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Original article

Why do Workers Generate Biased Risk Perceptions? An Analysis of Anchoring Effects and Influential Factors in Workers' Assessment of Unsafe Behavior

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A B S T R A C T

Background: Risk perception plays a crucial role in workers' unsafe behaviors. However, little research has explored why workers generate biased risk perceptions, namely underestimating or overestimating the risks of unsafe actions. Cognitive biases in risk perception arise from uncertainties about the dangers of unsafe behaviors. As a typical heuristic strategy, the anchoring effect is critical in decision-making under uncertain conditions. Consequently, this study empirically analyzed the influence of anchoring effects on workers' risk perception.

Methods: In 2022, a survey was conducted with 1,418 coal mine workers from Shanxi Province, China. The survey instruments assessed workers' risk perception of unsafe behavior, anchoring effects, need for cognition, and safety knowledge. Multivariable linear regression models were employed to analyze the associations among these variables.

Results: The findings verified the proposed anchoring effects. Specifically, experimenter-provided high-risk anchors led workers to overestimate unsafe behavior risks, thus reducing their tendency to engage in such behavior. In contrast, experimenter-provided low-risk anchors and accident-injury experiences (self-generated anchors) decreased workers' risk perception, increasing their propensity to engage in unsafe behavior. Additionally, workers' safety knowledge and need for cognition significantly affected anchoring effects.

Conclusion: This research enhances workplace safety studies by applying the anchoring effect from psychology to risk perception research. Suggestions for improving risk perception encompass implementing hazard warnings, fostering safety education, and providing training. Furthermore, managers should give special attention to workers with accident-injury experience and promptly correct their accident fluke mentality, thereby improving overall risk awareness.

1. Introduction

Production accidents result from the complex interaction of multiple hazards, including people, equipment, the environment, and management [1]. Among these, workers' unsafe behaviors are the primary cause of accidents [2]. Although extensive research has been conducted on the mechanisms and prevention strategies for unsafe behavior through safety regulations, safety climate, and safety leadership [3–5], unsafe workplace behavior cannot be entirely avoided. This persistence might stem from workers' biased risk perceptions, particularly their underestimation of the dangers associated with unsafe behavior. Consequently, exploring the risk perception mechanism of unsafe behavior among workers is crucial for accident prevention [6–8].

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Previous research indicates that workers' risk perception is influenced by both external and internal factors. Externally, an organization's safety culture, leadership, and training significantly affect workers' risk perceptions [9–12]. Internally, factors such as an individual's safety knowledge, personality traits, and cognitive needs also play crucial roles in shaping risk perceptions of unsafe behaviors [13–16]. However, previous studies often overlook the complex cognitive and psychological issues involved in risk perception. Few have explored why workers develop biased risk perceptions toward unsafe behaviors. Risk perception pertains to an individual's cognitive process in the face of uncertainty. Due to the inherent uncertainties of risks and individuals' limitations in processing information, workers often find it difficult to assess the risks associated with unsafe behaviors objectively. To simplify the decision-making process, they frequently use the intuitive heuristic thinking method, relying on personal experience or external references to make subjective risk judgments, which leads to risk perception bias.

In the cognitive process of risk perception, the anchoring effect prominently influences workers' judgments of risks regarding unsafe behaviors. Specifically, the anchoring effect refers to a cognitive bias in uncertain decision-making scenarios, where an individual's choices are significantly influenced by an initial reference point or "anchor" [17]. For instance, when workers attempt to take unsafe behavior, they cannot rationally predict the likelihood of an accident due to the complex and uncertain risk environment. At this time, if they receive external reference information suggesting low risk or have previously engaged in similar behaviors without suffering injuries, they might rely on these experiences as risk anchors, resulting in an underestimation of the dangers associated with current unsafe actions.

Anchoring effects have been validated in numerous studies of decision-making behavior. However, few studies have examined the anchoring effect in risk perceptions of unsafe behaviors. In light of this gap, this study aims to provide a comprehensive understanding of why workers generate biased risk perceptions of unsafe behaviors through the lens of the psychological anchoring effect. Specifically, we examine how risk anchors, provided by experimenters and those formed from workers' accident-injury experiences (self-generated risk anchors), influence their perceptions of risk related to unsafe behaviors. Furthermore, the study investigates how safety knowledge and the need for cognition affect the degree to which workers are influenced by the anchoring effect. Our findings contribute to a deeper empirical understanding of risk perception biases, offering theoretical insights and practical strategies for preventing unsafe behaviors in the workplace.

1.1. The anchoring effect and risk perception: proposition of hypotheses

Due to the complex operating environment, workers encounter a high degree of risk uncertainty in production, which provides the necessary conditions for the anchoring effect in the risk perception. In such uncertain circumstances, workers cannot perform a rational risk analysis on unsafe behaviors using professional safety knowledge. Instead, they often rely on specific risk-relevant anchors, using them as benchmarks to evaluate their risk perception of dangers when deciding whether to continue hazardous work behaviors. Furthermore, previous studies have demonstrated that the numerical features of anchors significantly influence the anchoring effect's mechanism. For example, Shan et al. [18] found that high experimenter-provided anchors increased individuals' risk perception regarding food-related diseases, whereas low anchors reduced these perceptions. Brewer [19] found that the numerical value of anchors significantly affected physicians' judgment of the probability of a patient suffering from pulmonary embolism. In this context, experimenter-provided risk anchors may influence workers' perception of the risk associated with unsafe behaviors. Therefore, this study divides workers into groups receiving either high or low-risk anchors to explore the impact of such anchoring on risk perception and proposes the following hypotheses:

Hypothesis 1: The experimenter-provided high-risk anchor will significantly increase workers' risk perception of unsafe behavior.
Hypothesis 2: The experimenter-provided low-risk anchor will significantly reduce workers' risk perception of unsafe behavior.

