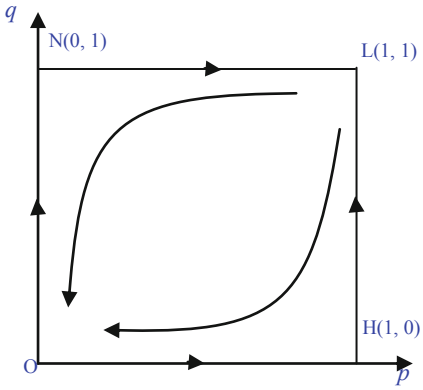

Fig. 2. Dynamic interactive process of case 2

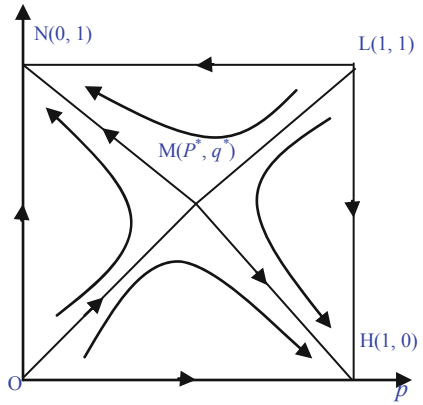

Fig. 3. Dynamic interactive process of case 3

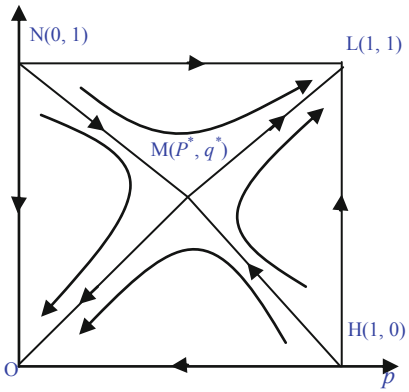

Fig. 4. Dynamic interactive process of case 4

noncompliance behavior to meet their own interests, at which time employees choosing safety compliance behavior will be inclined to choose the safety noncompliance strategy as they obtain smaller gains; however, with the seriousness of noncompliance, enterprise will strengthen the inspection, at which time employees will turn to choose the safety compliance behavior due to worrying about being punished and having their workmates get involved upon exposure of safety noncompliance, and those employees will not only get punished due to noncompliance with the standard for safety, but also the safety rating of their group will be affected and their workmates' bonus will be deducted, then employees choose safety compliance behavior will get gains higher than those of the employees choosing safety noncompliance behavior. To avoid the evolution of system into such a mode, the probability for the discovery of one employee's safety noncompliance behavior is required to be improved, which means enterprise shall immediately take measures to prevent and punish employees choosing safety noncompliance behavior instead of doing so until the safety noncompliance behavior in the group becomes serious.

Case 4: When $a - b > 0$ (or $e - g > 0$) and $c - d < 0$ (or $f - h < 0$), the system has five equilibriums, among which (0,1) and (1,0) are source point, (0,0) and (1,1) are stable point, while (p^*,q^*) is saddle point, and Fig. 4 shows the dynamic interactive process and Table 2 for analytic results of local stability.

$$p^* = q^* = \frac{(\alpha_2 - \alpha_1) + (\lambda - 1)S_Z + P_{C1}\varepsilon B - P_{C2}B + V + D}{P_{C1}B + P_{C1}E + P_{C1}\varepsilon B + \lambda S_Z + D - P_{C2}B} \tag{10}$$

In Fig. 4, the broken line between two unstable equilibriums (0,1) and (1,0) and saddle point (p^*,q^*) is the boundary where the system converges to the two different modes, (compliance, compliance) and (noncompliance, noncompliance), and the evolutionary process and stable state of group are affected by the proportion of employees choosing the different strategies in the group and relative location of saddle point M. The stable equilibrium result in the game between employees and their workmates may

