Mining, Metallurgy & Exploration
https://doi.org/10.1007/s42461-020-00293-8

Identify the Influence of Risk Attitude, Work Experience, and Safety Training on Hazard Recognition in Mining

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Received: 29 May 2020 / Accepted: 18 August 2020

Abstract
Mineworkers face a challenging and dynamic work environment every workday. To maintain a safe workplace, mineworkers must be able to recognize worksite hazards while they perform their jobs. Though hazard recognition is a critical skill, recent research from the National Institute for Occupational Safety and Health (NIOSH) indicates that mineworkers fail to identify a significant number of hazards. To further the understanding of mineworkers' hazard recognition ability and to begin to address hazard recognition performance, NIOSH researchers analyzed data collected during a laboratory research study to determine the effect of individual mineworker factors including risk attitude, work experience, and safety training on hazard recognition accuracy. The results of this study show that mineworker risk attitude and safety-specific work experience affect hazard recognition performance while hazard-specific safety training does not. These results suggest that some of these individual factors can be overcome through experience and training. Potential strategies that can be used to address these factors are also discussed.

Keywords Hazard recognition · Risk tolerance · Experience · Training

1 Introduction

From October 2013 through January 2015, the metal/nonmetal (M/NM) mining sector experienced an increase in occupational fatalities. During that time, 38 mineworkers were fatally injured [1], that is twice the number of fatalities that occurred in each of the previous 2 years. The Mine Safety and Health Administration (MSHA) identified inadequate performance on workplace examinations as a contributing factor to these fatalities and issued a program policy letter [2] focused on clarifying the requirements and responsibilities related to workplace examinations. To improve workplace examinations, MSHA approved a new workplace examination rule. Overall, this new workplace examination rule builds on the existing standard by adding the requirement that the exam be done before work begins in a specific area of the workplace and by adding new notification and recordkeeping requirements. However, a critical aspect of the workplace examination that is not addressed is guidance related to the "competent person," which is the person designated by the mine operator to examine the working place for conditions that adversely affect safety and health.

Within the Code of Federal Regulations (30 CFR 56.2), the competent person is defined as a person having abilities and experience that fully qualify him or her to perform the duty to which he or she is assigned [2]. In the case of workplace examinations, a competent person's primary assignment is to recognize and mitigate workplace hazards. To perform an effective workplace examination, the competent person must possess a specific set of competencies or the knowledge, skills, abilities, and other characteristics necessary to successfully identify and alleviate hazards. To date, that set of competencies has not fully been defined, in either the research literature or within the Code of Federal Regulation. Thus, research is necessary to identify the competencies critical to hazard recognition and to understand how competencies potentially interact to affect mineworkers' recognition of hazards.

2 Background

Hazard recognition is fundamental to every safety activity. Hazards that go unrecognized and unmanaged can potentially

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Published online: 31 August 2020

result in catastrophic incidents and injuries [3]. This is especially true for the mining industry because the environment is dynamic and often unpredictable, and mineworkers perform a variety of tasks in close proximity to heavy machinery [4]. It is critical that all mineworkers are able to identify hazards where they work. While hazard recognition is integral to worker health and safety, research indicates that workers are not recognizing a significant number of hazards in these environments [5, 6]. Carter and Smith studied hazard identification on three construction projects in the UK. The study results show that between 10 and 33.5% of hazards remain unrecognized [6]. Similarly, within the mining industry, Bahn found that underground coal mineworkers only recognized 43% of the hazards in a hazard recognition task [7].

An individual's risk attitude (e.g., risk tolerance or risk propensity) influences safe work behavior [8]. Risk attitude is defined as the amount of risk an individual is willing to accept in pursuit of a goal [9]. Individuals differ in the ways they manage personal risks [10], with some taking more risk depending on the situation (e.g., the personal value attached to the goal of the situation) [11, 12]. Research indicates that high-risk tolerance can lead to unnecessary hazard exposure [9] and that workers who are willing to take more risks are more prone to adverse events [13] and also report experiencing a greater number of near-miss incidents [14]. In terms of work experience, Haas et al. report that workers new to a specific job site or to the mining industry tend to be less risk tolerant and more compliant on the job [15]. However, there is research suggesting that risk attitude is not related to mineworker participation in workplace safety activities such as safety training or the number of worker self-reported, safety-related events (e.g., near misses) [16].

