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Differential Effects of Specific Negative Emotions on Individual Risk Preference Behaviors under Social Accidents: An Analysis from the Perspective of Affective Computing Theory

Jintao LU[1], Naiding YANG [2], Jinfu YE [3], Ting LEI [4], Nasir MAHMOOD [5]

Abstract

Traditionally studies on the affect of emotions on the behavioral decision-making assume that, individuals with negative emotions are risk-seeking. However in real situations, individual decision-making behaviors show different tendencies of risk preference, thus more and more scholars are attracted to analyze the effect of specific negative emotion on individual risk preference behaviors. From the perspective of Affective Computing Theory (ACT), the concepts of mixed negative emotion, emotional space, intensity of mixed negative emotions and threshold of mixed negative emotions were introduced, the questionnaire of emotional state transition based on Markov process was designed, empirical analysis and numerical modeling were adopted to discuss different effects of specific negative emotion on individual risk preference behavior under social accidents. It is concluded that decision-making behaviors of individuals with mixed negative emotions are mostly inclined to risk-aversion under social accidents. Three types of specific mixed negative emotions, which were divided as

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fear leading, anger leading and sadness leading, have different effects on individual risky decision-making behaviors, also behavioral selections of individuals show differentially balanced strategies among three types of rescue solutions with risk-seeking, risk-aversion and risks-neutralness. Furthermore, the personality trait and the rescue experience have important moderating effects during the process of individual's mixed negative emotion cognition and risky behavioral decision-making. The study reveals the differentially influence mechanism of specific negative emotion on individual risk preference behavior under social accidents, which has a significant meaning in individual emotion management, psychological adjustment, behavioral intervention and the improvement of the quality of emergency decision-making.

Keywords: mixed negative emotion, risk preference, affective computing, emotional arousal and adjustment, behavioral intervention

Introduction

With the sustainable development of science and technology as well as the increasingly close social activities, when sharing with the social civilizations brought by technological achievements, human beings are facing with the increasingly frequent risks in natural disasters, industrial accidents, public health and social security events on a global scale (Lauge, Hernantes & Sarriegi, 2014). For example, the 9.11 terrorist attack on the United States in 2001, China's SARS event in 2001 and 5.12 Wenchuan earthquake in 2008, the Japan's 3.11 earthquake in 2011 and the consequent accident of Fukushima nuclear leakage, the Philippines's "Sea Swallow" windstorm in 2013, and in 2014 Malaysia Airline Flight MH370 vanished, etc. The above social accidents have caused a large number of casualties, property losses and profound social effects (Benfield, 2014).

Social accidents evolve with the features of uncertainty, the urgency of the time, the destructive consequences, etc. On one hand, it requests the decision makers to promptly respond to the accidents and propose effective solutions within the shortest time. However, owing to the existence of information asymmetry during the process of emergency rescue, the decision options and rescue behaviors of individuals are not entirely rational (Helton, Kemp & Walton, 2013), namely, the dominant solution isn't formatted on the basis of the rational compensatory decision rules, but relying more on heuristic strategies based on connectionism. On the other hand, it often causes individuals to feel stronger negative emotions, like fear, anxiety, sadness and so on (Feng, Zhou & Gan, 2012), which makes individuals overestimate the uncertainty and uncontrollability of the current risky accidents and then prefer risk-averse behaviors (Lemer & Keltner, 2001). Furthermore, some studies concretely differentiated the discrete categories of fundamental negative emotions (Johnson-laird & Oatley, 1989), as well as proved

into the effect of specific negative emotions on individuals risk preference (Lerner, Gonzalez, Small & Fischhoff, 2003). The results show that, even under the situation of negative valence, various negative emotions have different effects on the risk judgment and strategy preferences. Terrified respondents, who evaluate the event risks more pessimistic, are more likely to take the defensive measures, while angry respondents who assess the risks more optimistic, are inclined to take the active actions. "Mapping" to the real situation, in the 2013 China's Ya'an earthquake, by browsing the related news reports and online videos, it can be find that both victims and rescuers are inclined to generate a certain degree of negative emotions, like anxiety, sadness, irritability, fear, anger and so forth. The fear and anxiety make the individuals deal with the small probability event with the attitude of sensitive, cautious and even avoidance. Anger has the individuals take action to "conquer" the current rescuing adversity. Irritability and uneasy also get individuals to take different irrational and aggressive behaviors. Therefore, faced with decision-making problems in social accidents, from both theoretical research and practical problem perspectives, the multi-dimensional negative emotion has different effect on individual risk preference behavior, while it conflicts with the classic affective generalization hypothesis (Johnson & Tversky, 1983) and mood maintenance hypothesis (Isen & Patrick, 1983). Thus, the exploration on the differential effect of specific negative emotion on individual risk preference behavior under social accidents possesses significantly theoretical and practical importance in emotion management, psychological adjustment and behavior intervention.

Related Literature

Aiming at the "emotion-behavior paradox" above, from various perspectives, scholars at home and abroad thoroughly analyzed the formative mechanism and influential factors of this differential effect. Although most current studies of these types focus on the fields of risk decision-making, consumer behavior and medical psychology, they still have significant value for the decision-making research under social accidents.

