



# Development of a Universal Safety Behavior Management System for Coal Mine Workers

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## **Abstract**

**Background:** In China, over 80% of all work-related deaths in the mining industry occur in coal mines and human factors constitute 85% of the direct causes of coal mine accidents, which indicates that significant shortcomings currently exist in the safety behavior management of Chinese coal mine workers. We aimed to verify the impact of human psychological behavior in coal mine accidents systematically through experimental study, theoretical analysis and management application.

**Methods:** Four test instruments (Sensory and cognitive capacity test, Sixteen-Personal Factor Questionnaire, Symptom Checklist 90 Questionnaire and the supervisors' evaluation) were employed from November 2013 to June 2014 to identify unsafe behavior factors, the self-established Questionnaire of Safety Behavior Norms (QSBN) was also used to propose the safety behavior countermeasures of coal mine employees.

**Results:** The mental health of most coal mine workers' is relatively poor. The sensory and cognitive capacity of those in different work posts varies greatly, as does the sense of responsibility. Workers are susceptible to external influences, and score low in site management. When the 16-PF and SCL-90 sensory and cognitive assessments were combined, the psychological index predictive power was greatest for estimating sense of efficiency and degree of satisfaction in internal evaluations, while at the same time lowest for estimating control of introversion-extroversion and stress character.

**Conclusion:** The psychological indicators can predict part of employee safety behavior, and assist a coal mine enterprise to recruit staff, develop occupational safety norms and improve the working environment.

**Keywords:** Coal mine, Safety psychological evaluation, Safety behavior management

## **Introduction**

Production safety and accident prevention have become major focal points in the Chinese coal mining industry. With this in mind, the safety-consciousness of employees is critical to improve coal mine safety in China. However, significant shortcomings exist in the safety behavior management of Chinese coal mine workers (1).

Chinese coal mine employees come from a variety of social backgrounds influenced by different factors during their work. Thus, their safety-related occupational psychological factors and behaviors can differ greatly, making it difficult to

identify universal patterns of unsafe behaviors that can be addressed by safety management. A successful manager of a coal mine should consider a multitude of factors in order to identify possibly risky actions and strive to reduce this risk (2). If a risky core action can be identified in the work process, it can be altered, and will subsequently become a component of the workers' training, their performance evaluation, and the promotion criteria at all applicable levels in production and management.

Most coal mine safety researchers are not experts

of the coal mining industry or the fields of psychology and praxeology, and their respective approaches to researching the subject are therefore limited. In other words, current research into coal mine safety is lacking in certain areas of relevant expertise (3), hence interdisciplinary collaborations are needed to identify the systematic problems impacting safety in Chinese coal mines. Furthermore, systematic safety-related problems require systematic countermeasures in order to fully implement appropriate safety management. However, although maladaptive safety-related behaviors may occur among workers at various levels of the production process, current safety management efforts in Chinese coal mines focus primarily on the single point in the production chain that is most closely related to the safety shortcoming.

Most studies of coal mine safety in China and elsewhere have focused on the occupational psychological factors that contribute to accidents and the response of management to address these safety-related shortcomings. Studies have investigated the direct causes of accidents, the motivations for maladaptive safety-related behaviors, and the management of safety behavior. Accident causation theories, such as the accidental release of energy and catastrophe theory, have served as the basis of previous studies of coal mine safety. Multiple-factor analyses of mining accidents conducted outside of China have examined the causes of accidents at the human, technological and organizational levels.

## **Literature review**

In 1980, a system theory of coal mine accidents was proposed, which stated that multiple interrelated factors contributed to accidents. Morrow et al. (4) explored the relationship between the mental concept of safety and the safe behavior of railway industry workers, and concluded that working tension is significantly related to safe behavior. Vinodkumar et al. (5) applied safe behavior theory to industry, identifying the performance of unsafe behavior

and how to avoid accidents. Leung et al. (6) studied the relationship between personal characteristics, job characteristics, platform features and specific accidents, researching the accident model quantitatively. Simanaviciene et al. (7) predicted the causes of mine workers' occupational injuries, and explored the physical discomfort and psychological pressure of witnesses in underground refuge chambers.