There is ample evidence in the research literature that worker experience affects worker hazard recognition [7, 17, 18]. For example, workers who experienced near-miss incidents are better able to perceive similar high-risk or hazardous events [19], and workers who lack recent experience working in a particular environment (e.g., underground coal mine) are less likely to recognize hazards specific to that environment (e.g., hazardous roof conditions) [20]. Perlman et al. tested the effect of worker experience on hazard recognition accuracy across three work experience levels: safety directors, superintendents, and civil-engineering students [17]. Of these three groups, researchers hypothesized that superintendents would identify the greatest number of hazards. Counter to this prediction, though, study results showed that safety directors—those workers with the greatest amount of formal safety-specific training—outperformed both civil-engineering students and superintendents, whom they were matched with in terms of number of years of work experience. Dzeng, Lin, and Fang's study results also suggest that general work experience may not be equivalent to safety-specific experience (e.g., experience gained by conducting safety inspections or trainings) [21]. Together, these studies suggest that safety training, in addition to work experience, improves workers' hazard recognition.

A traditional approach to improving hazard recognition in industries such as construction and mining is through safety training. Numerous studies indicate that training interventions can be used to improve worker hazard recognition [20, 22, 23]. Safety training is commonly used to improve workers' general hazard knowledge by increasing their understanding of basic hazards (e.g., slip, trip, fall, and electrical hazards) and site-specific knowledge by increasing their understanding of hazards that are unique to a commodity (e.g., ground control concerns specific to the geology of the material being mined) [24]. Komaki et al. found that using safety training to improve knowledge of hazards increases the number of safety acts workers perform and lowers the number of lost-time injuries [25].

To understand the influence of risk attitude, worker experience, and safety training on mineworker hazard recognition performance, the National Institute for Occupational Safety and Health (NIOSH) conducted a laboratory-based research study in an immersive virtual reality (VR) environment. In the study, participants were categorized into groups based on the amount of self-reported work experience within the mining industry, including health and safety professionals, experienced mineworkers, inexperienced mineworkers, and mining engineering students. The research task was a workplace examination search where participants were asked to visually scan panoramic images of typical work environments at a representative surface limestone mine for hazards. Research participants also completed a series of measures to assess their risk attitude and categorize the amount of safety training they had received, which provided the opportunity to investigate the relationship between hazard recognition performance and risk attitude, work experience, and safety training.

The first hypothesis is that mineworkers who report being more risk averse will identify a greater number of hazards than more risk-tolerant mineworkers. The second hypothesis is that mineworkers with more safety-specific work experience are more likely to identify hazards. The third hypothesis is that mineworkers with hazard-specific safety training are more likely to find hazards. By better understanding the relationship between these variables and the effect they have on hazard recognition performance, NIOSH can design more effective interventions that target specific competencies and improve hazard recognition and overall performance on workplace examinations.

3 Methods

3.1 Participants

Data collection started in February 2016 and was completed in December 2016. Fifty-two participants volunteered to take part in the study. Three participants were excluded due to technical difficulties; therefore, the dataset includes data for 49 participants. All participants traveled to the NIOSH research facility in Bruceton, PA. None of the participants received payment for their participation in the study. All participants were screened to verify they had normal or corrected to normal vision, normal peripheral vision, and were not colorblind (see [18]).

Participants were divided into four groups based on their total experience within the mining industry as well as the position they held at the mine: safety professionals, experienced mineworkers, inexperienced mineworkers, and students. Experienced mineworkers and safety professionals all had more than 2 years of mining experience. However, mineworkers held positions such as laborer, equipment operator, or foreman, while safety professionals held environmental, health, or safety positions. All participants, except for the students, also reported having completed at least 24 h of MSHA New Miner Training (30 CFR Part 46), and those categorized as experienced mineworkers and safety professionals reported having completed 8 h of MSHA Refresher Training annually (30 CFR Part 46) [26]. Lastly, participants self-reported if they had ever received hazard-specific training (e.g., site-specific training). The demographics of the study participants are shown in Table 1 below.

3.2 Panoramic Images and Hazards

The hazard recognition materials for this study included 32 panoramic images of four locations at a typical surface stone operation: pit, plant, roadway, and shop. There were eight panoramic images for each of the four locations. Six images for each location were experimental images, containing hazards, while the other two images were control images, containing zero hazards. The number of hazards per experimental image ranged from two to seven, totaling 101 hazards. The overall breakdown of the hazards was 19 in the pit, 25 at the plant, 26 on the roadways, and 31 in the shop.