Studies on social recognition and marketing fields found that, even with the same valence, different types of negative discrete emotions have differential effects on the consumer decision-making (Garg, 2003). Bodenhausen, Sheppard & Kramer (1994) studied the differentiation of anger, sadness and the specific neutral emotion during social-cognitive process, the result showed that, as the reaction to social stimuli, anger makes individuals rely more on single heuristic strategies when processing cues, compared with sadness and the neutral emotion, the angry individual is more inclined to make stereotyped judgments. Meanwhile, it's also related to the control and moderating effect of different elements of the

limbic system. Based on Fuzzy-trace Theory, Rivers, Reyna & Mills (2008) explained this differentiation further, assuming that although anger and sadness had the same valence, their own inner mechanisms of processing the obtained decision information were different. Angry individuals were inclined to take the mode of gist-based mental representations when processing the obtained information, and less concentrate on details. While sad individuals were preferred to take systematic methods to deal with more details, so the use of gist-based mental representations was reduced. Garg, Mittal & Inman (2010) considered the accountability degree (high and low) and accountability type (process accountability and results accountability) as moderating variables to explore the differentiation of the effect of anger and fear on the consumer decision-making. They found that, owing to the differentiation of individual cognition about the event's certainty caused by anger and fear, namely compared with fear, anger would make individuals' create a higher degree of certainty and controllability, in result individuals showed different decision-making behaviors (Tiedens & Linton, 2001). Based on the evolutionary theory of emotion, Fessler, Pillsworth & Flamson (2004) argued that, anger occurred as a response to violative (threatening) behaviors, and then through stimulating aggressive behaviors to prevent the violative (threatening) behaviors which are happening or about to happen, while disgust is a negative reaction to the loathsome person or thing, driving individuals away from it. Thus angry subjects are more inclined to take risk-seeking behaviors; subjects with the emotion of disgust are more preferred to take risk-aversion behaviors. Additionally, other studies explained the differentiation from the view of neurophysiology of emotions, which thought different specific emotions are associated with the corresponding parts of human's brain respectively; emotions are the results from collaborative activities of the neurological process of cerebral cortex and subcortical structure. For instance, individuals who suffered from frontotemporal dementia are more likely to lose the ability of recognizing anger, fear, disgust and other negative emotions (Kumfor *et al.*, 2011). Specifically speaking, fear is related to amygdaloid nucleus, disgust is connected with insula and globus pallidus, as well as anger is associated with the lateral orbitofrontal cortex (Murphy, Nimmo-Smith & Lawrence, 2003; Calder, Lawrence & Young, 2001), through stimulating different areas of each subcortical structure of the central nervous system (CNS), then it causes individuals to display different kinds of emotional behaviors. The latest research conclusion also supports this explanation (Cheng, Lu, Zhu, Chen & Gao, 2015), which found that the risky decision-making behaviors of subjects with cognitive-impairment existed a certain difference, the risky decision-making ability of whom is restrained in various degrees.

It should be pointed out that, in recent years, the research paradigm based on specific negative emotion has attracted increasing attention of policy makers and academic scholars from both China and abroad, which has proposed a new research idea to analyze the influential mechanism of specific emotion on

decision-making process. Appraisal-Tendency Framework (ATF) is considered as one of the most influential theories in this field (Han, Lerner & Keltner, 2007). Based on the cognitive evaluation theory and the functional theory of emotion, ATF argues that the specific emotion is composed of six evaluation dimensions: certainty, pleasantness, attentional activity, control, anticipated effort and responsibility. Individual attention will be respectively attracted by different emotions to the specific evaluative dimension, which will then further lead to the differentiation of emotional behaviors. For example, the event evaluation dimension of angry subjects is controllable and certain, its appraisal tendency is more optimistic, so individuals of this type prefer to take risk-seeking behaviors. While owing to the uncertainty and uncontrollability of risks, fearful subjects are adapt to make a relatively pessimistic appraisal and avoid current risks (Lench, Flores & Bench, 2011). It is also worth mentioning that, in artificial intelligence (AI), Affective Computing Theory proposed by scholars (Picard, 1997:11-28) has developed the studies of specific emotion from the traditionally discrete, linear, static, and planar dimension to the continuous, non-linear, dynamic and spatial dimension (Wang, 2009: 32-58). Especially, the method of emotional modeling based on mixed emotions provides a new approach to explore the differentiation effect of various kinds of negative emotions on risky preference behaviors of decision makers.

Through a review of relevant literatures, we find that, currently most studies in academia on differential effect of specific negative emotion on individual risk preference behavior are mainly focused on fields of psychology, cognitive science, brain science and so forth. Relevant findings reveal its differently influential mechanism in individual decision-making area while rarely considering the situation of social accident management. Meanwhile, most of the existing studies only consider the effect of single specific emotion, but in practical social accidents, both rescuers and victims are probable under the mixed emotion situation with the mode of "joy tempered by sadness" or "the co-existence of surprise and fear". In order to overcome these shortcomings of the current studies, the following two questions will be discussed in the paper: 1) Based on Affective Computing Theory, the concept and dimension of individual mixed negative emotion in social accidents is defined, then whether there exists a difference of the effect of various mixed negative emotions on individual risky decision-making is verified; 2) The concepts of emotional intensity and emotional threshold are introduced, using the methods of empirical survey and numerical modeling, then the effect of specific negative emotion on individual risk preference behavior is analyzed to exploringly explain the above "paradox" problem, hoping the conclusion can provide theoretical references for the individual emotional and psychological adjustment, behavioral intervention and the improvement of the quality of emergency decision-making under social accidents.