With advancements in cognitive behavioral theory, scholars have increasingly extended research on anchoring effects to include self-generated anchoring effects. Zajac and Bazerman's [20] study on the "winner's curse" illustrates how decision-making outcomes from similar past situations influence current behavior decisions. For former "winners," past successes foster an inherent mindset that can lead to overconfidence with new decisions. This overconfidence often prevents individuals from fully considering the evolving environment and the complexities of specific tasks. Especially in the risk perception of unsafe behaviors, past accident-injury experiences may affect workers' current risk assessments [21], resulting in self-generated anchoring effects. Additionally, these accident-injury experiences may stem from both the workers' own and their colleagues' past incidents. Therefore, to explore self-generated anchoring effects on workers' risk perception of unsafe behavior, this study examines the impact of both personal and colleagues' accident-injury experiences on risk perception and proposes the following hypotheses:

Hypothesis 3: Workers' own accident-injury experiences will significantly influence their risk perception of unsafe behavior.
Hypothesis 4: Workers' colleagues' accident-injury experiences will significantly influence workers' risk perception of unsafe behavior.

According to previous research, individuals' need for cognition and expertise level can influence the extent of the anchoring effect. First, the need for cognition reflects an individual's willingness to think actively [22]. People with a high need for cognition tend to seek out and process information more diligently during cognitive tasks. In contrast, those with a lower need for cognition rely more on external advice or heuristic cognitive strategies. For example, Guo [23] found that the need for cognition significantly affected the degree of the anchoring effect, and investors with a high need for cognition showed lower anchoring effects in online lending. Specifically in the risk perception of unsafe behaviors, workers with an increased need for cognition will more actively explore and think about external risk information. Therefore, this study proposes the following hypothesis:

Hypothesis 5: The need for cognition will significantly influence the anchoring effect in workers' risk perception of unsafe behavior.

Second, Wilson et al. [24] demonstrated that the knowledge level of decision-makers significantly correlates with the anchoring effect; the more knowledgeable individuals are, the less they are influenced by the anchoring effect. For instance, Kausita [25] found that experienced investors were less prone to the anchoring effect compared to college students with little investment experience. Regarding the risk perception of unsafe behaviors, workers' safety knowledge directly reflects their ability to identify potential hazards and make emergency decisions. Acquiring more safety knowledge not only improves workers' safety attitudes but also enhances their overall safety performance. Furthermore, safety knowledge forms the foundation for workers' assessments of the risks associated with unsafe behaviors. Therefore, this study proposes the following hypothesis:

Hypothesis 6: Safety knowledge will significantly influence the anchoring effect in workers' risk perception of unsafe behavior.

2. Materials and methods

2.1. Research setting and participants

The underground coal mining sector is recognized as one of the most hazardous industries globally, with unsafe miner behaviors accounting for over 90% of accidents [26]. This context provided a relevant sample for examining the impact of anchoring on workers' risk perception of unsafe behavior. Consequently, this study utilized three questionnaires—control, high-anchor, and low-anchor—based on Jacowitz and Kahneman's research model to assess the effects of experimenter-provided anchors on risk perception [27].

Specifically, online questionnaires were distributed via the WeChat Mini Program to workers of six coal mining companies in Shanxi Province. Before the distribution, we coordinated with each company's managers to explain the survey's background, objectives, and methodology, thereby securing their understanding and support. Managers then shared the online questionnaires with workers, clarifying that the study aimed to better comprehend workers' risk perception of unsafe behaviors. The survey assured anonymity and did not require any private individual data. Participation was entirely voluntary and without compensation.

The formal research was conducted in two stages. In September 2022, the first phase involved distributing an online questionnaire to the control group. Participants provided demographic information (sex, age, marriage, education, working years) and answered questions about their safety knowledge, need for cognition, and accident-injury experiences. Subsequently, workers assessed the probability and severity of accidents resulting from the unsafe behavior provided by the researchers (See Fig. 1). The questions asked included, 'Please carefully analyze the unsafe behavior provided and select the possibility of an accident?' and 'If an accident occurs, please select the severity of the accident?'. A five-point Likert scale was used to measure accident probability and severity (See Table 1), following the methodology of Pandit and Cabello et al. [28,29].

In the second survey (December 2022), online questionnaires were distributed to high-risk and low-risk anchor groups. Workers in the control group were excluded from this phase to prevent overlap. Specifically, a screening question was implemented at the start of the second online survey, asking participants if they had previously taken part in a similar survey about workers' risk perceptions of unsafe behaviors. Respondents affirming previous participation were automatically redirected to the survey's end, and their participation was terminated. Moreover, individuals were included in either the high-risk or low-risk group, but not both. The questionnaire design for personal characteristics remained identical to that of the control group; however, risk anchors were incorporated into the items evaluating risk judgments of unsafe behaviors. The specific details are presented in Appendix I.