Hazards in the images were selected to represent the type, severity, and prevalence of hazards found in MSHA's accident and injury database. Hazard placement and inclusion was vetted by subject matter experts. Hazards were staged to the extent possible and otherwise edited or enhanced. See Eiter et al. [18] for a discussion of the hazard selection and panoramic image evaluation process and Bellanca et al. [27] for a detailed explanation of the methods taken to create the panoramic images. Figure 1 depicts an example panoramic image of the pit along with two representative hazards.

3.3 Laboratory Procedure

Upon arriving at NIOSH's Virtual Immersion and Simulation Laboratory (VISLab), researchers obtained informed consent from the study participants to participate in the Institutional Review Board (IRB) approved protocol. Participants then completed a demographics questionnaire about their training and mining experience and completed the vision screening. Participants were then outfitted with the eye-tracking glasses (ETG 2.0, SensoMotoric Instruments, Teltow, Germany) and a custom-made, hand-held, two-button joystick in their dominant hand. The participants also wore a small backpack to carry the eye-tracking laptop. Lastly, researchers affixed reflective markers to the participants' C7, acromioclavicular joints, sternum, right scapula, and eye tracking glasses frames (Fig. 2). In preparation for data collection, participants performed a two-minute simple reaction time test, followed by a static calibration of the motion capture system and a 3-point calibration using the SMI iView software. Next, an additional 4-point, 10-degree fixation calibration was performed to orient and synchronize the motion capture and eye-tracking systems in order to determine the point of regard on the 360-degree projection screen. After the calibrations, participants reviewed two practice panoramic images to adapt to the setup.

For hazard identification data collection, participants were presented with four blocks of eight panoramic images grouped by location (pit, plant, shop, and roadway). The block orders

Table 1 Participant demographic counts and means (standard deviation)

Group	Number	Hazard-specific training (*N*)		Age (years) *M* (SD)	Total mining (years) *M* (SD)	Current position (years) *M* (SD)
		No	Yes			
Safety professionals	12	1	11	47.7 (11.0)	20.3 (13.5)	8.0 (5.7)
Experienced miners	11	0	11	39.1 (11.2)	13.8 (11.0)	9.2 (11.1)
Inexperienced miners	12	3	9	26.2 (8.2)	0.6 (0.5)	0.3 (0.3)
Students	14	7	7	22.9 (2.8)	0.7 (1.1)	N/A

Fig. 1 The top image depicts an unwrapped panoramic image used in the laboratory procedure. The bottom two images show two hazards included in the panoramic images. The hazard on the left is a small vehicle parked in close proximity to an overloaded haul truck, and the hazard on the right is a mineworker using an inappropriate tool and cutting technique to cut beltline

were distributed across participant experience groups, and individual images within the block were randomized per participant. Participants were given up to 2 minutes to view each image and were instructed to press a button to identify the hazards as quickly and as accurately as possible. Subjects were also instructed to only press the button once per hazard and to assume that all belts and conveyors were in motion. If a participant finished the identification early, they could end the trial by pressing the second button on the joystick. Participants were given a break between each block. The hazard identification task typically took between 45 and 90 min to complete.

3.4 Risk Attitude: Risk Propensity and Risk Tolerance

The study concluded with participants completing the Risk Propensity Scale and the Surface Mine Specific Risk Tolerance Workplace Scenarios. The Risk Propensity Scale was developed to measure the general tendency to take risks [28]. The Risk Propensity Scale includes seven items related to risk taking. The first six items are rated on a 9-point scale ranging from 1 (totally disagree) to 9 (totally agree), and participants were asked to indicate the extent to which they agreed or disagreed with the following statements:

Safety First.
I do not take risks with my health.
I prefer to avoid risks.
I take risks regularly.
I really dislike not knowing what is going to happen.
I usually view risks as a challenge.

The last item is rated on a scale from 1 (risk avoider) to 9 (risk seeker).

I view myself as…

A more detailed explanation can be found in Meertens and Lion's study [28], but, in general, higher Risk Propensity

Fig. 2 The image on the left depicts the participant setup including motion capture markers, eye tracking glasses, and backpack with laptop. The image on the right depicts the 360-degree projection screen and space where the hazard recognition task was conducted in NIOSH's VISLab

Scale scores indicate higher risk-seeking tendencies where items 1, 2, 3, and 5 are reverse coded. However, for this study the coding was reversed to match the risk tolerance measure, resulting in a higher score indicating lower risk-seeking tendencies.