Methodology

Affective Computing Theory

Affective Computing Theory (ACT), as a new research area combining with computational science, psychological science and cognitive science, has attracted many concerns from academia and industrial circles since it was proposed in 1995 by Prof. R. Picard from MIT Media Lab of United States (Picard, 1997; Wang, 2009: 32-58), and has been widely applied in human-computer interaction (Tews, Oehl, Siebert, Höger & Faasch, 2011), health care (Lisetti, Nasoz, LeRouge, Ozyer & Alvarez, 2003), distance education (Duo & Song, 2012) etc. Emotion is considered as a continuous, dynamic multi-dimensional nonlinear system in the affective computing area, also emotion and affection is identical in ACT. The typical mathematical models of emotion include: OCC (Ortony- Clore-Collins) cognitive model of emotion, Salt & Pepper model and emotional state transition model based on Markov process. Based on the study by Wang (2009: 32-58), a novel method that combines Markov process and OCC model is proposed in the article to describe the negative emotional space.

Definition of Mixed Negative Emotion

Mixed emotion refers to a kind of emotional states and mental phenomena under the same incident scenario, of which two or more different types of emotions or ambivalence co-exist, including homogeneity and heterogeneity mixed emotions (Priester & Petty, 1996). This paper only considers the homogeneous mixed emotion of which the component has negative valence. Mixed negative emotion consists of four kinds of basic emotions, namely fear, anger, sadness, disgust according to R.Plutchik's emotional space model (Plutchik, 1962), the other states of the negative emotion are a mixture of these four basic elements. For example, as a kind of mixed negative emotions, anxiety is composed of sadness, fear and anger, fear is the core component, fear interacts with other basic components to form anxiety (Byrnea & Eysenck, 1995). On the basis of Hidenori & Fukuda's concept of emotional space (Hidenori & Fukuda, 2001), OCC (Ortony-Clore-Collins) cognitive model of emotion (Dong, 2011: 40-50) and The Euclidean Space based-emotional model (Wang, 2009: 32-58), considering the problems described above, a 3D space of basic negative emotions **S** which is only comprised of three types of basic emotions is constructed in the article. Wherein, $\mathbf{S} = \{S_1, S_2, S_3\}$, S_1 represents fear, S_2 denotes angry, S_3 expresses sadness, as shown in *Figure 1*.

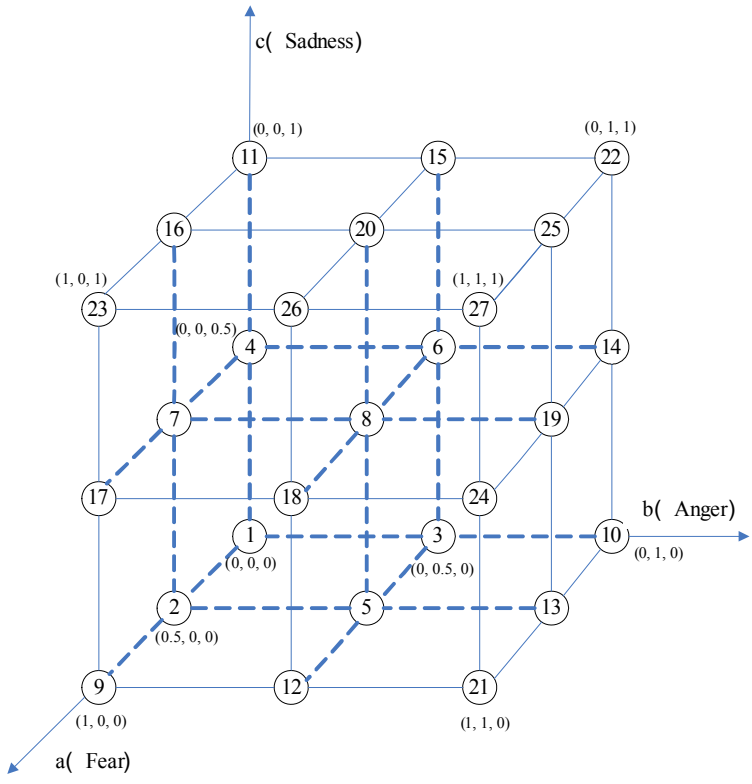

Figure 1. Three-dimensional Space of Negative Emotions

In the emotional space described above, X axis, Y axis and Z axis respectively denotes fear, anger and sadness which are the three basic emotions defined in the study, the coordinate value indicates the intensity of the certain emotion experienced by the individual. For convenience, all the values of the three basic emotions in their own representational dimensions are processed discretely, namely, let the state value of each emotional dimension only be 0, 0.5 and 1, while setting the maximum value of each emotional state is 1. The larger the value of each emotional state is, the higher the intensity of the corresponding basic negative emotion it represents. Since there are three kinds of basic negative emotions, and the state of each basic emotion is divided into three grades, so as shown in figure 1, the space of basic negative emotions **S** has $3^3=27$ kinds of mixed emotional state. In fact, due to the grade of emotional intensity describes the instant state of individual emotional experience, the state of each basic emotion can take on any value from the appointed interval ș0, 1ț, we can then further consider mixed negative emotion as a continuous variable which is defined in the given emotional space **S**. According to the above analysis, the mixed negative emotion