Finally, the first phase collected 538 valid questionnaires. In the second phase, questionnaires adjusted for high-risk and low-risk anchors garnered 443 and 437 valid responses, respectively.

Table 1
Variable description of accident probability and accident severity

Variable	Value	Description
Accident Probability	1	Accident is highly unlikely: The probability of an accident ranges from 0% to 20%
	2	Accident is somewhat unlikely: The probability of an accident ranges from 20% to 40%
	3	Accident is possible: The probability of an accident ranges from 40% to 60%
	4	Accident is quite likely: The probability of an accident ranges from 60% to 80%
	5	Accident is very likely: The probability of an accident ranges from 80% to 100%
Accident Severity	1	No injuries or economic losses
	2	Minor injuries and the worker can return to work immediately after treatment
	3	Injuries that cause fracture, etc., requiring the worker to stop work for recovery
	4	Injuries that make workers incapacitated and unable to work anymore
	5	Injuries that result in death of worker

Fig. 1. Unsafe behavior provided by the researchers.

Demographics detailed in Table 2 indicate homogeneity across groups, predominantly married men aged 31–50 with lower education levels and 4–14 years of employment.

2.2. Measures

2.2.1. Risk perception and anchoring effects

This study evaluates the anchoring effect on workers' risk perception of unsafe behavior by introducing the risk perception index (RP). RP is calculated using the likelihood (L) of an accident from unsafe behavior and its severity (S), combining both factors to reflect the overall risk. A higher RP indicates greater perceived risk.

$$RP = L \times S$$

The core of studying the influencing factors of the anchoring effect is to find reasonable metrics to measure the degree of the anchoring effect in risk perception. This study introduces the Anchoring Index (AI) as a measure of this effect, defined by the following formula:

$$M = \max(|RP_i - RP_{anchor}|), AI = 1 - \frac{|RP_i - RP_{anchor}|}{M}$$

$RP_{\boldsymbol{i}}$ is the estimated risk perception of the worker $\boldsymbol{i}$ and $RP_{\boldsymbol{anchor}}$ is the experimenter-provided anchor value ($RP_{\boldsymbol{anchor}} = 12$ in the high-anchor group and 1 in the low-anchor group). The value range of AI is between 0 and 1. Specifically, $AI = 0$ indicates that the experimenter-provided anchor does not affect the worker's risk perception. $AI = 1$ indicates that the worker risk perception is consistent with the experimenter-provided anchor value, and the anchoring effect is very strong.

2.2.2. Need for cognition and safety knowledge

The need for cognition was assessed using six items based on the scale developed by Coelho [30]. A sample item was "I prefer to deal with more difficult problems than simple ones." All items were rated on a 5-point Likert scale, ranging from 1(strongly disagree) to 5(strongly agree). The Cronbach's alpha of the current sample was 0.86, and the average variance extraction (AVE) was 0.68, suggesting adequate reliability and validity.

Safety knowledge was assessed using four items based on the scale developed by NEAL [31]. A sample item was "I know how to work in a safe way." All items were rated on a 5-point Likert scale, ranging from 1(strongly disagree) to 5(strongly agree). The Cronbach's alpha of the current sample was 0.89, and the average variance extraction (AVE) was 0.66, suggesting adequate reliability and validity.

2.2.3. Control variables

To mitigate potential confounding variables, this study incorporated sex, age, marital status, educational level, and working years as control variables. Specifically, sex was categorized as male and female. Age groups were defined as 18–25, 26–30, 31–40, 41–50, 51–60, and over 60. Marital status was identified as either married or unmarried. Educational levels were classified into high school and below, junior college, undergraduate, and master's degree. Working years were segmented into less than 3 years, 4–8 years, 9–14 years, and over 15 years.

2.3. Analytic strategy

Multiple linear regression was used to investigate the anchoring effect and its determinants on risk perception of unsafe behaviors. Initially, a model was built to ascertain the presence of an anchoring effect on workers' risk perception, expressed as follows:

$$RP = \beta_0 + \beta_1 \times Anchor + \beta_i \times Controls + \varepsilon \quad (1)$$

The dependent variable RP represents workers' estimated risk perception of unsafe behavior. Independent variables are risk anchors: high-risk (Anchor_H), low-risk (Anchor_L), personal injury experience (Anchor_I1), colleagues' injury experience (Anchor_I2), and combined anchors (Anchor_C1 to Anchor_C4), detailed in Table 3. Controls for gender, age, marital status, education, and working years are included.

To delve into the factors affecting the anchoring effect on risk perception of unsafe behavior, we constructed the following regression model for AI:

$$AI = \beta_0 + \beta_1 \times NC + \beta_2 \times SK + \beta_i \times Controls + \varepsilon \quad (2)$$

AI quantifies the extent of the impact of the anchoring effect on workers. Independent variables include the need for cognition (NC) and safety knowledge (SK), detailed in Table 3. Control variables comprise gender, age, marital status, education, and working years.