Table 2. Analytic results of local stability

Equilibriums	Det J		Tr		Result
$p = 0, q = 0$	$-(c-d)(f-h)$	+	$(c-d)+(f-h)$	–	ESS
$p = 0, q = 1$	$-(c-d)(e-g)$	+	$-(c-d)+(e-g)$	+	Unstable
$p = 1, q = 0$	$-(a-b)(f-h)$	+	$(a-b)-(f-h)$	+	Unstable
$p = 1, q = 1$	$(a-b)(e-g)$	+	$-(a-b)-(e-g)$	–	ESS
$p = p^*, q = q^*$	$-p^*q^*(1-p^*)(1-q^*)$ $(a-b-c+d)(c-g-f+h)$	–	0		Saddle point

be compliance or noncompliance behavior, and their evolutionary path and stable state depend on the area S_{HMNO} and S_{HLNM} of the region HMNO and HLNM respectively. To conduct the parameter analysis and regulation through analyzing the factors affecting the area S of regions. When $S_{HLNM} > S_{HMNO}$, the system will evolve into the compliance behavior along the path ML in a higher probability; when $S_{HLNM} < S_{HMNO}$, the system will evolve into the noncompliance behavior along the path MO in a higher probability; according to Fig. 4,

$$S_{HLNM} = 1 - \frac{1}{2}(p^* + q^*) = 1 - \frac{(\alpha_2 - \alpha_1) + (\lambda - 1)S_Z + P_{C1}\varepsilon B - P_{C2}B + V + D}{P_{C1}B + P_{C1}E + P_{C1}\varepsilon B + \lambda S_Z + D - P_{C2}B} \tag{11}$$

In the compliance model of employees of middle and small-sized enterprises, there are 11 parameters involved therein in total, based on which the evolutionary direction of safety compliance behavior of employee group is analyzed below, with the result shown in Table 3.

Proposition 1: Proportion p and q of employees choosing compliance behavior in the group is in direct proportion to the extra labor L required to be contributed by employees choosing safety compliance behavior, puppyish gains V, variations of gains $(\alpha_2 - \alpha_1)$ and probability P_C for the discovery of noncompliance behavior, while in inverse proportion to negative effect D and psychological blow E.

As the L, V, $(\alpha_2 - \alpha_1)$ and E have a monotonic relationship with p^* and q^*, the impact of increase and decrease on p^* and q^* can be seen obviously. By seeking partial derivatives of P_C and D through p^* and q^* respectively, we can get.

$$\frac{\partial p^*}{\partial p_{C2}} = \frac{\partial q^*}{\partial p_{C2}} = \frac{B(b-a)}{(a-b-c+d)^2} < 0 \tag{12}$$

$$\frac{\partial p^*}{\partial D} = \frac{\partial q^*}{\partial D} = \frac{a-b}{(a-b-c+d)^2} > 0 \tag{13}$$

The proposition is proved.

Proposition 2: The impact of punishment B upon employees due to noncompliance on the employees' choice for behavior is uncertain.

By seeking partial derivatives of B through p^* and q^*, we can get:

$$\frac{\partial p^*}{\partial B} = \frac{\partial q^*}{\partial B} = \frac{(P_{C1}\varepsilon - p_{C2})(a-b) - P_{C1}(d-c)}{(a-b-c+d)^2} \tag{14}$$

When

$$\varepsilon < \frac{1}{P_{C1}}\left[\frac{P_{C1}(d-c)}{a-b} + P_{C2}\right] \tag{15}$$

And

$$\frac{\partial p^*}{\partial S_Z} = \frac{\partial q^*}{\partial S_Z} < 0 \tag{16}$$

B is in inverse proportion to the proportion p and q of employees choosing compliance behavior in the group; when

$$\varepsilon > \frac{1}{P_{C1}}\left[\frac{P_{C1}(d-c)}{a-b} + P_{C2}\right] \tag{17}$$

And

$$\frac{\partial p^*}{\partial S_Z} = \frac{\partial q^*}{\partial S_Z} < 0 \tag{18}$$

B is in direct proportion to the proportion p and q of employees choosing compliance behavior in the group; therefore, the proposition is proved.

Proposition 3: Impact of potential loss S_Z on the employees' choice for behavior is uncertain.

By seeking partial derivatives of S_Z through p^* and q^*, we can get:

$$\frac{\partial p^*}{\partial S_Z} = \frac{\partial q^*}{\partial S_Z} = \frac{(\lambda-1)(a-b)+c-d}{(a-b-c+d)^2} \tag{19}$$

When

$$0 < \lambda < \frac{d-c}{a-b} + 1 \tag{20}$$

And

$$\frac{\partial p^*}{\partial S_Z} = \frac{\partial q^*}{\partial S_Z} < 0 \tag{21}$$

The potential loss S_Z is in inverse proportion to the proportion p and q of employees choosing compliance behavior in the group; when

$$\lambda > \frac{d-c}{a-b} + 1 \tag{22}$$

And

$$\frac{\partial p^*}{\partial S_Z} = \frac{\partial q^*}{\partial S_Z} > 0 \tag{23}$$

The potential loss S_Z is in direct proportion to the proportion p and q of employees choosing compliance behavior in the group; therefore, the proposition is proved.