Previous studies have also examined workers' motivations for safety behaviors based on a number of theoretical models, including Maslow's (8) hierarchy of needs, the Porter et al. (9) expectancy model, Herzberg et al. (10) two-factor theory, Petersen's motivation-reward-satisfaction model, Vroom's (11) expectancy theory, and the safety performance model of Neal and Griffin. Other safety researchers (12, 13) have focused on the specific safety behaviors. Others have assessed the efficacy of safety behavior management through training, observing, and correcting employee actions in the workplace in order to enhance safety performance (14, 15).

Researchers in China have investigated the occupational psychological factors that contribute to violations of safety regulations and the efficacy of preventative measures. Human error analysis, the quantitative analysis of behavioral mechanisms that contribute to accidents, and studies of countermeasures to prevent human errors have also been performed in China. Cao et al. (16) analyzed a system of risk management methods in a coal mine and implemented it into a system which manages and controls potential accident risks, hazard sources and human behavior risks. Liu et al. (17) used a dynamic gray relational analysis method concerning the human error influence degree to analyze three violations of a coal company in 2008-2011. Li et al. (18) analyzed different behaviors of coal mine workers using the ABC method, collecting information on miners' work behavior through an ABC questionnaire.

Differences may exist between employees and managers with regard to their view of safety behavior management. Employees report that their unsafe behavior choices are influenced by the work environment, production quotas,

management communications that may encourage unsafe behaviors and the system of rewards and punishments used by management. However, managers report that safety education and training are sufficient for the management and control of mine employees' unsafe behaviors. Differences also exist between management and production workers with regard to the effectiveness of countermeasures that are implemented.

Recent studies of behavior management based on occupational psychological factors have assessed the efficacy of various strategies for improving employee safety behaviors. Chen et al. (19) and Boada-Grau et al. (20) performed quantitative and confirmatory studies of safety behaviors associated with accidents in other industries. Li et al. (21) designed a model of miner safety behavior based on an evaluation of miners' thought processes, with the aim of modifying miners' decision-making skills regarding safety behaviors.

Studies of the evaluations of safety behaviors have also been based on game theory, grounded theory, and planned behavior theory, such as that of Mohammadi et al. (22) and Bi et al. (23). Interdisciplinary research and application of related theories and methods regarding safety-related psychological factors have been employed, including the use of virtual reality and electronic simulation techniques, such as that of Guan et al. (24) and Wang et al. (25).

Certain shortcomings exist with regard to the findings of previous studies of safety psychology and safety behaviors in China. Most of the qualitative studies performed in China were not based on original data. Safety evaluation methods, such as the grey theory evaluation and fuzzy comprehensive evaluation, were based on the experience of experts that were then adopted for the purpose of risk assessment, and were thus subjective in nature. The reliability and validity of the methods used in the quantitative studies of safety-related psychological factors and behaviors in China have not been confirmed among Chinese test subjects, which may also have resulted in bias. Furthermore, a number of studies did not perform a systematic analysis. At present, the application of many theories and technologies to

the study of human safety behavior is highly problematic, especially with regard to the analysis of psychological factors and the quantitative analysis of group safety behaviors.

Because the human factors associated with accidents in coal mines may occur throughout the entire production process, an overall re-examination of safety management techniques in Chinese coal mines is required to assess the efficacy of current safety countermeasures. The aim of our current study was to analyze the relationship between the safety-related occupational psychological factors and the safety behaviors of Chinese coal miners and the countermeasures taken by safety management to identify systematic methods for improving the efficacy of safety management in coal mines in China.