3. Results

3.1. Descriptive statistics and correlation analysis

Table 4 presents the means, standard deviations, and correlation coefficients for the primary variables of this study. The correlations align with the hypothesized relationships, lending preliminary support to the study's hypotheses. Specifically, the high-risk anchor (Anchor_H) exhibited a positive correlation with risk perception (RP) ($r = 0.37$, $p < 0.01$), while the low-risk anchor (Anchor_L) showed a negative correlation ($r = -0.32$, $p < 0.01$). Similarly, workers' personal accident-injury experiences (Anchor_I1) were inversely related to risk perception ($r = -0.09$, $p < 0.01$), as were colleagues' accident-injury experiences (Anchor_I2) ($r = -0.11$, $p < 0.01$).

3.2. Analysis of Variance

Table 5 displays the results of variance analysis for mean values of Risk Perception (RP), Anchoring Index (AI), Need for Cognition (NC), and Safety Knowledge (SK) among various worker groups. First, RP analysis showed significant differences in mean values

Table 2
Basic information of the respondents

Group	Sex		Age	Marriage		Education	Work years
	Male	Female	Median	Married	Unmarried	Median	Median
Control group	504	34	31–40	442	96	High school and below	4–8 years
High-anchor group	400	43	41–50	393	50	High school and below	9–14 years
Low-anchor group	398	39	31–40	370	67	High school and below	4–8 years

Table 3
Variables definition

Variable	Definition
RP	Workers' risk perception toward the diagram of unsafe behavior.
Anchor_H	The high-risk anchor, provided by the experimenter, queries if the likelihood of an accident is over 70% and whether its severity would exceed that of causing fractures or amputations; denoted as Anchor_H = 1 for the high-anchor group, and 0 for others.
Anchor_L	The low-risk anchor, set by the experimenter, assesses if the accident probability is under 10% and whether its severity would be minor, without casualties or economic loss; assigned as Anchor_L = 1 for the low-anchor group and 0 for the rest.
Anchor_I1	Self-generated anchor of workers' accident-injury experiences; Anchor_I1 = 1 when the worker has accident-injury experiences since joining the job, otherwise 0.
Anchor_I2	Self-generated anchor of colleagues' accident-injury experiences; Anchor_I2 = 1 when the worker's colleagues have accident-injury experiences since joining the job, 0 otherwise.
Anchor_C1	Anchor_C1 = 1 when workers are in the high-anchor group and without accident-injury experiences, 0 otherwise.
Anchor_C2	Anchor_C2 = 1 when workers are in the high-anchor group and with accident-injury experiences, 0 otherwise.
Anchor_C3	Anchor_C3 = 1 when workers are in the low-anchor group and without accident-injury experiences, 0 otherwise.
Anchor_C4	Anchor_C4 = 1 when workers are in the low-anchor group and with accident-injury experiences, 0 otherwise.
AI	The degree of the anchoring effect, ranging from 0 to 1.
NC	The level of need for cognition of workers.
SK	The level of safety knowledge of workers.
Sex	Gender of workers.
Age	Age of workers.
Marriage	Marital status of workers.
Education	Educational level of workers.
Work years	Worker's years of work experience.

across the control, high anchor, and low anchor groups. The highest mean RP was in the high-anchor group (9.831), followed by the control group (6.656) and the low-anchor group (4.513). Workers with their own accident-injury experiences had a significantly lower mean RP (6.200) than those without such experiences (7.324), and those with colleagues' accident-injury experiences also had a significantly lower mean RP (6.473) compared to workers without these experiences (7.522). Second, for AI, the high-anchor group's mean AI (0.668) was significantly lower than the low-anchor group's (0.855). Workers with their own accident-injury experiences had a significantly lower mean AI (0.714) compared to those without (0.768), and this trend was similar for workers with colleagues' accident-injury experiences (mean AI: 0.714) compared to those without (0.783). Third, NC scores showed no significant difference between the high and low anchor groups, standing at 3.521 and 3.457, respectively. Workers with personal accident-injury experiences had a significantly lower mean NC (3.331) than those without (3.511). However, no significant difference was found between workers with and without colleagues' accident-injury experiences, with mean NCs of 3.496 and 3.486, respectively. Last, regarding SK, no significant difference was found in mean scores between the high (3.856) and low anchor (3.799) groups. Workers with their own accident-injury experiences recorded a significantly lower mean SK (3.660) than those without (3.852). However, no significant difference was found between workers with and without colleagues' accident-injury experiences, with mean SKs of 3.877 and 3.806, respectively.

3.3. Analysis of the existence of anchoring effects in risk perception

We investigated the anchoring effects on workers' risk perception of unsafe behavior using dummy variables derived from a control group without prior accident injuries, assigning each experimental anchor as a variable with the control as a reference. Using SPSS 26.0 for hierarchical regression analysis, the findings are in Table 6. The dependent variable, RP, indicates workers' risk perception, with models 2–5 for various anchors. Model 2 confirms H1, showing a significant positive effect ($\beta = 2.178^{***}$) of high-risk anchors on risk perception; Model 3 supports H2 with a negative impact ($\beta = -2.843^{***}$) of low-risk anchors. Models 4 and 5, incorporating personal and colleagues' accident experiences as variables, respectively, indicate these experiences ($\beta = -3.040^{***}$ and $\beta = -2.722^{***}$) reduce risk perception, affirming H3 and H4.