The Surface Mine Specific Risk Tolerance Workplace Scenarios were developed by Lehmann et al. [16] in accordance with Reyna and Lloyd [29] and Hunter [9] where situationally relevant, hypothetical scenarios were presented to participants to determine risk tolerance. Lehmann et al. developed three mining-specific scenarios and asked participants to indicate comfort level—an indicator of potential behavior—with the hypothetical scenarios [16]. The three scenarios differ based on levels of personal risk to the participant. Participants are asked to determine "If you did this, how comfortable would you be?" and to rate the risk tolerance using the following: very comfortable, comfortable, uncomfortable, and very uncomfortable. Each response is scored from 1 to 4 with one being very comfortable and four being very uncomfortable. In this case, a higher score indicates lower risk tolerance.

3.5 Risk Scenario 1: Low Personal Risk

It is the end of the work shift. On the way out, a worker notices a broken electrical conduit. It is not in his area of the work site. Reporting the problem will make him late getting home. He leaves without reporting what he saw.

3.6 Risk Scenario 2: Medium Personal Risk

It is Friday, the end of the work week. The person responsible for doing the pre-shift inspections is rushed for time. Today, he hurries through the pre-shift inspection in just a few minutes. Usually, the inspection takes much longer to complete thoroughly.

3.7 Risk Scenario 3: High Personal Risk

A worker is in the process of changing a screen, and he drops a wrench onto the conveyor belt. Instead of locking out the conveyor belt first, he climbs onto the belt, picks up the wrench and continues working.

3.8 Statistical Analysis

Correlation coefficients were calculated between subjects' hazard recognition accuracy (i.e., the percent of hazards correctly identified), Risk Propensity Scale score (RP), and Surface Mine Specific Risk Tolerance Workplace Scenarios score (RT). Spearman's rank-order correlation coefficient was used due to violations in normality and the ordinal nature of the raw data. The effect of experience on accuracy was also calculated independently for experience group (student, inexperienced, experienced, and safety professional), and if the subject received hazard-specific training (HazTrain; yes/no) using non-parametric tests. The effect of experience and risk attitude (RP and RT) on accuracy was tested using logistical modeling. The clustering of the accuracy data by subject was accounted for by using generalized estimating equations (GEEs) to model the data. A binomial distribution with a logit link function was used, and an independent correlation structure was assumed. Due to the small sample size and unequal group distribution of HazTrain, group and HazTrain were analyzed separately. Full factorial experience and risk attitude models were used, where correct hazard identification (yes/no) was the response. Odds ratios were calculated for any significant effect with the students and no hazard training as the reference. Post hoc pairwise comparisons were calculated for any significant interaction effect. All data were analyzed using IBM SPSS Statistics Software (Cary, NC). The alpha was set to 0.05 for all multivariate models and post hoc comparisons.

4 Results

The Risk Propensity Scale had good internal consistency with a Cronbach's alpha of 0.758. However, the Safety First and Uncertainty questions were less correlated than the others, and their inclusion lowers the Cronbach's alpha slightly from 0.763 and 0.766 with the deletion of each respectively. The internal consistency of the Surface Mine Specific Risk Tolerance Workplace Scenarios was lower and marginal at 0.674, but all scenarios positively contributed to the measure. As shown in Fig. 3, RT scores described all groups as less risk seeking than that of the RP, but both measures describe the study population as risk adverse. However, only RT scores were significantly correlated with accuracy with a correlation coefficient of 0.283 ($p = 0.049$). RP and RT were not significantly correlated ($\rho = 0.204$; $p = 0.160$). Furthermore, experience group also showed a significant relationship with accuracy ($p = 0.013$), where safety professionals identified significantly more hazards than students ($p = 0.008$). There were no other statistically significant differences between experience groups. There was also no statistically significant difference in hazard recognition accuracy for mineworkers with and without hazard-specific training ($p = 0.082$).

Overall, the GEE models indicate that risk attitude is significantly, positively related to hazard recognition accuracy in that mineworkers who are more risk adverse are more likely to recognize hazards. The models also indicate that safety-specific experience increases the odds that a mineworker will correctly identify a hazard, but the effect of risk attitude is negated by experience. Lastly, the models did not find any statistically significant effect of hazard-specific training (Table 2).