## **Materials and Methods**

### *Study design*

Psychological assessments from November 2013 to June 2014 were performed on 30 coal mine managers and 370 employees who performed all types of work in a mine to gain an overall understanding of their safety-related psychological characteristics and safety behaviors. These individuals completed several psychological assessments in order to identify the human factors which lead to accidents in coal mines. These factors mainly include psychological factors and behavior factors. Potentially negative characteristics and behaviors were identified based on the results of the psychological assessments, including a sensory and cognitive capacity test, personality test, mental health test and adaptability to working. Using these factors as independent variables, and using work safety performance as dependent variables, a multiple linear regression method was used to pick up the main psychological and behavior factors which lead to accidents in the coal mine. On this basis, certain countermeasures to improve work safety can be proposed. The coal mine workers and managers were interviewed to identify the types of countermeasures taken by safety management, such as work environment

optimization, employee psychological selection and arrangement, and standard management of safety behavior. These countermeasures were subsequently put into use, their effectiveness to

improve production safety evaluated, and the results were used to provide feedback to safety management. The design and flow of information in our study are represented in Fig.1.

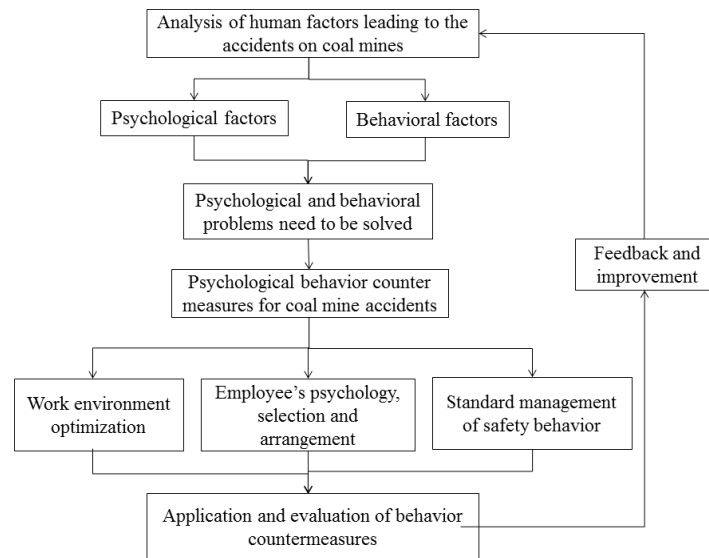


Fig. 1: Research design and the flow of information

### Study variables

The goal of our research was to establish a systematic safety behavior management strategy for coal mines. We performed a systematic study of the influence of psychological factors and safety behaviors on the frequency of coal mine accidents using a combination of experimental research, theoretical analysis and management application. By applying theories of safety psychology, safety behavior, and safety management, we examined the requirements of coal mine production activities for employees' psychological behaviors using psychological assessments, a behavioral evaluation, and an occupational analysis. Predictive psychological indexes were established based on a quantitative analysis of the variation in psychological factors. Management countermeasures were also assessed based on the psychological index.

### Selection for the Psychological Questionnaire

Seventy employees comprising production supervisors, production workers, and gas checking employees consented to undergoing the psychological assessments. The sensory and cognitive

capacity test was used to assess attention distribution, attention span, difference threshold sensitivity, choice reaction time and recognition capacity. The Sixteen-Personal Factor Questionnaire (16-PF), recognized as one of the most authoritative personality test methods available and can be used for anyone aged over 16, was administered to the employees. Boyle et al (26) has applied this questionnaire to research and proved its rationality. The results of the 16-PF were then analyzed to assess the employees' adaptability to working in a coal mine environment. The Symptom Checklist 90 Questionnaire (SCL-90), which is one of the most renowned mental health test scales, was used to assess the employees' general psychological health. Derogatis et al (27) have used this assessment in primary care. Based on a job performance evaluation provided by their immediate supervisor, the employees' understanding of the safety procedures used in coal mines and their work performance also allowed a psychological index to be ascertained. These psychological indexes were established based on

the results of the sensory and cognitive capacity test, 16-PF, SCL-90, and the supervisors' own evaluations.

### ***Safety behavior countermeasures***

In the past, safety regulations and operation rules were only applied to the working area. However, now employee safety responsibilities extend far further. The safety awareness and behavior of employees is recognized as being critical to ensuring workers' safety at all times and in all places within and around the mine. Safety behavior countermeasures were designed based on the evaluation of 60 coal mine employees representing each of the five following work categories (n=300): mining, driving, electromechanical work, ventilation and explosion prevention, and transportation. Each group of employees was assessed using a self-reporting questionnaire that demonstrated acceptable levels of reliability and validity. The safety behavior countermeasures were established based on the analysis of the results of the safety behavior norms questionnaire.