To explore how experimenter-provided and self-generated anchors jointly affect risk perception, Models 7–10 assessed

Table 4
Means, SD, and correlations of variables ($N = 1418$)

Variables	M	SD	1	2	3	4	5	6	7	8	9	10	11
1. Sex	1.08	0.27	1										
2. Age	3.29	1.08	−0.11**	1									
3. Marriage	1.85	0.36	0.02	0.50**	1								
4. Education	1.44	0.65	−0.04	−0.28**	−0.16**	1							
5. Work years	2.41	0.97	−0.06*	0.52**	0.39**	−0.01	1						
6. Anchor_H	0.31	0.46	0.04	0.12**	0.07**	0.05	0.25**	1					
7. Anchor_L	0.31	0.46	0.02	−0.02	−0.01	0.02	−0.05*	−0.45**	1				
8. Anchor_I1	0.12	0.32	−0.07*	0.11**	0.02	−0.07**	0.11**	0.02	0.00	1			
9. Anchor_I2	0.26	0.44	−0.14**	0.14**	0.04	−0.03	0.15**	0.14**	0.05	0.32**	1		
10. NC	3.46	0.66	−0.09**	−0.05	0.03	0.14**	0.04	0.06*	0.00	−0.09**	−0.03	1	
11. SK	3.85	0.60	−0.07**	−0.06*	−0.04	0.12**	0.01	0.01	−0.06*	−0.11**	−0.01	0.51**	1
12. RP	6.99	5.15	0.03	−0.07**	−0.01	0.14**	0.12**	0.37**	−0.32**	−0.09**	−0.11**	0.19**	0.16**

***Note*:** M, the sample mean; SD, the sample's standard deviation. In this and all subsequent tables, asterisks denote levels of statistical significance as follows: * p-value < 0.05; ** p-value < 0.01; *** p-value < 0.001.

Table 5
Analysis of variance for means

Categories	Sample size	RP			AI		
		M	SD	*p*	M	SD	*p*
Workers in the control group	538	6.656	5.474	0.000	—	—	—
Workers in the high-anchor group	443	9.831	4.984		0.668	0.256	0.000
Workers in the low-anchor group	437	4.513	3.071		0.855	0.128	
Workers with own accident-injury experiences	105	6.200	4.900	0.028	0.714	0.261	0.021
Workers without own accident-injury experiences	775	7.324	4.913		0.768	0.217	
Workers with colleagues' accident-injury experiences	279	6.473	4.449	0.030	0.714	0.239	0.000
Workers without colleagues' accident-injury experiences	601	7.522	5.097		0.783	0.212	
Categories	**Sample Size**	**NC**			**SK**		
		M	SD	*p*	M	SD	*p*
Workers in the high-anchor group	443	3.521	0.695	0.144	3.856	0.620	0.145
Workers in the low-anchor group	437	3.457	0.599		3.799	0.570	
Workers with own accident-injury experiences	105	3.331	0.626	0.008	3.660	0.693	0.002
Workers without own accident-injury experiences	775	3.511	0.789		3.852	0.579	
Workers with colleagues' accident-injury experiences	279	3.496	0.705	0.832	3.877	0.601	0.100
Workers without colleagues' accident-injury experiences	601	3.486	0.623		3.806	0.593	

Note: *p-value*, the results' significance from the Analysis of Variance (ANOVA).

Table 5-1
Post-hoc test results of RP among control, high-anchor, and low-anchor groups

(I) Group name	(J) Group name	(I) Mean	(J) Mean	Mean d ifference (I-J)	*p*
Control group	High-anchor group	6.656	9.831	−3.175	.000
Control group	Low-anchor group	6.656	4.513	2.143	.000
High-anchor group	Low-anchor group	9.831	4.513	5.318	.000

Note: *p-value*, the results' significance from the LSD test.

Table 6
Existence test of anchoring effect in risk perception of unsafe behavior

Variables	RP				
	Model 1	Model 2	Model 3	Model 4	Model 5
Sex	0.898	0.621	0.368	1.132	1.201
Age	−0.578**	−0.641***	−0.633***	−0.521*	−0.548*
Marriage	0.168	0.317	−0.188	−0.767	−0.629
Education	0.892***	0.742**	0.561**	0.761*	0.583
Work years	1.166***	0.829***	0.778***	1.203***	1.224***
Anchor_H		2.178***			
Anchor_L			−2.843***		
Anchor_I1				−3.040***	
Anchor_I2					−2.722***
ΔR^2	0.051	0.035	0.089	0.022	0.027
F	9.136***	32.437***	85.090***	10.266***	13.902***
Cohen's d		0.483	0.608	0.524	0.512
Glass's Δ		0.455	0.894	0.723	0.855
Hedges' g		0.483	0.607	0.524	0.511