$\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}}$ and intensity of mixed negative emotion $\gamma_{mixed-t_0}$ can be described as follows:

$$\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}} = [x_{t_0}, y_{t_0}, z_{t_0}] \tag{1}$$

Where t_0 represents the current time, $x_{t_0} = \{x \mid x \in R, 0 \le x \le 1\}$, $y_{t_0} = \{y \mid y \in R, 0 \le y \le 1\}$, $z_{t_0} = \{z \mid z \in R, 0 \le z \le 1\}$.

$$\gamma_{mixed-t_0} = \sqrt{x_{t_0}^{\ 2} + y_{t_0}^{\ 2} + z_{t_0}^{\ 2}} = \begin{cases} 1 & \text{if } \gamma_{mixed-t_0} > 1 \\ \gamma_{mixed-t_0} & \text{if } \gamma_{mixed-t_0} \le 1 \end{cases} \quad \left(0 \le \gamma_{mixed-t_0} \le 1\right) \tag{2}$$

In equation (2), the intensity of mixed negative emotion $\gamma_{mixed-t_0}$ is measured using Euclidean distance. Being consistent with the formulation of the intensity of basic negative emotions, we also stipulate that $\gamma_{mixed-t_0}$, can take on any value in the interval [0, 1]. The larger the value is, the higher the intensity of the corresponding mixed negative emotion it represents. Additionally, owing to the intensities of the three basic negative emotions which constitute the mixed negative emotion $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}}$ are time-dependent variables, hence we assume that, the three basic negative emotions have their own time-dependent weight coefficients in the component dimension of mixed negative emotion $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}}$. Based on this, the defined mixed negative emotion $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}}$ in this study can be divided into three kinds, that is, fear leading, anger leading and sadness leading. The state of the leading negative emotions of these types is decided by the state of basic negative emotions with the maximum value in the 3D coordinate space.

According to Theory of Emotional Arousal and Cognitive Theory of Emotion (Dong, 2011: 40-50), the certain mixed negative emotion $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}}$ can be activated when its intensity increases up to a certain level. However, the activation is influenced by factors of external stimuli, physiological arousal, and emotional cognition. Meanwhile, in the activation and adjustment system of emotion, the scenario of social accidents, rescue experiences and personality traits also have an impact on the emotional cognition and emotional behavior (Lu, Yang, Ye & Wu, 2014; Pulido-Martos, Luque-Reca, Augusto-Landa & Ruiz, 2014). All of these mentioned factors make the activation of negative emotions show a threshold value, namely the threshold of mixed negative emotion T which is defined as below:

$$T = f(p, e) \tag{3}$$

In equation (3), is the value in the appointment interval [0, 1], *f* is the function of negative emotion, *p* represents the individual, *e* denotes the event. Obviously, the value of the threshold is associated with the individual and event stimuli. We stipulate that, event stimuli are arise from the negative stimulus caused by the social accident, the factors involve with individuals are only rescue experiences and personality traits. The personality trait is characterized using Big Five Personality model which is composed of conscientiousness, extraversion, openness, agreeableness and neuroticism. Several evidences prove that, the defective personality is related to negative emotion, capricious emotion and passive behavior while the healthy personality is positive emotion, rational emotion and active behavior (Dong, 2011: 40-50). Consequently, the threshold value of individuals with rich rescue experiences and healthy personality traits (conscientiousness, extraversion, openness, agreeableness), is much higher. On the contrary, the threshold value of individuals who have a defective personality (neuroticism) and are lack of rescue experiences, is relatively smaller.

Questionnaire Design of Emotional State Transition Based on Markov Matrix

Under social accidents, when individuals are suffering from negative stimuli, the activated state of mixed negative emotion $\boldsymbol{e}_{mixed\text{-}negative\text{-}t_0}$ is transferred in the constructed 3D space of negative emotions **S**, and then the state of the current mixed negative emotion is updated. At the same time, the activated state of mixed negative emotion $\boldsymbol{e}_{mixed\text{-}negative\text{-}t_0}$ as well as the corresponding explicit emotional behaviors (escape, attack and exploratory actions etc.) will make individuals take different decision-making behaviors (risk-proneness, risk-aversion and risks-neutralness) on the basis the differential risky preference. According to the above process description, we assume that the state transition of individual mixed emotions approximately has the Markov property, namely, if individual emotional state at the present time t_0 and the corresponding behavior are known, then in the next time t_1, the transition probability from the current state to the next only depends on the current state while having nothing to do with the past emotional state. Accordingly, the rule for updating the state of mixed negative emotion $\boldsymbol{e}_{mixed\text{-}negative\text{-}t_0}$ is defined as follow (Wang, 2009: 32-58):