### ***Data collection***

The research data were collected using the sensory and cognitive capacity test, psychological questionnaires, and self-reported safety behavior norms questionnaire. The assessments were performed in two separate investigations. In the first investigation, the psychological indexes were developed based on the assessments administered to a sample of 70 workers from the Wang Zhuang coal mine of the Lu'an Group, all of whom were male, from November 2013 to March 2014. The results for only 30 to 60 employees were included in the analysis of the psychological assessments due to incomplete answers. 30 workers who were the immediate supervisors of the 70 psychologically assessed employees provided their own work performance evaluations. In the second investigation, behavioral norms were assessed using a second sample of 300 workers from the Wang Zhuang coal mine, all of whom were male, from March to June of 2014.

### ***Establishment of safety behavior norms***

The safety behavior norms were based on the typical safety behaviors of employees occupying various posts throughout the Wang Zhuang coal mine. The norms addressed behaviors associated with the employees' daily routines. To ensure that the standardized management of safety behavior was integrated into the production process and that safety behavior norms were applied effectively, a software program for the standardization of safety management was developed, which considered employees' violation records, rewards and punishments, employment management, performance evaluation, prediction of safety behaviors, and others.

The safety behavior norms were divided into the following three categories: 1) The behavior norms of employees' daily routines, which included having a meeting before work, entering the coal mine, taking a vehicle into the coal mine, walking on the main roadway, walking in a mining area tunnel, walking in a working area tunnel, beginning a shift, participating in safety behavior training, and others; 2) behavior norms associated with all types of work in the working areas of the coal mine; and 3) the standardized management of safety behavior.

The three-level index of the safety behavior norms was validated using a factor analysis. The index demonstrated a moderate level of reliability (Kronbach coefficient,  $\alpha = 0.50$ ) for all of the behaviors. The behaviors associated with beginning a shift demonstrated a high level of reliability ( $\alpha = 0.71$ ). Behaviors associated with working demonstrated a low level of reliability ( $\alpha = 0.34$ ), whereas behaviors associated with completing a shift demonstrated a high level of reliability ( $\alpha = 0.68$ ). These results showed that the safety behavior norms clearly reflected the safety requirements for coal mines and the performance standards of the employees. Therefore, they can be used as the basis for daily safety management to improve the efficacy of employees' safety behavior.

**Optimization of safety behaviors based on work environment**

Coal mine employees' safety behavior is influenced not only by their own attitudes and beliefs but also by their work environment. The coal mine environment can cause nervousness and anxiousness among mine workers. To ensure the employees' safety behavior, people, objects, and the environment must be coordinated to allow workers to focus on safe production practices, rather than requiring them to constantly adapt to their surroundings, which contributes to behavioral errors by distracting and mentally fatiguing workers.

The integrated application of safety behavior science can be used to optimize coal mining systems

using human-machine system modeling, the goal of which is to obtain a high level of work efficiency and eliminate the physiological and psychological risk factors that contribute to accidents in the workplace. Our proposed design framework for the optimization of coal mines is shown in Fig. 2. The main tasks include an ergonomic assessment of mine workers' actions in the coal mine environment and the derivation of mathematical descriptions of the psychological patterns that contribute to feelings of fear and anxiety among workers in the production environment. The results of these analyses were used to improve the safety and efficiency of the coal mine production process.