Table 7
The impact of combined anchors on risk perception of unsafe behavior

Variables	RP				
	Model 6	Model 7	Model 8	Model 9	Model 10
Sex	0.898	0.405	0.739	0.448	0.857
Age	−0.578**	−0.426*	−0.772***	−0.635***	−0.631**
Marriage	0.168	−0.260	0.112	−0.188	−0.503
Education	0.892***	0.918***	0.347	0.518*	0.560
Work years	1.166***	0.957***	1.093***	0.872***	1.124***
Anchor_C1		3.027***			
Anchor_C2			0.522		
Anchor_C3				−2.769***	
Anchor_C4					−3.157***
ΔR^2	0.051	0.062	0.002	0.075	0.062
F	9.136***	48.634***	0.980	58.261***	37.090***
Cohen's d		0.666	0.171	0.540	0.563
Glass's Δ		0.631	0.164	0.867	0.957
Hedges' g		0.666	0.172	0.539	0.562

combined anchors as independent variables with results in Table 7. Models 7 and 8 contrasted high-anchor effects in workers without ($\beta = 3.027$***) and with ($\beta = 0.522$) accident-injury experiences, demonstrating that such experiences mitigate the high-anchor effect. In the high-anchor group, workers without injury experiences exhibited the most elevated risk perception, whereas those with injury experiences showed no increased perception, nullifying the high-anchor effect. Models 9 and 10, for the low-anchor group without ($\beta = -2.769$***) and with ($\beta = -3.157$***) injury experiences, showed consistently negative coefficients, suggesting accident-injury experience has a negligible impact on the low-anchor effect in risk perception.

3.4. *Analysis of influencing factors of anchoring effects in risk perception*

Table 8 outlines the 'need for cognition's' role in anchoring influence on workers. The AI metric reflects how much the anchoring

Table 8
The influence of the need for cognition on the anchoring effect

Variables	AI			
	High-anchor group		Low-anchor group	
	Without AE	With AE	Without AE	With AE
NC	0.109***	0.077***	−0.044***	−0.062***
Sex	−0.161***	0.072	−0.004	0.099
Age	−0.025	−0.010	0.027***	0.024**
Marriage	0.062	0.037	−0.011	0.021
Education	−0.031	0.013	−0.017	−0.021
Work years	0.003	0.031	−0.005	−0.004
R^2	0.144	0.074	0.105	0.203
p-value	0.180		0.189	

Note: *p*-value represents the significance of testing the difference in NC-coefficients between groups, employing Fisher's Permutation test (Bootstrap 1000).

Table 9
The influence of the safety knowledge on the anchoring effect

Variables	AI			
	High-anchor group		Low-anchor group	
	Without AE	With AE	Without AE	With AE
SK	0.143***	0.115***	−0.041***	−0.072***
Sex	−0.151***	0.012	−0.002	0.078
Age	−0.023	−0.014	0.027***	0.029**
Marriage	0.063	0.027	−0.012	0.022
Education	−0.039*	0.013	−0.016	−0.029*
Work years	0.001	0.035*	−0.005	−0.007
R^2	0.177	0.106	0.101	0.204
p-value	0.228		0.093	

Note: *p*-value represents the significance of testing the difference in SK-coefficients between groups, employing Fisher's Permutation test (Bootstrap 1000).

effect alters risk perception. Among the high-anchor group, a strong link was found between higher cognition need and greater anchoring impact, regardless of past accident-injury history, indicating those with a greater cognition need are more influenced by high-risk anchors, leading to increased perceived risk of unsafe behaviors. Conversely, for the low-anchor group, high cognitive need lessens the low-anchor effect, suggesting that workers with higher cognitive engagement can better resist the risk underestimation induced by low-risk anchors.

Table 9 displays the impact of safety knowledge on the magnitude of anchoring effects experienced by workers in their risk perception of unsafe behavior. In the high anchor group, both workers with and without accident-injury experience showed a significant increase in anchoring effect strength when safety knowledge was enhanced. This suggests that workers with high levels of safety knowledge are more susceptible to the influence of high-risk anchors, resulting in a higher risk perception of unsafe behavior. In the low anchor group, both workers with and without accident-injury experience showed a significant decrease in anchoring effect strength when safety knowledge was enhanced. Thus, workers with high safety knowledge are more capable of avoiding the underestimated risk of unsafe behavior brought about by low-risk anchors.

3.5. *Further analysis*

3.5.1. *Analysis of the nonlinear effect of accident-injury experiences on risk perception*

The previous analysis reveals that accident-injury experiences significantly reduce workers' risk perceptions of unsafe behaviors. However, such a finding may not fully capture the nonlinear relationship between these experiences and risk perception. In detail, workers with minor accidents might form a lower intrinsic risk anchor, potentially leading to overconfidence and reduced risk perception in new unsafe situations. Conversely, those experiencing severe accidents tend to establish a higher inherent risk anchor, enhancing their risk awareness in hazardous scenarios. Therefore, the study delves into the nonlinear effects of accident-injury experiences on risk perception. We used Risk Perception (RP) as the dependent variable and included control variables, consequence severity of accident-injury experiences (AE_Severity), and its squared term ($AE\_Severity^2$) in the regression model. Table 10 shows a significant negative correlation between AE_Severity and RP across control, high anchor, and low anchor groups. A notable positive correlation between $AE\_Severity^2$ and RP was also observed, confirmed by the U-test. These results suggest a pronounced U-shaped relationship between the severity of accident-injury consequences and risk perception. Specifically, workers with milder accidents may adopt a dismissive safety attitude, lowering their risk perception. In contrast, increased accident severity can amplify risk awareness, significantly elevating risk perception in unsafe conditions.