Suppose that the state transition process of individual mixed emotions is a Markov process in the state-space of mixed negative emotions **S**. At the present time t_0, the individual is under the *i*-th state of basic negative emotion and takes

the corresponding decision-making behavior a_i. When suffering from negative event stimuli, in the next time t_1, the probability which denotes the individual negative emotion is transferring from the *i*-th state to *j*-th is expressed using $p_{ij}(a_i)$. As we employ fear (X axis), anger (Y axis) and sadness (Z axis) as the three-dimensional vector $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}} = [x_{t_0}, y_{t_0}, z_{t_0}]$ to represent the state-space of mixed negative emotions **S**, so the transition probability matrix ***P*** of mixed negative emotion based on Markov process can be described as follow:

$$\boldsymbol{P} = \begin{pmatrix} p_{xx} & p_{xy} & p_{xz} \\ p_{yx} & p_{yy} & p_{yz} \\ p_{zx} & p_{zy} & p_{zz} \end{pmatrix} \tag{4}$$

In equation (4), $p_{i,j}\,(i, j \in (x, y, z)$ is the one-step transition probability which shows the state of individual basic emotions is transferring from the *i*-th to *j*-th, and meets the following constraints:

$$\sum_{i=x} p_{i,j} = 1, j \in (x, y, z), \sum_{i=y} p_{i,j} = 1, j \in (x, y, z), \sum_{i=z} p_{i,j} = 1, j \in (x, y, z), \; p_{i,j} \geq 0$$

With regard to the determination of the transition probability matrix ***P*** of mixed negative emotion, scholars proposed various computational methods (Wen *et al*., 2014; Farahat & Asada, 2010). Taking the coal mining accidents as the survey background, on the basis of the scales in the studies by Wang (2009: 32-58) and Plutchik (1962), which are also adopted to measure the relevant variables in this study, we developed a survey questionnaire which is aimed at obtaining the transition probability matrix ***P*** of mixed negative emotion. The main measurement items of the questionnaire are shown in *Table 1*.

Table 1. Main Items of the Survey Questionnaire of Emotional State Transition

Item A: Suppose when you are working in underground coal mines, a mine fire occurs. Your workmates and you are trapped in the mine, the lives of some injured workers are in danger, and you are *Extreme Fear*. At this time, the emergency rescue on the ground can't be obtained in time, also there is a possibility of secondary gas explosions at any time, your further inner feeling is (You can only select one of the below three options):
1) Being afraid of the a greater harm caused by the secondary accident, the inner feeling is more fearful;
2) Assuming that the occurrence of the coal mining accident is due to the lack of effective supervision of coal mine safety and the insufficient investment in

safety technologies and equipments by relevant administrative organizations and enterprises, and being discontent and angry at the emergency rescue & response on the ground after the accident;

3) Being helpless and miserable, the tragic scene of the accident makes you feel more sorrowful.

Further more, what kind of rescue behavior below will you select? (You can only select one of the below three options)

1) Waiting for help in the mine refuge chamber;

2) To conduct Self-help/ mutual aid in the mine;

3) Being eager to save the trapped workmates, and conduct the rescue blindly.

Item B: Suppose when you are working in underground coal mines, a mine fire occurs. Your workmates and you are trapped in the mine, the lives of some injured workers are in danger, and you are *Exceptionally Angry.* At this time, the emergency rescue on the ground can't be obtained in time, also there is a possibility of secondary gas explosions at any time, your further inner feeling is (You can only select one of the below three options):

1) Being afraid of the a greater harm caused by the secondary accident, the inner feeling is more fearful;

2) Assuming that the occurrence of the coal mining accident is due to the lack of effective supervision of coal mine safety and the insufficient investment in safety technologies and equipments by relevant administrative organizations and enterprises, and being discontent and angry at the emergency rescue & response on the ground after the accident;

3) Being helpless and miserable, the tragic scene of the accident makes you feel more sorrowful.

Further more, what kind of rescue behavior below will you select? (You can only select one of the below three options)

1) Waiting for help in the mine refuge chamber;

2) To conduct Self-help/ mutual aid in the mine;

3) Being eager to save the trapped workmates, and conduct the rescue blindly.

Item C: Suppose when you are working in underground coal mines, a mine fire occurs. Your workmates and you are trapped in the mine, the lives of some injured workers are in danger, and you are *Deeply Sad.* At this time, the emergency rescue on the ground can't be obtained in time, also there is a possibility of secondary gas explosions at any time, your further inner feeling is (You can only select one of the below three options):

1) Being afraid of the a greater harm caused by the secondary accident, the inner feeling is more fearful;

2) Assuming that the occurrence of the coal mining accident is due to the lack of effective supervision of coal mine safety and the insufficient investment in safety technologies and equipments by relevant administrative organizations and enterprises, and being discontent and angry at the emergency rescue & response on the ground after the accident;

3) Being helpless and miserable, the tragic scene of the accident makes you feel more sorrowful.

Further more, what kind of rescue behavior below will you select? (You can only select one of the below three options)

1) Waiting for help in the mine refuge chamber;

2) To conduct Self-help/ mutual aid in the mine;

3) Being eager to save the trapped workmates, and conduct the rescue blindly.

