



Risk Perception with and Without Workers Present in Hazard Recognition Images

Jennica L. Bellanca¹(✉), Brianna Eiter¹, Jonathan Hrica¹,
Robert Weston², and Terry Weston²

¹ Pittsburgh Mining Research Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Pittsburgh, PA, USA

{JBellanca, BEiter, JHrica}@cdc.gov

² Center for Business and Industry, South Central College, Mankato, MN, USA
{Robert.Weston, Terry.Weston}@southcentral.edu

Abstract. Effective training is a critical component in improving mineworkers' ability to identify and assess hazards and ultimately reduce accidents and injuries. Previous research has identified the importance of context and cultural relevance as significant factors in the effectiveness of training. Research from adult education, social marketing, and public health education also suggest that the inclusion of a personal connection to training may improve communication. However, there is limited empirical knowledge about the effects of training content composition. Specifically, it is unclear how the inclusion of workers in training materials may affect how mineworkers' perceive a hazard. The goal of this paper is to examine if the presence of workers in the context of hazards affects how mineworkers' assess the risks. Researchers collected risk assessments from participants in the laboratory and during mandatory, annual refresher training. The results have implications for training material development and workplace examination timing.

Keywords: Risk assessment · Training · Hazards · Mining

1 Introduction

With 38 fatal injuries occurring between October 1, 2013, and December 31, 2014, the number of fatalities in the metal/nonmetal mining industry nearly doubled from the previous 15 months [1]. This sharp increase in fatal injuries led to an increased focus on hazard recognition in order to improve hazard mitigation. This focus supports the idea that mineworkers must be able to first recognize that a condition or behavior can cause harm that it is a hazard and that mineworkers must be able to appropriately assess the risk of the hazard [2]. Previous research has identified both hazard knowledge and risk perception as critical competencies of hazard recognition [3]. Risk assessment has also been shown to influence mitigation behaviors [4], and an increased level of risk perception has been associated with a decrease in risky behaviors [4–7]. However, mineworkers still fail to recognize a significant number of hazards [8]. Research suggests that there is a great deal of variability in how workers perceive risk [7, 9].

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Therefore, effective training is a key component to improving mineworkers' ability to recognize and assess hazards and ultimately reduce accidents and injuries.

Effective training is engaging, authentic, and includes relevant and understandable content. Research has shown that training that is more engaging (e.g., behavioral modeling) leads to greater knowledge acquisition and reductions in accidents and injuries [10]. As a part of maintaining engagement, research has also shown that adult learners need to perceive the training content to be personally relevant to apply it [11]. Problems with relevant content may come in the form of context or understanding. For example, a study by Wilkins on construction workers' perceptions of the Occupational Safety and Health Administration's (OSHA's) 10-h construction safety course found a correlation between workers expressing lack of relevance and a lower score on the knowledge assessment. This difference exemplifies a disconnect between the training and the critical concepts [12]. Research has shown that when trainees perceived training to be useful and valuable they are more likely to apply it in the workplace [13, 14]. Previous studies also found that training that is more realistic improves training transfer [15, 16]. Ultimately, improving mineworkers' ability to recognize and assess hazards through training may lead to better safety outcomes.

The same principles that govern effective training suggest that the inclusion of a person in the context of a hazard may improve hazard knowledge training. For example, research from social marketing suggests that a personal connection and clear context may improve communication [17]. The addition of a person in hazard imagery may allow the trainees to more easily put themselves in the situation. Including a person in a hazard image may also improve the trainees' ability to predict the consequences of a hazard by clarifying the context. Isolated hazards often require discussion or text to describe possible outcomes, but language and literacy can be barriers in safety training [12, 17]. The addition of a person may also affect cultural relevance. This is important because previous work suggests that appropriate cultural relevance improves engagement and retention, and a mismatch may have a negative impact [18]. Additionally, hazard images including people may directly improve training strategies. Behavioral modeling an engaging form of training that includes demonstration and practice is most effective with the inclusion of both positive and negative examples [19]. Including a person in context with the hazard may serve as a negative example. However, it remains unclear how the presence of a person in the context of a hazard affects risk perception, as there is a lack of consensus on the effect of social and cultural framing on risk perception [20].

Therefore, the goal of this study was to determine the effect of the inclusion of a person in hazard images on risk assessment, including overall risk and its principal components, probability and severity. Because research suggests that training effectiveness [12] and risk assessment [9] may change based on experience, this study also explores the role mining experience plays on the effect of a person's presence in hazard images on risk assessment.

2 Methods

2.1 Data Collection

The data discussed in this paper comes from two different sources. The first source was a larger, more in-depth laboratory study that drove the development of a broader training study. Researchers selected hazards from the laboratory study to be used in the training study to gather a larger sample of participants and explore identified effects. As such, the analysis of the laboratory study is a secondary analysis. Only part of both data collection efforts will be examined here.

Each study is briefly described below. For a more complete description, see [9]. Table 1 presents the participant demographics from both studies. Age and mining experience are presented as categorized in the training study for comparison, where the categories were defined as [18–29, 30–39, 40–49, 50–59, 60+] and [0–2, 3–10, 11–20, 21–30, 30+] years respectively.