Table 3. Impact of variations of parameters on employees' behavior strategies

Variations of parameters		Variations of saddle point	S_{HLNM}	Evolutionary direction
$L \downarrow$		$p^* \downarrow, q^* \downarrow$	$\uparrow$	(Compliance, compliance)
$V \downarrow$		$p^* \downarrow, q^* \downarrow$	$\uparrow$	(Compliance, compliance)
$(\alpha_2 - \alpha_1) \downarrow$		$p^* \downarrow, q^* \downarrow$	$\uparrow$	(Compliance, compliance)
$E \uparrow$		$p^* \downarrow, q^* \downarrow$	$\uparrow$	(Compliance, compliance)
$P_{C2} \uparrow$		$p^* \downarrow, q^* \downarrow$	$\uparrow$	(Compliance, compliance)
$D \uparrow$		$p^* \uparrow, q^* \uparrow$	$\downarrow$	(Noncompliance, noncompliance)
$B \downarrow$	$\varepsilon < \frac{1}{P_{C1}}\left[\frac{P_{C1}(d-c)}{a-b} + P_{C2}\right]$	$p^* \uparrow, q^* \uparrow$	$\downarrow$	(Noncompliance, noncompliance)
	$\varepsilon > \frac{1}{P_{C1}}\left[\frac{P_{C1}(d-c)}{a-b} + P_{C2}\right]$	$p^* \downarrow, q^* \downarrow$	$\uparrow$	(Compliance, compliance)
$S_Z \uparrow$	$0 < \lambda < \frac{d-c}{a-b} + 1$	$p^* \downarrow, q^* \downarrow$	$\uparrow$	(Compliance, compliance)
	$\lambda > \frac{d-c}{a-b} + 1$	$p^* \uparrow, q^* \uparrow$	$\downarrow$	(Noncompliance, noncompliance)

4 Results

In order to reflect the impact of variations of parameters on the evolutionary result more intuitively, and as some variables cannot be analyzed through derivation of saddle point, numerical experiment is hereby conducted with Matlab simulation software against the complex evolution of Case 4 to analyze the impact of initial proportion of the group choosing one tactic and variations of parameters affecting the gains of game players on the system evolutionary result. By considering the preconditions of Case 4 and constraint from facts, the value of parameters besides the analyzed object parameters is as follows: $\alpha_1 = 1.2$, $\alpha_2 = 2$, $L = 1.4$, $\lambda = 0.2$, S_Z=2, $P_{C1} = 0.5$, $P_{C2} = 0.6$, ε=0.6, $B = 0.3$, $V = 0.5$, $D = 0.6$ and $E = 0.06$.

(1) See Fig. 5 for the result of numerical experiment on the impact of changes of initial proportion of the group choosing one tactic on the evolutionary result, among which p_0 and q_0 respectively represent the initial proportion of employees choosing the safety compliance behavior in Group A and Group B.

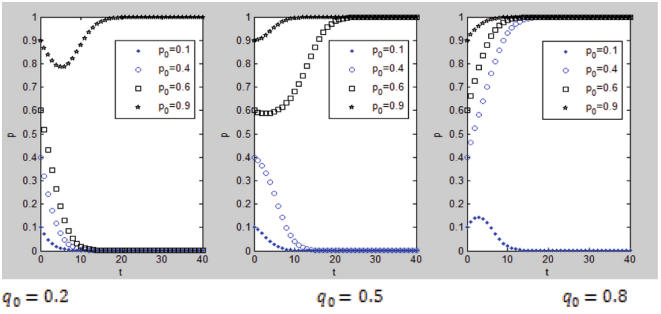

Fig. 5. Impact of changes of initial proportion's difference of the group choosing one tactic on the evolutionary result

The caption According to Fig. 5, the evolutionary process of strategy interaction behavior between employees and workmates has the path dependence. Path lines starting from different initial conditions will not be overlapped before converged to the equilibrium state. The time length for the convergence to the equilibrium state is related to the initial proportion of employees choosing different strategies in the group, when the proportion approaches to the equilibrium state, the rate of convergence becomes faster. For the circumstances where more employees choose safety noncompliance behavior, this essay will next focus on the analysis of the circumstance where the initial proportion of the group choosing safety compliance behavior which is lower (i.e. $q_0 = 0.2$) and analyze the impact of variations of different parameters on the evolutionary result of the group through numerical experiment to guide the system to evolve into the ideal stable state of (compliance, compliance).