Lastly, according to the Memoryless property of Markov process, the process of updating the state of mixed negative emotion $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}}$ at time t_0 can be expressed as below:

$$\begin{aligned}\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_1}} &= \boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}} + \boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}}\boldsymbol{p} \\ &= [x_{t_0}, y_{t_0}, z_{t_0}] + [x_{t_0}, y_{t_0}, z_{t_0}]\begin{pmatrix} p_{xx} & p_{xy} & p_{xz} \\ p_{yx} & p_{yy} & p_{yz} \\ p_{zx} & p_{zy} & p_{zz} \end{pmatrix} = [x_{t_1}, y_{t_1}, z_{t_1}]\end{aligned} \tag{5}$$

Wherein, $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_1}}$ represents the updated state of the mixed negative emotion through one-step probability transition at time t_1 after individuals are stimulated by negative events. If the value of intensity of mixed negative emotion at this time is greater than that of the threshold of individual negative emotion, namely $\gamma_{mixed-t_1} > \mathrm{T}$, then the state of individual mixed negative emotion at time t_1 is $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_1}}$. Otherwise, the state at time t_1 is still the state at time t_0 $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}}$.

Results

Data Collection

Taking the miners and managers at the grass-root level of Shandong Xinwen Mining Group and Hebei Kailuan Group in China as the survey objects, the convenience sampling method was employed to conduct the questionnaire survey from May 25th to June 20th in 2015. It is required that the respondents recall the coal mining accidents they had experienced, and then selected and filled one item (A, B and C) which had the highest degree of fitting with the accident situation at that time. In the survey, a total of 400 questionnaires were distributed and 382 were returned (Response Rate: 95.5%), of which 360 were completely filled (Effective Response Rate: 90%). The completion of the questionnaires was voluntary and anonymous.

Data Processing

As is defined by Law of Large Numbers, when the sample is large enough, the event frequency ***f*** can be regarded as the approximation of the event probability *p*. So when calculating the transition probability matrix ***P*** of mixed negative emotion, the transition frequency of different basic negative emotions can be used to approximately estimate the transition probability. The specific procedure for statistical processing of collected data can be followed as below to obtain the general transition probability matrix ***P*** of mixed negative emotion:

1) Regarding each item (A, B, C), to count the number N_i of the n (n=360) effective questionnaires respectively which include the corresponding selected item, the subscript *i* identifies the state of respondents' basic negative emotion is in the *i-th* state at time, wherein, $i \in (x, y, z)$.

2) Based on item 1), to count respectively the amount n_{ij} of classified questionnaires which indicate the state of respondents' basic negative emotion is transferred from the current *i-th* state at time t_0 to the state *j* at time t_1, the subscript *j* identifies the state of respondents' basic negative emotion is in the *i-th* state at time t_1, wherein, $i, j \in (x, y, z)$.

3) To calculate each element p_{ij} of the transition probability matrix ***P*** of the respondents' mixed negative emotion using the below formula:

$$p_{i,j} = \frac{n_{i,j}}{N_i}, (i, j = x, y, z) \tag{6}$$

4) For each classified item (A, B, C), the above procedure is followed to process the survey results, therefore the transition probability matrix ***P*** of mixed negative emotion is concluded:

$$\boldsymbol{P} = \begin{pmatrix} p_{xx} & p_{xy} & p_{xz} \\ p_{yx} & p_{yy} & p_{yz} \\ p_{zx} & p_{zy} & p_{zz} \end{pmatrix}$$

In addition, since the questionnaire requires the respondents to report the change of their respective emotions and the selected rescue solutions (i.e., risk-aversion rescue (D_a), risk-proneness rescue (D_p)and risk-neutralness rescue (D_n)) under the present negative emotion at time t_0 when suffering from negative event stimuli, thus with regard to the number $N_i (i \in (x, y, z))$ of each classified item (A, B, C), the number $M_k$of each selected rescue solution (D_a, D_p, D_n) under the current situation is counted respectively to analyze the distribution of individual risk preference behaviors under different kinds of mixed negative emotions in depth (Frequency Analysis), wherein, $k \in (D_a, D_p, D_n)$.

Result Analysis

According to the above method and procedure of data processing, the data in the survey were classified and processed. The result is as shown in *Table 2*.

Table 2. Statistical Result of Survey Data

N_i (Copies)		$n_{i,j}$ (Copies)		M_k (Copies)	
N_x	158	$n_{x,x}$	52	M_{D_a}	106
		$n_{x,y}$	46	M_{D_p}	17
		$n_{x,z}$	60	M_{D_n}	35
N_y	85	$n_{y,x}$	7	M_{D_a}	12
		$n_{y,y}$	59	M_{D_p}	50
		$n_{y,z}$	19	M_{D_n}	23
N_z	117	$n_{z,x}$	37	M_{D_a}	50
		$n_{z,y}$	28	M_{D_p}	13
		$n_{z,z}$	52	M_{D_n}	54

As can be seen from *Table 2*, the transition probability matrix ***P*** of mixed negative emotion and the distribution of individual risk preference behaviors under different kinds of mixed negative emotions (i.e., fear leading, anger leading and sadness leading) can both be calculated, as is shown in *Figure 2*.

$$\boldsymbol{P} = \begin{pmatrix} 0.33 & 0.29 & 0.38 \\ 0.08 & 0.69 & 0.23 \\ 0.32 & 0.24 & 0.44 \end{pmatrix}$$