3.5.2. *Analysis of the moderating effect of experimenter-provided risk anchors*

Prior research revealed that the influence of cognitive needs and safety knowledge on anchoring effects varies under different conditions of experimenter-provided risk anchors. To further examine the moderating effect of these risk anchors, this study centralized

Table 10
The nonlinear effect of accident-injury experiences on risk perception

Variables	Control group		High-anchor group		Low-anchor group	
	RP	RP	RP	RP	RP	RP
Sex	1.229	1.014	0.303	−0.257	−0.194	−0.217
Age	−0.752***	−0.646**	−0.625**	−0.498*	−0.670***	−0.689***
Marriage	−0.568	−0.741	1.314	1.017	0.217	0.253
Education	0.887**	0.872**	0.871**	0.869**	0.569***	0.550**
Work years	1.119***	1.148***	0.387	0.531*	0.189	0.201
AE_Severity		−3.704***		−2.440***		−0.811*
$AE\_Severity^2$		1.385***		0.497**		0.394**
ΔR^2	0.053	0.026	0.034	0.047	0.073	0.011
F	5.995***	7.405***	3.045**	11.242***	6.788***	2.482*
Utest		2.24**		1.58*		1.68**

Note: AE_Severity represents the severity of consequences from accident-injury experiences, calculated as the average severity of the worker's personal accident-injury experiences and those of their colleagues. $AE\_Severity^2$ is the squared term of AE_Severity.

the cognitive needs and safety knowledge and conducted hierarchical regression analysis by constructing risk anchors and their interaction terms. The results of this analysis are presented in Table 11: Model 13 indicates that the interaction term of risk anchors and cognitive needs significantly positively influences the anchoring effect (β = 0.158***). Similarly, Model 15 shows that the interaction term of risk anchors and safety knowledge also has a significant positive impact on the anchoring effect (β = 0.185***).

To more clearly demonstrate the moderating effect of experimenter-provided risk anchors, this study presents graphs depicting these effects under high-risk and low-risk anchor conditions (see Fig. 2). Specifically, under high-risk anchor conditions, both cognitive needs and safety knowledge intensify the anchoring effect on workers. Conversely, under low-risk anchor conditions, they diminish this effect.

4. Discussion

4.1. Research findings and implications

This study examined the anchoring effect and its determinants on workers' risk perception of unsafe behavior. The findings are summarized as follows:

First, our research confirmed the presence of experimenter-provided anchoring effects on workers' risk perception of unsafe behaviors. The numerical value of the anchor significantly influences how it affects risk perception; high-risk anchors increase the perceived risk associated with unsafe behavior, while low-risk anchors decrease it. Specifically, due to workplace complexity, workers often cannot analyze risks rationally and tend to over-rely on initial risk anchors. In our study, a high-risk anchor (questioning if the accident probability is over 70% and if severity could exceed causing fractures or amputations) led workers to estimate higher risk levels. Conversely, a low-risk anchor (asking if the accident probability is over 10% and if the severity could be more than no casualties and economic loss) led to lower perceived risk levels.

Second, this study confirmed the existence of self-generated anchoring effects on workers' risk perception of unsafe behaviors. However, unlike Oah's findings [9] that accident experiences significantly increased the risk perception among manufacturing workers, our study indicates that the impact of accident experiences on the risk perception of unsafe behaviors largely hinges on the severity of those accidents' consequences. Our observations revealed a distinct U-shaped relationship between the severity of accident consequences and workers' risk perception. Workers who experience minor accidents might adopt a casual attitude toward unsafe behaviors, consequently reducing their risk perception. However, as the severity of accidents increases, the severe repercussions can amplify their recognition of potential dangers, significantly elevating their risk perception of unsafe behaviors.

Third, our study observed that self-generated anchors from accident-injury experiences negated high-risk experimenter-provided anchors but barely affected low-risk ones. In the high-risk group, high-risk anchors did not heighten risk perception in workers with injury histories, as their experience overshadowed the provided anchor's influence. While in the low-risk group, workers'

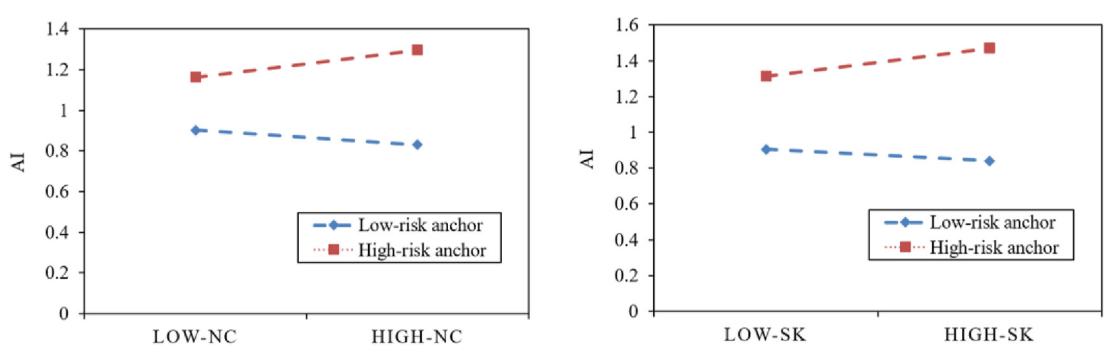

Fig. 2. The moderating effect of experimenter-provided risk anchors.