(2) See Fig. 6 and Fig. 7 for the result of numerical experiment on the impact of extra labor L required for safety compliance behavior and changes of gains $(\alpha_2-\alpha_1)$ on the evolutionary result.

According to Fig. 6, when the extra labor L required for safety compliance behavior and gains difference between production and safety input $(\alpha_2-\alpha_1)$ rise to a certain extent, the employees' and their workmates' behavior will totally evolve into the mode of (noncompliance, noncompliance). Especially under the circumstance where the enterprise implements the piecework wage, grass-roots employees can clearly realize the gains from production, and work safety can be easily ignored for the saving of labor. Therefore, on one hand, enterprise should provide favorable conditions for work safety, improve production environment, have its safety facilities, equipment and products conform to the Standard for Ergonomics, and reduce additional operational steps and difficulty in operation to the greatest extent; on the other hand, enterprise should also provide the favorable cultural atmosphere for work safety instead of focusing on the improvement of production efficiency to make its employees fully realize the potential benefits of work safety for the enterprise, especially for themselves and their workmates.

(3) See Fig. 8 and Fig. 9 for the result of numerical experiment on the impact of puppyish gains V from safety noncompliance and psychological blow E after being discovered on the evolutionary result. V and E are the analysis of evolutionary result from the perspective of psychology, differently, the former refers to the psychological satisfaction of employees from following their workmates' noncompliance, while the later refers to the psychological damage caused to the employees due to their workmates' complaint and isolation as their noncompliance behavior causes injury and even death to their workmates. According to the figures, when the puppyish gains rise to a certain extent, the system will evolve into the mode of (noncompliance, noncompliance), which explains employees in the group can follow their workmates' safety noncompliance behavior and such behavior is infectious. Besides, psychological blow E has little influence on the evolutionary result, but the system will need a longer time to converge to the equilibrium state with the increase of E. Therefore, it is vital to improve the safety atmosphere of the group and to improve employees' sensitivity towards their workmates' noncompliance behavior to make the con-compliance behavior lack proper environment and thus try to reduce the psychological satisfaction to the employees from noncompliance behavior. Moreover, conduct training for the safety education to make employees fully realize the potential damage of noncompliance behavior to their workmates and improve their awareness to the cost of noncompliance behavior.

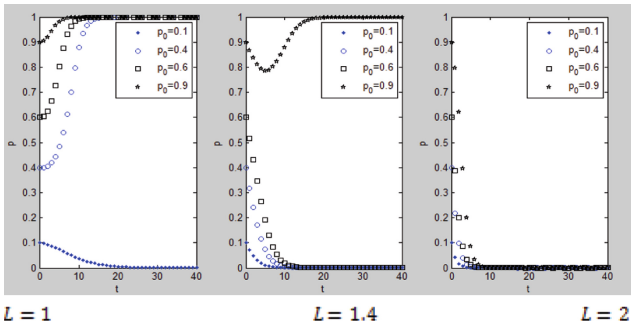

Fig. 6. Impact of changes of extra lab of safety compliance behavior on the evolutionary result

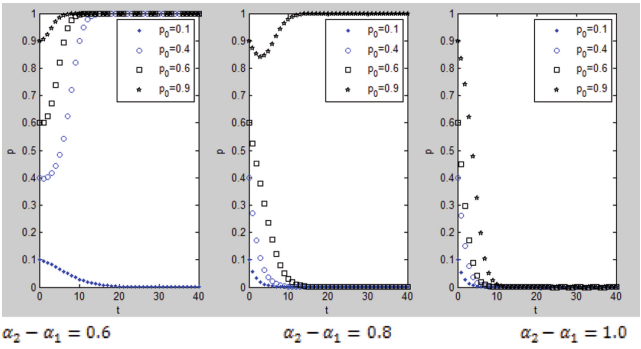

Fig. 7. Impact of changes of the gains difference between production and safety input on the evolutionary result