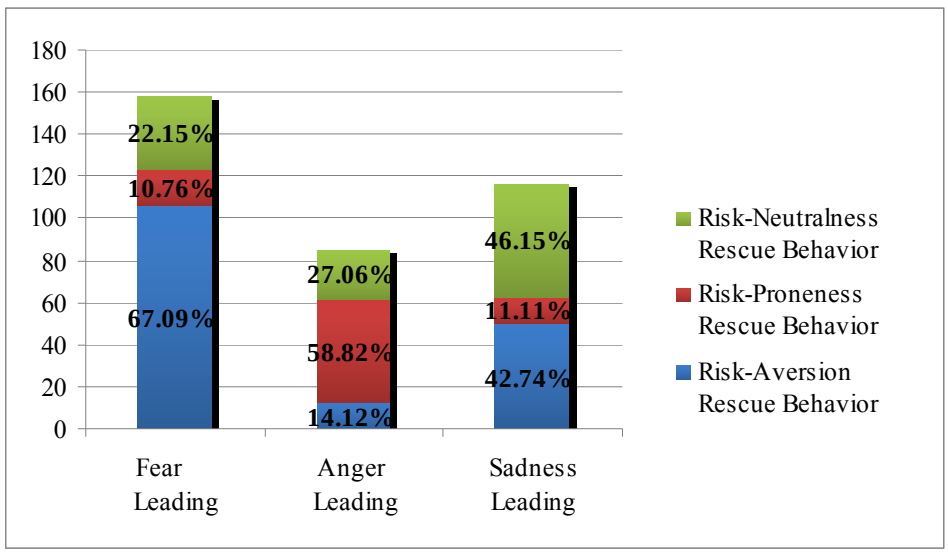

Figure 2. *Distribution of Individual Risk Preference Behaviors under Mixed Negative Emotions*

As we can see from Table 2 and Figure 2, under social accidents, the individual behavioral selection in mixed negative emotions is wholly inclined to risk-aversion on the whole (46.67%), with only a small quantity of risk-proneness rescue behavior (22.22%). Besides, the study also reports a higher proportion of respondents (31.11%) who select risk-neutralness rescue, it is assumed that the higher proportion is related to the concept definition and category description of risk-neutralness rescue behavior in the survey questionnaires design, but the relative difference of the selection ratio between risk-aversion behavior and risk-proneness behavior won't be affected by the selection quantity of risk-neutralness rescue behavior. Meanwhile, as seen from the overall analysis result, in the three kinds of specific mixed negative emotions (i.e., fear leading, anger leading and sadness leading), the behavioral selections of respondents respectively tend to risk-

aversion (67.09%), risk-proneness (58.82%) and risk-neutralness (46.15%), which is essentially consistent with the existing studies (Feng, Zhou & Gan, 2012; Lemer & Keltner, 2001; Lerner, Gonzalez, Small & Fischhoff, 2003). In other words, this further positively responds to the first question proposed in this study, namely, different types of mixed negative emotion affect the individual decision-making differently.

Furthermore, according to the study by Wang (2009: 32-58), let the threshold of mixed negative emotion of individuals with healthy personalities be 0.7, namely $T_h = 0.7$, while that of individuals with defective personalities be 0.3, namely $T_h = 0.3$. Based on this, suppose the initial emotional state of different individuals with two personalities is fear leading and $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}} = [0.4, 0.2, 0.1]$. After the individuals are stimulated by negative aspects of social accidents, as is defined in equation (5), through one-step probability transition, the updated state of mixed negative emotions at time t_1 is: $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_1}} = [0.58, 0.48, 0.34]$.

Due to the intensity of individual mixed negative emotion at time t_1 is $\gamma_{mixed-t_1} = \sqrt{0.58^2 + 0.48^2 + 0.34^2} \approx 0.83$, and $\gamma_{mixed-t_0} > T_h$, $\gamma_{mixed-t_0} > T_d$, $x_{t_1} > y_{t_1} > z_{t_1}$, so the mixed negative emotions of individuals with two personalities are both physiologically activated, the updated states are still fear leading. According to the attribution principle of negative stimuli, the individual cognition makes a special mark on the emotional arousal of this type, which leads to the individual's emotional experience with the type of fear leading, as well as the specific explicit emotional behavior. Then the corresponding rescue behavior (solution) is selected as a kind of stress response to the social accident individuals are facing (See figure 2).

Likewise, according to the analysis procedure above, suppose the initial emotional state of different individuals with two personalities is anger leading and $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}} = [0.05, 0.3, 0.15]$. Through emotion transition, the updated state of mixed negative emotions at time t_1 is: $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_1}} = [0.08, 0.25, 0.13]$. Since $\gamma_{mixed-t_1} \approx 0.29 < T_d$, $\gamma_{mixed-t_1} \approx 0.29 < T_h$, $y_{t_1} > z_{t_1} > x_{t_1}$, neither the mixed negative emotion of individuals with healthy personalities nor that with defective personalities is physiologically activated, the updated states are still fear leading at time t_0. As a kind of the actually existing and subsidiary emotion, though the state of individual emotion at time t_1 is implicit, unobservable and unconscious, as well as unable to be directly experienced and measured, it also can lead to certain physiological response and decision-making behavior (See figure 2).