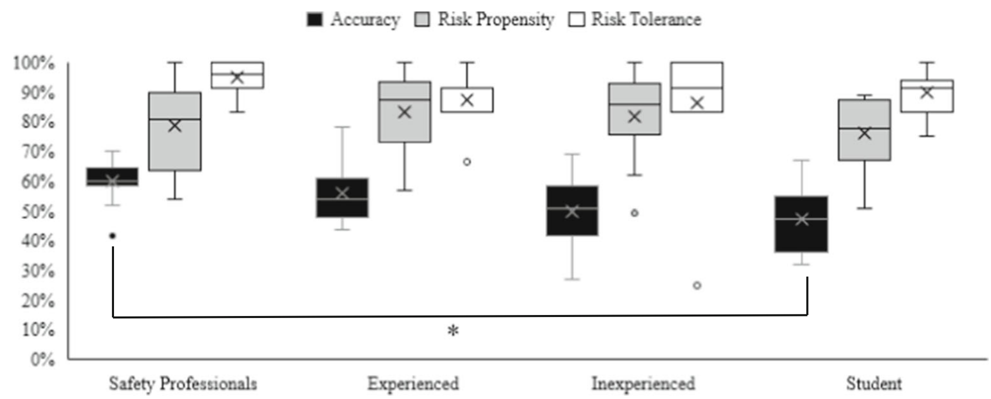

Fig. 3 Box and whisker graph depicting subjects' hazard recognition accuracy, Risk Propensity Scale (RP) scores, and Surface Mine Specific Risk Tolerance Workplace Scenarios (RT) scores by experience and hazard training group, where 0% represents the lowest and 100% represents the highest possible score on both scales. As computed, 0% is the most risk-seeking and 100% is the least risk-seeking for both measures. The Xs indicate the across-subject mean for each experience group, and circles indicate values that are greater than 1.5 but less than 3 times the interquartile range. Significant differences are indicated with an asterisk

Interestingly, group was only significant when modeled with RP. The group-RP model estimates that the odds of a safety professional correctly identifying a hazard was 9.040 (95% CI 3.111 to 26.269) times that of a student ($p = < 0.001$). The model also estimates that, in general, as mineworkers' RP increases (less risk seeking) the odds are higher that they correctly identify hazards ($\beta = 0.235$, OR = 1.265; $p = < 0.001$). However, this relationship differed across experience group (Fig. 4), in that it lessens with increased safety experience to the point where safety professionals showed no significant change in accuracy as RP changed ($\beta = -0.244$, OR = 0.784, $p = 0.002$). Table 3 provides the change in coefficient values from the RP reference.

When examined with HazTrain, RP was similarly related to accuracy. The model estimated that the odds of a mineworker correctly identifying a hazard were 1.250 (95% CI 1.088 to 1.435) ($\beta = 0.223$; $p = 0.002$). However, there was no significant effect of hazard-specific training (Table 2).

Similar to RP, the GEE models with RT indicated that as RT increased (i.e., less risk seeking) mineworkers were more likely to correctly identify hazards. The group-RT model estimated that the odds of a mineworker with a higher RT correctly identifying a hazard was 2.216 times higher (95% CI 1.075 to 4.569) than one with a lower RT ($\beta = 0.796$, $p = 0.031$). The HazTrain-RT model similarly estimated that the odds of a mineworker with a higher RT correctly identifying a hazard was 1.410 (95% CI 1.167 to 1.704) than one with a lower RT ($\beta = 0.344$; $p = < 0.001$). There were no significant effects of either group or HazTrain when modeled with RT.

5 Discussion

The purpose of this study was to determine the relationship of risk attitude, worker experience, and hazard-specific training with hazard recognition performance. The first hypothesis was that less risk tolerant mineworkers—those that are more risk averse—would identify more hazards. Risk attitude was assessed in two ways: through the Risk Propensity Scale which measures general risk-taking tendencies [28] and through the Surface Mine Specific Risk Tolerance Workplace Scenarios which includes situationally relevant, hypothetical scenarios [16]. Analysis of both risk attitude measures supports the first hypothesis that mineworkers who report being more risk averse identified a greater number of hazards. Findings for both measures of risk attitude align with previous research, showing that workers who are more risk tolerant are more likely to engage in

Table 2 Model effects of risk attitude (RP or RT) and experience (group or HazTrain) GEE models of accuracy