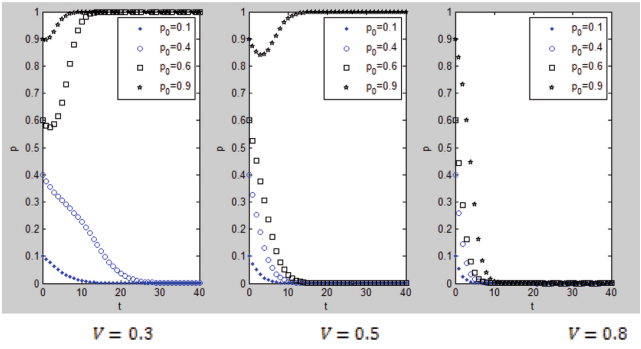

Fig. 8. Impact of changes of puppyish gains on the evolutionary result

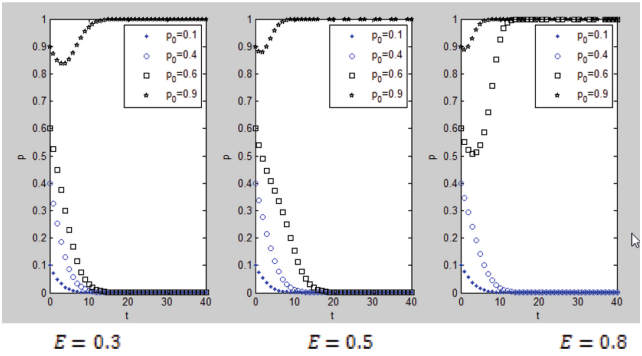

Fig. 9. Impact of changes of psychological stress the evolutionary result

(4) See Fig. 10 to Fig. 12 for the result of numerical experiment on the impact of punishment B for and accident loss S_Z from safety noncompliance behavior and enterprise supervision on the evolutionary result. The trend of influence of B and S_Z, such two losses on the system evolutionary results are same. However, with respect to the punishment actually incurred, the expected accident loss is the potential loss, to which employees are insensitive. Changes of enterprise supervision exert a significant influence on the system evolutionary result, which means the system will evolve into the ideal mode of (compliance, compliance) when the supervision is greater. Moreover, it is important to note that when the probability for the discovery of safety noncompliance of employees of one player is lower, the system will eventually evolve into the adverse "locking" state of (noncompliance, noncompliance), even though the initial proportion of employees in the group choosing the safety compliance behavior is particularly high; when the probability for the discovery of safety noncompliance of employees of one player remains the same ($P_{C1} = 0.30$), the evolutionary direction of the system will witness changes when the probability for the discovery of safety noncompliance by the players is increased. Therefore, under the circumstance where the safety noncompliance is serious, enterprise shall strengthen the safety inspection to timely discover its employees' safety noncompliance behavior, and it is very necessary for the enterprise to impose strict punishment on employees having safety noncompliance behavior. When necessary, enterprise may introduce the system for the report of employees' safety noncompliance behavior, and drive its employees to participate in the management over work safety to make the safety noncompliance behavior discovered once it occurs and employees involved therein punished (Fig. 11).