Lastly, suppose the initial emotional state of different individuals with two personalities is sadness leading and $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_0}} = [0.1, 0.15, 0.25]$. Then at time t_1, the updated states of mixed negative emotions of individuals with healthy and defective personalities both are: $\boldsymbol{e}_{\boldsymbol{mixed\text{-}negative\text{-}t_1}} = [0.13, 0.2, 0.18]$. Due to $T_d = \gamma_{mixed-t_1} \approx 0.3 < T_h$, $y_{t_1} > z_{t_1} > x_{t_1}$, so the mixed negative emotion of individuals with defective personalities is physiologically activated which belongs to threshold stimulus, and the updated state is anger leading. While that with healthy personalities is not physiologically activated which belongs to below-threshold stimulus, and the updated state is still sadness leading at time t_0, the behavioral decision-making of individuals under this situation belongs to subliminal perception.

Discussion

According to the analysis result above, we can find that, though the respondents' selections of rescue behaviors reflects their own consistent risk inclination which respectively correspond to the three kinds of mixed negative emotions defined in the article, the selections of the three rescue solutions with different risky levels (i.e., risk-seeking, risk-aversion and risks-neutralness) shows differentially balanced strategies. It is assumed in this study that the reasons for differential decision-making behaviors of this type are as follows, firstly, as it has been recognized by the academia about the basic emotion, the generation of mixed negative emotion is an interactive process of accident stimulus, physiological arousal, cognitive evaluation and behavior selection (Wherein, physiological arousal mainly refers to the physiological change which consists of nervous system, endocrine system, somatic system and nervus centralis). However owing to the negative emotion defined in the study is kind of mixed emotion which is composed of three basic negative emotions, namely, fear, anger and sadness, the three basic negative emotions have their respectively dynamic weight coefficients in their own dimension. During the process of generation, transition and update, different processing procedures of various mixed negative emotions (i.e., different kinds of composite patterns of basic negative emotions) make the emotional intensity appear in diverse levels. Secondly, the threshold of individual negative emotions varies with personality trait and rescue experience, which will make the transition and update of emotions show implicit and explicit types, then further lead to the self-reported errors of individual emotion experience and measurement. Finally, for convenience, according to the existing studies, the activation threshold

of mixed negative emotions was only defined in the study (we regard it as the weighted average of the thresholds of various mixed negative emotions), which will also lead to a certain degree of analysis error when processing the data obtained from the survey questionnaires. While in fact, in the space of negative emotions, each basic negative emotion has its own physiologically activation threshold. So seen from the perspective of mixed emotion, the three mixed negative emotions with the types of fear leading, anger leading and sadness leading, have their own activation thresholds.

In conclusion, as can be seen, through introducing the concept of mixed negative emotion, this study, from the view of Affective Computing Theory (ACT), reveals the differential influential mechanism of different specific negative emotions on individual risk preference behaviors, as well as further explains the "emotion-behavior paradox" proposed at the beginning of this study, the relevant conclusions can be served as decision-making references for the individual emotional adjustment, the psychological and irrationally behavior intervention under social accidents.

Conclusion

A great deal of studies prove that, the negative emotion is one of most important factors influencing behavioral decision-making, but the reasons that different types of negative emotions differentially influence individual risk preference behaviors still haven't been explained systematically up to now. From the perspective of Affective Computing Theory (ACT), in combination with multidisciplinary theories and methods, differential effects of specific negative emotions on individual risk preference behaviors under social accidents were discussed in this study. The results indicate that, decision-making behaviors of individuals with mixed negative emotions are mostly inclined to risk-aversion under social accidents. Three types of specific mixed negative emotions, which were divided as fear leading, anger leading and sadness leading, have different effects on individual risky decision-making behaviors, also individual's behavioral selections show differentially balanced strategies among three types of rescue solutions with risk-seeking, risk-aversion and risks-neutralness. An interesting finding in the study is that, the personality trait and the rescue experience play important roles in moderating the mixed negative emotion cognition and risky behavioral decision-making of individuals, which will especially affect the threshold of mixed negative emotions, mixed negative emotions experience and negative emotional state transition, and then further influence the individual decision-making behavior via the mixed negative emotional cognition. The study reveals the differentially influence mechanism of specific negative emotions on individual risk preferences under social accidents, which enriches the theory of emotion and

behavioral decision-making to some extent. Especially to be viewed from the practical level, realizing the differentially influence mechanism of the compositionality of negative emotions, the personality trait, the rescue experience as well as the arousal and transition of mixed negative emotions on the individual risk preference behavior is beneficial to managers, so that they can timely take intervening measures to adjust the irrational emotion and behavior of individuals from the view of improving the quality of emergency decision-making, making the development of social accidents to be proceeded towards the favorable direction.

Nonetheless, this study also have some limitations, such as the questionnaire design and social survey are directly conducted while taking coal mining accidents and miners as the objects, the initial state of mixed negative emotions is assigned randomly and so on, which makes the representativeness of samples and the universality of conclusions to be questionable. In future studies, on the one hand, Emotion Volatility Index (EVI) can be introduced, with the help of large-sample empirical analysis and psychological experiments, to figure out the relationship among personality traits, rescues experiences and the change of individual emotions, and then accomplish the quantitative description of the emotional threshold. On the other hand, the questionnaire design can be further improved and other research methods (e.g., in-depth interview, case study, social survey, psychology experiments) should be combined, to enhance the validity of the conclusion in this study.

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