Table 11
Results of hierarchical regression

Variables	AI				
	Model 11	Model 12	Model 13	Model 14	Model 15
Sex	−0.065**	−0.050**	−0.045*	−0.049**	−0.043*
Age	0.001	0.003	0.003	0.003	0.002
Marriage	0.032	0.020	0.027	0.019	0.026
Education	−0.014	−0.015	−0.014	−0.017	−0.017
Work_years	−0.026***	−0.003	−0.001	−0.003	−0.001
Risk_anchor		−0.188***	−0.189***	−0.189***	−0.189***
NC		0.036***	−0.055***		
NC*Risk_anchor			0.158***		
SK				0.046***	−0.054***
SK*Risk_anchor					0.185***
ΔR^2	0.019	0.175	0.051	0.179	0.060
F	3.305**	94.401***	58.859***	97.406***	70.636***

Note: Risk_anchor signifies the experimenter-provided risk anchor (Risk_anchor = 1, high-risk anchor; Risk_anchor = 0, low-risk anchor).

injury experiences did not alter the low-risk anchor's impact which significantly lowered workers' risk perception. This discrepancy arises because workers rely on past minor injuries, forming a 'fluke mindset' and giving more weight to personal experiences over high-risk external cues. Conversely, they readily align with low-risk prompts, leaving the low-risk anchor's effect intact.

Fourth, contrary to Shan et al. [18], who suggested that the need for cognition and professional knowledge consistently diminishes the anchoring effect, our study reveals that their impact varies with the anchoring context. Specifically, cognition needs and safety knowledge lessened the anchoring effect in the low-anchor scenario but heightened it in the high-anchor one. This variance is attributed to better risk awareness in workers with higher cognition and safety knowledge. For instance, workers with greater cognition need and safety knowledge had notably higher risk perception (RP_Mean = 9.797 and RP_Mean = 9.200, respectively) than their less knowledgeable counterparts (RP_Mean = 6.061 and RP_Mean = 5.669, respectively). Hence, in high-risk contexts, these workers are more receptive to the high-risk anchors due to their advanced risk awareness, whereas they tend to reject low-risk anchors because of their higher understanding of potential dangers.

Compared to existing literature, this study offers novel theoretical implications in various aspects. First, risk perception has been found to impact unsafe behaviors significantly. Although previous studies have examined the effects of factors like workers' perceptions of hazards and safety climate on workers' risk perception [32,33], they do not entirely clarify why workers generate biased risk perceptions, namely underestimating or overestimating the risks of unsafe behaviors. Bridging this gap, our research investigates the influence of cognitive anchoring effects, particularly how risk anchors provided by experimenters and workers' experiences of accidents (self-generated anchors) shape their risk perception concerning unsafe actions. This methodological approach significantly deepens the empirical understanding of bias in risk perception. Second, workers' accident-injury experiences are important in safety and health research. Previous studies have examined the impact of these experiences on workers' risk-taking behavior. This study further extends this examination to include the correlation between the consequence severity of accident-injury experiences and workers' perception of risk in unsafe behavior. It uncovers a U-shaped relationship between the severity of accident consequences and risk perception, thereby broadening our understanding of the impact of accident-injury experiences on risk perception. Third, the research demonstrates that the need for cognition and safety knowledge profoundly impact the anchoring effect in risk perception among workers, providing scientific guidance for mitigating biases in workers' risk assessments.

Finally, this study also offers several practical implications. Managers can improve workers' risk perception by establishing warning signs for dangerous operations, such as setting high-risk anchors in the current study. Additionally, to effectively realize the warning function of risk-warning signs, managers should pay more attention to the safety education and training of workers to improve their safety knowledge and need for cognition. Moreover, workers with accident-injury experience should be the primary focus of managers, and correcting their fluke psychology of accidents to improve their risk awareness should be the top priority.

4.2. Research limitations and future research

This study is limited in certain aspects. Primarily, it only examines numerical risk anchors within the context of external risk anchors. In reality, diverse and complex external risk anchors, such as textual, auditory, and visual information, can profoundly influence workers' perception of risks in hazardous environments. Thus, future research should investigate the varied impacts of different forms of external risk anchors on risk perception. Additionally, this study's analysis of factors influencing the anchoring effect was limited to individual-level factors, including cognitive needs and safety knowledge. However, macro-level factors like a company's safety culture and leadership style also significantly affect workers' risk perception. Future research should, therefore, also examine the influence of these macro-level factors on the anchoring effect in risk perception.

Conflicts of interest

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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CRediT authorship contribution statement

Zunxiang Qiu: Conceptualization, Formal analysis, Resources, Validation, Writing – original draft. **Quanlong Liu:** Funding acquisition, Supervision, Writing – review & editing. **Xinchun Li:** Supervision, Writing – review & editing. **Yueqian Zhang:** Formal analysis, Investigation, Resources.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shaw.2024.05.004.

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