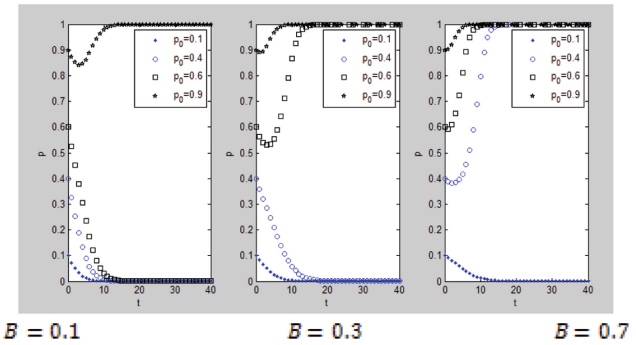

Fig. 10. Impact of changes of fine on the evolutionary result

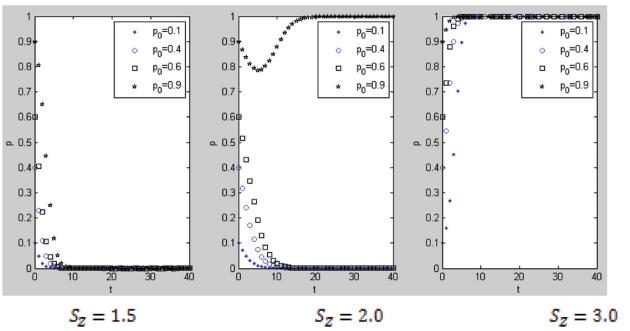

Fig. 11. Impact of changes of potential loss on the evolutionary result

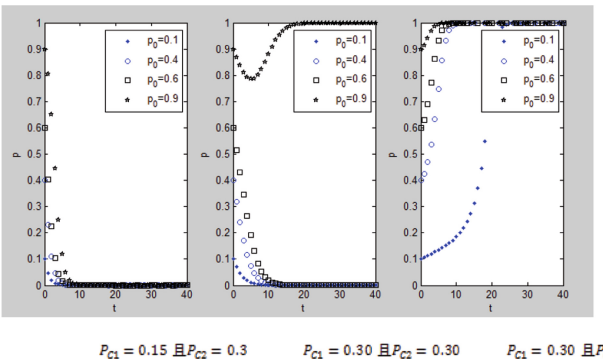

Fig. 12. Impact of changes of safety check frequency on the evolutionary result

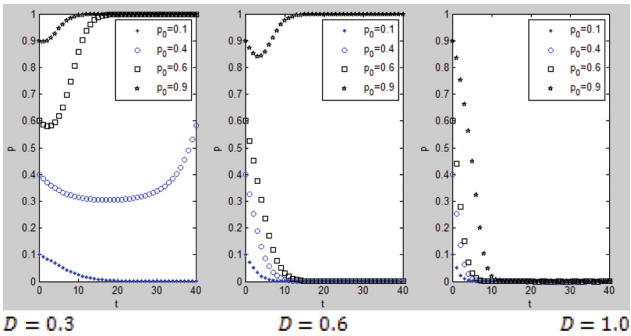

Fig. 13. Impact of changes of negative effect on the evolutionary result

(5) See Fig. 13 for the result of numerical experiment on the impact of negative effect D of safety noncompliance on the evolutionary result.

According to Fig. 13, the system will totally evolve into the mode of (noncompliance, noncompliance) when D reaches a certain degree. As employees can communicate with their workmates in the daily production and be influenced by their behavior, they will re-examine themselves when their workmates' noncompliance behavior does not cause any accident, nor discovered by enterprise; besides, more employees will follow their workmates as the noncompliance behavior is infectious; as a result, the poor safety atmosphere is formed and will bring a huge potential safety hazard and loss to the enterprise.

5 Conclusion

The grass-roots employees' safety behavior is the key to improve the level of enterprise in work safety, and the interaction effect of behavior among employees dynamically determines the safety state of group (workshop and team). In such group, the single employee will constantly adjust his or her strategy according to other employees' choice for behavior, and the system will eventually evolve into a certain stable state, which is the process for the employees to choose the group behavior after comprehensively measuring the factors, such as amount of labor necessary for safety compliance, safety gains, potential loss from safety noncompliance, reaction from workmates and enterprise supervision. During such process, enterprise can adjust and control relevant parameters to guide the system to evolve into an ideal state.

(1) Based on the facts that the safety awareness of most of grass-roots employees is low, and they will consider the gains from safety noncompliance behavior are greater than those form safety compliance behavior when they cannot realize the potential, indirect and non-economic benefits of safety compliance behavior, and then take the noncompliance behavior, which will exert an adverse demonstration effect in the group, on one hand, enterprise executives shall strengthen the safety inspection to timely discover, prevent and correct the safety noncompliance

behavior, and impose corresponding punishment thereupon, improve employees' awareness to the cost of safety noncompliance behavior and reduce their satisfaction thereto. On the other hand, enterprise shall reduce the extra labor necessary for the safety compliance behavior and the cost of safety compliance behavior to the knowledge of employees through normalizing the procedures for production and operation and optimizing the production environment.

(2) In the group of grass-roots employees, employee relationship is relatively close and many employees are fellow-villagers or relatives, employee's individual behavior is more susceptible to other workmates and group, and the group's noncompliance behavior is highly infectious, therefore, the strict prejob safety education and training is of great importance, through which employees can have a good command of Safety Operating Procedures and fully realize the importance of work safety, realize their own safety noncompliance behavior which may cause damage to themselves and their workmates, and other workmates' noncompliance may do harm to themselves, and can thus form the awareness of "no harm" [14], in this way, can employees refuse operation against rules and also actively stop their workmates from doing so.