Accuracy model	Goodness of fit (QIC)	Experience group or HazTrain		Risk attitude RP or RT		Interaction	
		Wald χ^2	p value	Wald χ^2	p value	Wald χ^2	p value
Group + RP +Group × RP	6808.4	17.846	< 0.001*	7.387	0.007*	11.067	0.011*
HazTrain + RP + HazTrain × RP	6831.8	3.188	0.074	9.082	0.003*	2.118	0.146
Group + RT +Group × RT	6795.8	4.026	0.259	7.775	0.005*	3.235	0.357
HazTrain + RT + HazTrain × RT	6809.9	1.397	0.237	4.504	0.034*	1.045	0.307

* denotes signifance

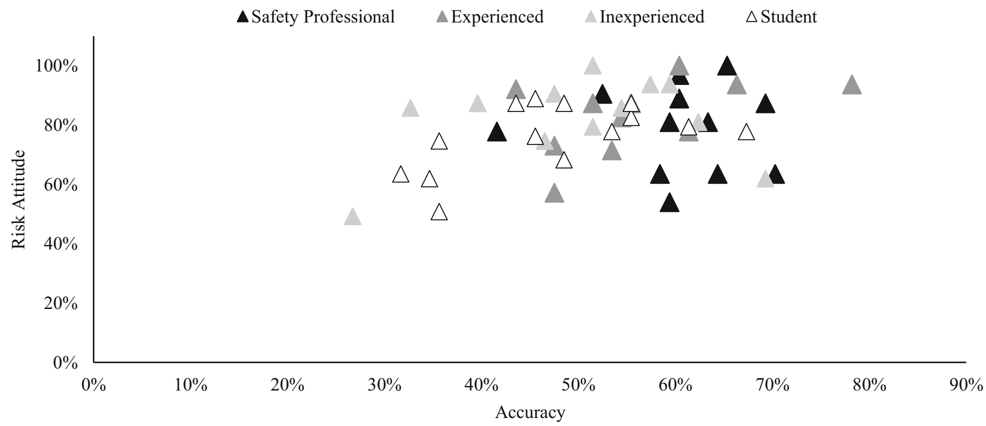

Fig. 4 Scatter plot depicting hazard recognition accuracy versus Risk Propensity Scale (RP) scores by experience group. The graph shows how the relationship between accuracy and RP lessens with increased experience

unsafe behavior that exposes them to unnecessary hazards and near-miss incidents [9, 14]. However, this contradicts Lehmann et al.'s findings with the Surface Mine Specific Risk Tolerance Workplace Scenarios, where no relationship between risk tolerance and safety-related events was found [16]. More research is needed to characterize this effect in the field.

The results of this study also support the second hypothesis. Consistent with previous research [17, 20], experience, specifically safety-specific experience, is correlated with better hazard recognition performance. In this study, safety professionals identified more hazards than mining engineering students. Previous research suggests that safety-specific experience is associated with greater job performance (e.g., identifying workplace hazards) because, over time as experience increases, workers gain more tacit knowledge and can more effectively perform their jobs [30]. Furthermore, research has also shown that experience improves people's cognitive representation of hazards and relative risk possibly also contributing to their ability to recognize hazards [31]. To increase safety-specific experience, safety professionals or mine managers can devise strategies to expose new or less experienced mineworkers to low-hazard conditions and monitor their ongoing exposure to potential hazards [32].

However, specific to the Risk Propensity Scale, the effect of risk attitude on hazard recognition performance completely disappears for mineworkers with safety-specific experience—safety professionals. This finding suggests that with enough safety-specific training, work experience, and standardization of training curriculum focused on hazards and risk assessment, the effects of individual risk biases may be overcome. It is unclear why this effect was not present with risk tolerance. However, based on the lack of correlation with the Risk Propensity Scale scores, the Surface Mine Specific Risk Tolerance Workplace Scenarios may be measuring risk behavior in a slightly different way. Because the Surface Mine Specific Risk Tolerance Workplace Scenarios include specific scenarios, it may be more related to the understanding of the risk associated with the specific hazards. Furthermore, this supports Lehmann et al.'s findings that there was no relationship between safety training and risk attitude [16]. Additional research should be conducted to examine risk perception in conjunction with the Surface Mine Specific Risk Tolerance Workplace Scenarios to clarify the differences.