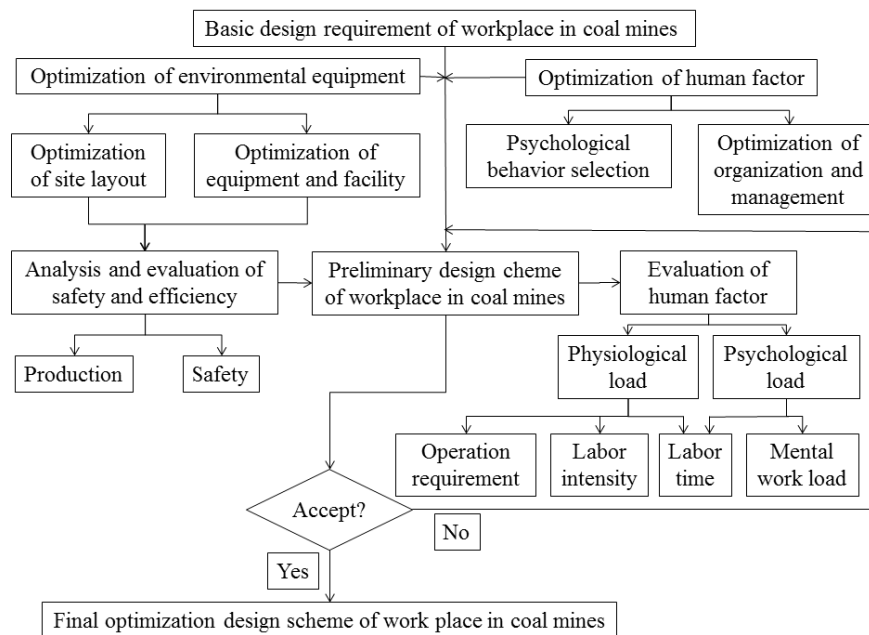


Fig. 2: Design framework for optimization of the coal mine workplace

**Results**

**Variability in sensory and cognitive capacities**

The results of the sensory and cognitive capacity testing of 32 employees are shown in Table 1. The test consisted of five assessments of various cognitive functions. The results in Table 2 displayed low levels of variability, except for the scores for attention span and attention distribution, which

indicated that, although the productivity of workers in the same position was similar, their sensory and cognitive capacities differed significantly. Because attention span and distribution are highly relevant to safety performance, management should place personnel with poor scores for these assessments in positions that are suitable for their capacity for safety behaviors.

**Table 1:** Results of sensory and cognitive capacity assessment

Item	Range	Mean	SD	SE
Difference threshold	0-10.00	3.21	2.66	0.49
Recognition capacity	0-60.00	32.64	14.54	2.7
Choice reaction time	0-1158.00	730.86	223.2	41.45
Attention distribution	0-0.59	0.5438	0.14	0.03
Attention span	0-9.00	7.52	1.15	0.21

SD: Standard deviation; SE: Standard error

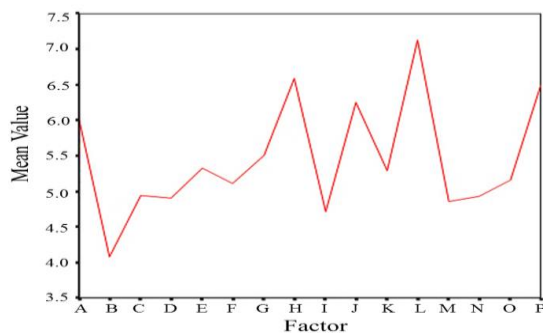
**Table 2:** Variance analysis results of sensory and cognitive capacity of personnel from different posts

	SoS	DoF	F-value	P-value
Difference threshold (intergroup)	6.78	2	0.46	0.63
Group distinction (intragroup)	189.98	26		
Choice reaction time (intergroup)	63676.83	2	0.62	0.55
Group distinction (intragroup)	1331270.61	26		
Recognition capacity (intergroup)	491.31	2	1.18	0.32
Group distinction (intragroup)	5431.02	26		
Attention distribution (intergroup)	0.09	2	2.5	0.1
Group distinction (intragroup)	0.46	26		
Attention span (intergroup)	4.23	2	1.66	0.21
Group distinction (intragroup)	33.02	26		

SoS: Sum of squares; DoF: Degrees of freedom

**Adaptability to the coal mining environment**

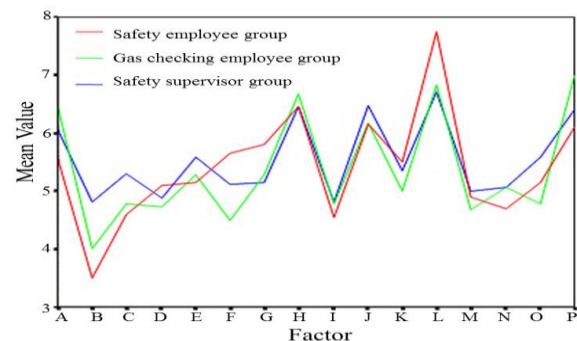
The results of the 16-PF and the assessment of the adaptability of employees to working in a coal mine environment are shown in Table 3.