(3) It is very important to completely eradicate the employees' safety noncompliance behavior and create a favorable safety atmosphere [15]. Employees break rules and regulations for saving labor and puppyism. Therefore, enterprise can build a favorable enterprise safety culture atmosphere to make employees break the rules unable to feel the psychological satisfaction and subject to the resistance from other workmates, to make employees clearly realize the safety noncompliance behavior does not conform to the enterprise requirements, but also the requirements of group norm so as to reduce the workmates' indifference or self-identity towards noncompliance behavior and lower the motivation of employees' safety noncompliance behavior and its adverse influence. In the meantime, enterprise shall reward and punish employees according to their performance in work safety, and impose strict punishment upon the employees having safety noncompliance behavior, provided that it shall cautiously use the employee's individual performance in work safety to measure other workmates' safety performance, otherwise, it may discourage the employees who take the safety compliance behavior strategy.

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References

1. Hackett, E.J., Parker, J.N.: Ecology reconfigured: organizational innovation, group dynamics and scientific change (Book style with paper title and editor). In: The Local Configuration of New Research Fields. Springer International Publishing, Heidelberg (2016)
2. Bandura, A.: Social learning theory of aggression (Periodical style). J. Commun. **28**(3), 12–29 (2010)
3. Rozin, P.: Social psychology and science: some lessons from solomonasch (Periodical style). Pers. Soc. Psychol. Rev. **5**(1), 2–14 (2001)
4. Degoey, P.: Contagious justice: exploring the social construction of justice in organizations (Periodical style). Res. Organ. Behav. **22**(00), 51–102 (2000)
5. Lingard, H., Cooke, T., Blismas, N.: Do perceptions of supervisors' safety responses mediate the relationship between perceptions of the organizational safety climate and incident rates in the construction supply chain? (Periodical style). J. Constr. Eng. Manag. **138**(2), 234–241 (2012)
6. Mohamed, S.: "Safety climate in construction site environments" (Periodical style). J. Constr. Eng. Manag. **128**(5), 375–384 (2002)
7. Chen, Y., Wong, L., Fang, D.: Safety climate in construction industry: a case study in Hong Kong (Periodical style). J. Constr. Eng. Manag. **132**(6), 573–584 (2006)
8. Zhou, Q., Fang, D., Mohamed, S.: Safety climate improvement: case study in a Chinese construction company (Periodical style). J. Constr. Eng. Manag. **137**(1), 86–95 (2011)
9. Zohar, D.: Thirty years of safety climate research: reflections and future directions (Periodical style). Acci. Anal. Prev. **42**(5), 1517–1522 (2010)
10. Fugas, C.S., Silva, S.A., Meliá, J.L.: Another look at safety climate and safety behavior: deepening the cognitive and social mediator mechanisms (Periodical style). Accid. Anal. Prev. **45**(1), 468–477 (2012)
11. Zhou, Q., Fang, D., Wang, X.: A method to identify strategies for the improvement of human safety behavior by considering safety climate and personal experience (Periodical style). Saf. Sci. **46**(10), 1406–1419 (2008)
12. Schütte, N., Blickle, G., Frieder, R.E., Wihler, A., Schnitzler, F., Heupel, J., Zettler, I.: The role of interpersonal influence in counterbalancing psychopathic personality trait facets at work (Periodical style). J. Manag. **27**(8), 1–34 (2015)
13. Goh, E., Ritchie, B., Wang, J.: Non-compliance in national parks: an extension of the theory of planned behaviour model with pro-environmental values (Periodical style). Tourism Manag. **59**(4), 123–127 (2017)
14. Bonafede, M., Corfiati, M., Gagliardi, D., Boccuni, F., Ronchetti, M., Valenti, A., Iavicoli, S.: OHS management and employers' perception: differences by firm size in a large Italian company survey (Periodical style). Saf. Sci. **89**, 11–18 (2016)
15. Chib, S., Kanetkar, M.: Safety culture: the buzzword to ensure occupational safety and health (Periodical style). Procedia Econ. Finan. **11**(14), 130–136 (2014)