These analyses also show that the third hypothesis was not supported; there was no difference in hazard recognition performance based on hazard-specific safety training. The lack of

Table 3 Parameter estimates for group and RP GEE model of accuracy

Parameter	Wald χ^2	*p* value	β	Odds ratio	Odds ratio 95% Confidence	
					Lower	Upper
Inexperienced	1.138	0.286	0.694	2.003	0.559	7.174
Experienced	0.684	0.408	1.013	2.754	0.250	30.404
Safety professionals	16.366	< 0.001*	2.202	9.040	3.111	26.269
Students	Reference					
RP	13.474	< 0.001*	0.235	1.265	1.116	1.434
Inexperienced × RP	0.418	0.518	−0.064	0.938	0.771	1.140
Experienced × RP	0.786	0.375	−0.140	0.869	0.638	1.185
Safety professionals × RP	9.702	0.002*	−0.244	0.784	0.672	0.914
Students × RP	Reference					

* denotes signifance

significance of hazard-specific training is not that surprising. Despite reporting not receiving any additional training, all mineworkers in this study had at least received new miner training, which is required to include a section of hazard recognition. It is likely that some mineworkers did not think of this component as significant and, therefore, differentially reported receiving hazard-specific training. However, new miner and annual refresher training minimally provides for the basics in understanding common mining hazards. In addition, the hazard-specific training measure did not assess when a participant received training. Research indicates that training most positively impacts immediate performance, as determined by assessing performance immediately following training [22]. Research also shows that if training does not occur consistently, at regular intervals (e.g., weekly, monthly, or bimonthly), then performance tends to degrade over time [33]. It is therefore likely that any effect of hazard-specific training was diluted across participants. The mining industry has recognized this fact and adopted more regular and consistent training of other critical competencies, such as mine emergency evacuation training and self-contained self-rescuer use training that is mandated to occur quarterly (as per 30 CFR 75.1504) [34]. Safety professionals and mine managers can similarly improve hazard recognition training by incorporating toolbox talks into daily pre-shift meetings or by focusing on site-specific hazards during monthly training. Additional research could also further explore the effect of hazard-specific interventions or safety-specific training topics (e.g., risk assessment or risk mitigation).

6 Conclusion

There are several limitations identified for this research study. First, the measure used to capture hazard-specific training may not have been explicit enough to capture the full extent of training participants in the study completed. A more detailed series of questions could be used to tease apart types of training, the focus of the training, and the number of hours spent in training. Additional questions could also probe for non-safety or non-occupational experiences as those type of trainings could also uniquely affect hazard recognition performance. This would allow researchers to better operationalize a hazard-specific training measure. Additionally, measures of internal consistency revealed that the Surface Mine Specific Risk Tolerance Workplace Scenarios [16] were only marginally consistent. This could be because the scenarios were developed and tailored for use at a specific workplace and, therefore, may not fully or accurately capture risk attitude for a varied group of participants. NIOSH relied on convenience sampling for this study, which led to an unequal number of participants in each experience and training group. And, while some individual characteristics were assessed in the study—through measures of risk attitude—the study did not assess other personality traits and non-occupational experiences which may contribute to participants' occupational choice, risk attitude, level of training, and overall hazard recognition performance. Lastly, due to time constraints, NIOSH was only able to collect a relatively small sample of participants which could have limited the effects of some of the statistical analyses.

Overall, the purpose of this study was to determine the influence of risk attitude, worker experience, and hazard-specific training on hazard recognition performance. The study demonstrates that both positive risk attitude (less risk seeking) and work experience improve hazard recognition accuracy. However, the effect of safety-specific worker experience appears to be stronger than that of an individual's risk attitude, supporting the need for additional safety-specific training. Hazard recognition is critical to mineworkers' health and safety. To this point, the necessary competencies for the competent person, the person responsible for performing workplace examinations, have not been effectively defined. Future research is needed to not only identify additional competencies but to also develop effective strategies and interventions focused on competencies to improve both hazard recognition ability and workplace examination performance.

Compliance with Ethical Standards

Disclaimer The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of company names or products does not constitute endorsement by NIOSH.

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethics Approval This work was reviewed and approved by the National Institute for Occupational Safety and Health's Institutional Review Board.

Consent to Participate Prior to the start of the study, all participants consented and agreed to voluntarily participate. Participants could withdraw from the study at any time, for any reason, without penalty.

Consent for Publication NIOSH employees have consented to use of their images within publication.

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