**Fig. 3:** Overall results of the sixteen-personality-factor test (N = 5)

Fig. 3 shows that the factor B scores were low, and that the factor O scores were high. Fig.4 shows that there was substantial variability in the scores regarding dedication to duty, with the production worker group displaying a higher mean than that of the production supervisor group,

which was followed by that of the gas checking group of employees. Thus, substantial differences were observed in the level of dedication to duty among employees in different positions. Notes: (the same in the following): A. Congeniality; B. Reasoning; C. Emotional Stability; E. Dominance; F. Liveliness; G. Rule-Consciousness; H. Social Boldness; I. Sensitivity; L. Vigilance; M. Abstractedness; N. Privateness; O. Apprehension; Q1. Openness to Change; Q2. Self-Reliance; Q3. Perfectionism; Q4. Tension.



**Fig. 4:** Group results of measurement of personal adaptability to mining safety work (N = 55)

**Table 3:** Variance analysis results of measurement of personal adaptability to mining safety work

	SoS	DoF	Mean <sup>2</sup>	F-value	P-value
Dedication (intergroup)	12.53	2	6.27	3.3	0.05
Group distinction (intragroup)	98.82	52	1.9		

SoS: Sum of squares; DoF: Degrees of freedom

**Occupational psychological health of coal mine employees**

The SCL-90 was used to assess the general psychological health of the coal mine employees. The domain scores and the norms of the SCL-90 of employees within the same age group were compared. As shown in Table 4, somatization,

sensitivity to personal relationship, depression, anxiety, fear, paranoia, psychosis, and overall scores were much higher than the norm for each age group, which indicated that the general psychological health of the coal mine employees was poor.

**Table 4:** Comparison results of all test samples of SCL-90 and the norm of the same age group of the country

Psychological Symptom	Domain Score (mean ± SD)	Norm (mean ± SD)	Intergroup Difference
Somatization	2.08 ± 0.83	1.34 ± 0.45	12.2**
Obsessive-compulsive symptoms	2.31 ± 1.12	1.69 ± 0.61	1.46
Sensitivity to personal relationship	2.02 ± 0.89	1.76 ± 0.67	4.76**
Depression	2.04 ± 0.74	1.57 ± 0.61	5.6**
Anxiety	1.84 ± 0.67	1.42 ± 0.43	7.25**
Hostility	1.87 ± 0.86	1.50 ± 0.57	1.89
Fear	1.62 ± 0.56	1.33 ± 0.47	4.58**
Paranoia	1.85 ± 0.69	1.52 ± 0.60	4.08**
Psychosis	1.75 ± 0.66	1.36 ± 0.47	6.16**

SD: Standard deviation/\*P < 0.05; \*\*P < 0.01

**Coal mine employees' safety behaviors**

The results of the assessment of the coal mine employees' safety behaviors are shown in Table 5. The safety behavior characteristics were scored on a five-point scale. The score for the employee's sense of efficiency was highest, which was followed by their degree of satisfaction. However, the scores for stress character and control of introversion-extroversion were comparatively low. These results indicated that the employees were satisfied with their work performance for maintaining the status quo, but their behaviors were

easily influenced by the external environment. The questionnaire demonstrated an acceptable level of internal consistency and reliability (r = 0.76).

**External evaluation of employees work performance**

Table 6 shows the results of the supervisors' (n=30) evaluation of the performance of their subordinates (n=43). In general, the scores for familiarity with duties were high, and those for site management were low.

**Table 5:** Results of coal mine safety work characteristics questionnaire

Statistic	Control of introversion-extroversion	Sense of efficiency	Degree of satisfaction	Stress character
Mean	2.91	3.81	3.52	2.88
SD	0.42	0.99	0.53	0.6
SE	0.06	0.15	0.08	0.09

SD: Standard deviation; SE: Standard error



**Table 6:** External evaluation results of work responsibility performance

Item	Mean	SD	SE
Familiarity with work	4.31	0.37	0.07
Sense of responsibility	4.18	0.41	0.08
Ability to work independently	4.17	0.32	0.06
Cooperation	4.22	0.37	0.07
Site management	4.13	0.37	0.07
Observing regulations while working	4.26	0.4	0.07
Completion of goals	4.3	0.3	0.06

SD: Standard deviation; SE: Standard error

### *Predicting job performance*

The scores for adaptability to the coal mine environment and work performance were subjected to a multiple linear regression analysis to estimate the appropriateness of their individual work assignments with regard to an optimal level

of predicted safety (Table 7). The scores for self-reported stress character and external evaluated familiarity with duties, sense of responsibility, ability to work independently, cooperation, and site management were stronger predictors than the other characteristics examined.

**Table 7:** Individual regression analyses of the internal and external assessment results

Regression equation	R <sup>2</sup>
Internal assessment of adaptability to coal mine work environment	
Score for sense of efficiency = 2.38 + 0.30F	0.14
Score for degree of satisfaction = 2.33 + 0.13C + 0.10M	0.26
Score for Control of introversion-extroversion = 3.53 - 0.18A + 0.08M	0.3
Score for stress character = 5.44 + 0.24f2 - 0.13Q2 - 0.16O - 0.14C - 0.13Q3	0.58
External assessment of adaptability to coal mine work environment	
Score for familiarity with duties = 2.33 + 0.14G + 0.14O + 0.05B	0.62
Score for sense of responsibility = 4.74 + 0.10G + 0.12O - 0.14Q4 - 0.11E - 0.11Q1	0.71
Score for ability to work independently = 2.30 + 0.14O + 0.12G + 0.049B	0.66
Score for cooperation = 2.93 + 0.17G + 0.09O + 0.07B - 0.09E + 0.08N - 0.074C	0.78
Score for site management = 2.81 + 0.11G + 0.10D	0.31
Score for observing regulations while working = 4.49 - 0.13Q4 + 0.11L	0.31
Score for completion of goals = 3.25 + 0.09G - 0.08O	0.31

### *Predictive index of adaptability to coal mine work*

When the external evaluation predicted the scores for the sensory and cognitive test and/or the SCL-90, the intergroup difference was not significant. Therefore, the predictive power of these assessments used alone or in combination was weak. However, as shown in Table 8, when the scores for the sensory and cognitive assessment, 16-PF, and SCL-90 were combined in the psychological index, the predictive power of the index was highest for estimating sense of efficiency and degree of

satisfaction in the internal evaluation, whereas the predictive power was lowest for estimating control of introversion-extroversion and stress character. Therefore, the psychological index is useful when hiring new employees and assigning them to posts that are appropriate for their individual characteristics, as well as analyzing the work performance of current employees to determine whether their assigned post is a suitable match for their individual characteristics.

**Table 8:** Regression analyses of sensory and cognitive, 16-PF, and SCL-90 assessment scores

Regression equation	R <sup>2</sup>
Score for sense of efficiency = - 0.58 + 0.112M + 0.03N of Recognition ability + 0.24N of attention span + 0.17F	0.8
Score for degree of satisfaction = 0.10 + 0.28N of attention span + 0.11M + 0.13Q1	0.61
Score for control of introversion-extroversion = 3.83 - 0.12A	0.21
Score for stress character = 4.08 - 0.27Q3	0.33

**Establishment and classification of coal mine employees’ safety behavior norms**

Based on the psychological behavior index related to work, the following four dimensions of coal mine safety behavior norms were established (Table 9): preparing for work, beginning a shift, working, and completing a shift. Weight determination for each index was based on the subject’s

response to the Questionnaire of Safety Behavior Norms (QSBN), as previously described, which was used to demonstrate the validity of our study. The 46-item QSBN used a total of 5 responses for each question that ranged from “complete non-conformity” to “complete conformity.”

**Table 9:** Classification of coal mine employees’ safety behavior norms\*

First level factor	Second level factor
Preparation before work	Factor 1 Employee routine behavior norm
	Factor 2 Pre-shift meeting
	Factor 3 Entering the coal mine and taking a vehicle into the coal mine
	Factor 4 Walking on the main roadway, in a mining area tunnel, or a working area tunnel
Beginning a shift	Factor 1 Inquiring about the work situation at the start of a shift
	Factor 2 Conducting spot inspections
	Factor 3 Handling problems
	Factor 4 Completing end-of-shift duties
Working	Factor 1 Preparations before the beginning of a shift
	Factor 2 Working
	Factor 3 Ceasing working
	Factor 4 Handling special problems
Completing a shift	Factor 1 Preparing for the end of a shift
	Factor 2 Informing the relevant individual of a situation and conducting spot inspections
	Factor 3 Handling problems
	Factor 4 Completing end-of-shift duties

\*Third level factor was omitted

**Discussions**

Ineffective control of human behavioral factors is a major cause of frequent accidents in Chinese coal mines. Accordingly, the control of coal mine employee behaviors is a primary goal of safety management. The systematic analysis of the behaviors of coal mine workers that contribute to accidents, and the identification of solutions to

human-error-related safety problems, are key components of standard safety management. Comprehensive measures, such as position reassignment of coal mine employees, normative evaluation, and work environment optimization and design, have been used to reduce all kinds of potential coal mine accidents caused by human errors, and to improve production safety.

Psychological factors, such as self-esteem, perceived performance pressure, job security, safety orientation etc. have proved to be important antecedent variables of workplace accidents (28). Hence, the identification of psychological factors and behaviors associated with accidents is critical for the improvement of coal mine safety. The occupational psychological factors associated with accidents in Chinese coal mines are systematic in nature, involving both the production process and management. Although multiple studies have investigated the problems involved, no systematic solutions have been proposed thus far. Major systematic obstacles to improving coal mine safety in China have included variation in work-related behaviors across coal mine employee categories, a lack of comprehensive research approaches to coal mine safety, and a lack of systematic countermeasures taken by coal mine safety management. Based on the results of our analysis, we propose the use of predictive methods that consider the employees' occupational psychological characteristics, their work performance, and the coal mine work environment. Psychological evaluations were performed to assess employee characteristics, and a predictive index of psychological behavior was established, which was used to predict the employee's safety behaviors. When hiring new employees and assigning them to the various posts in the coal mine, the predictive index can be used to estimate the new employee's safety performance for the respective position assigned. Thus, the predictive index can be used as a reference for safety management decisions. It is vital to ensure work efficiency, reduce physical and mental stress for employees, and minimize labor intensity and risks in coal mines (29, 30). In order to achieve this goal, through the analysis of employees' psychological characteristics and work performance, key safety behavior norms were established that were applicable on a systematic scale. These safety behavior norms allowed the establishment of corresponding universal behavior standards and evaluation criteria, which promote the standardization of routine assessments that ensure the protection of all mine employees by reducing all types of

accidents resulting from human error. Our analysis also indicated that engineering the work environment in coal mines to conform to the behavioral characteristics of the workers can reduce fatigue and improve employee safety performance. Therefore, we propose that coal mines should be designed to minimize the physical and mental stress of mine workers to ensure the safety of the production process. The integration of the safety behavior management measures into a universal coal mine safety management system that would be applicable to all mine employees, regardless of their position, allows the optimization of both safety and production. The findings of our study fill the theoretical gaps in the current knowledge base of coal mine safety research, and provide a useful and practical means of preventing coal mining accidents due to human factors.

## **Conclusion**

Based on an understanding of employees' occupational mental health and mine safety requirements, a method to predict coal mine employees' work performance was devised. Combined with psychological and behavioral evaluation results, the key behaviors and norms for completing can be determined, and appropriate standards for conduct and a behavior evaluation system accordingly developed. The management of employees' occupational mental health should be integrated into an interlinked, harmonious and unified mine safety management system.

## **Ethical considerations**

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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