Laboratory Study. The initial data collection took place in a virtual reality laboratory as a part of a larger study examining hazard recognition and risk perception of mineworkers. As a part of an Institutional Review Board (IRB) and Office of Management and Budget approved protocol, NIOSH researchers recruited 51 participants with various types and levels of surface mining experience; this included safety professionals, experienced miners, inexperienced miners, and students. Safety professionals had at least two years of environmental, health, or safety experience with a mine operator or government agency. Experienced mineworkers had more than two years of mining experience. Inexperienced mineworkers had some but less than two years of mining experience. Lastly, students were participants enrolled in a mining-related program and not otherwise classified [8].

The laboratory study first required participants to search for hazards in life-size panoramic images, performing a simulated workplace exam [8], [21]. Next, during a debrief of their search performance, participants completed risk assessments of all 102 hazards included in panoramic images. This paper focuses on the risk assessments of a subset of hazards, matched sets of slip, trip, and fall (STF) hazards with and without mineworkers present in the images.

Table 1. Participant demographics from laboratory study and training study

Study	Group	N	Median age category	Median mining experience category
Lab	Safety professionals	13	40–49	11–20
	Experienced	11	40–49	11–20
	Inexperienced	13	18–29	0–2
	Students	14	18–29	0–2
Training		1,232	40–49	3–10

Training Study. In order to get a broader picture of risk perception across the surface mining industry, a second data collection was performed during MSHA-mandated annual health and safety refresher training (30 CFR § 46/48). The fourth and fifth authors of this paper facilitated all the data collection sessions during their normal training classes in their capacity as certified MSHA trainers. As such, data collection was a convenience sample, including mine companies, mine service companies, engineering firms, and open public classes. A total of 1,508 participants in 52 training sessions were recruited to participate in an IRB approved protocol. Sixty-six declined to participate and 210 participants were eliminated due to missing data, leaving a total of 1,232. Participants consented to participate and recorded their answers via an audience response system (clickers). Participants performed risk assessments on four of the hazards from the laboratory study. This paper focuses on one matched set of STF hazards with and without mineworkers present in the images.

2.2 Hazards

The original panoramic images from the laboratory study were of typical locations at a surface limestone mining operation, including the pit, plant, shop, and roadway. The images included hazards that matched the type, severity, and prevalence of hazards in MSHA's accident and injury database. Subject matter experts reviewed the images and hazards for accuracy and realism. To the extent possible, hazards were staged, but otherwise they were edited or enhanced (see [21]). Any people included in the images were dressed in typical mine site attire, except where omitted as a hazard.



Fig. 1. *Fall to walk way or working surface.* The left image displays a slip, trip, and fall (STF) hazard without a person, where the pipes and cables inside the orange rectangle are the hazard. The right image displays a STF hazard with a person, where a bucket being used as a step is the hazard. Both hazards were included in the laboratory and training data collections.

Researcher chose to focus on STF hazards, because they are one of the most prevalent types of hazards in metal/nonmetal mining [8] and can be clearly

demonstrated with and without mineworkers. In the original laboratory study, the panoramic images included 102 hazards; 23 of the original hazards were STF. From the 23, researchers identified matched sets of hazards by selecting ones with the same accident type [22] and similar average risk assessment ratings by the safety professionals in the laboratory study. Researchers included safety professional rating in the selection criteria in order to minimize perceived differences in the hazards because exact matches were not available. Researchers specifically chose safety professionals as a reference because no objective or gold standard for risk assessment exists, but they are considered experts, as they are responsible for the health and safety of all the mineworkers at a mine site. This resulted in the identification of two matched sets of hazards in the laboratory study (Figs. 1 and 2), one of which was incorporated into the training study (Fig. 1).



Fig. 2. *Fall from equipment.* The left image displays a slip, trip, and fall (STF) hazard without a person, where the bottom rung of the ladder on the haul truck is missing. The right image displays a STF hazard with a person, where the mineworker cannot maintain three points of contact while climbing the ladder because he is carrying a lunchbox. Both hazards were included in the laboratory study only.

2.3 Risk Assessment

The risk assessment procedure was similar for both data collections. Researchers first reviewed the risk assessment scales with the participants (Table 2), [7]. Then, for each hazard, the participants received a brief description of what the hazard was (e.g., Fig. 1 - left: in this picture, you can see the pipes and cables in front of the main entrance to the shop). Next, researchers asked participants to rate: (1) how *severe* you think the likely resulting accident would be, (2) the *likelihood* that an accident will occur, and (3) your *overall risk* assessment on a 5-point scale. Researchers instructed participants to go with their first instincts and rate the hazards as quickly as possible.

Table 2. Risk assessment rating scales [7]

Scale	Numerical value				
	1	2	3	4	5
Accident severity	No injury	Minor injury No leave	Injury \geq 3 days leave	Non-fatal Major injury	Fatal
Accident probability	Very unlikely	Fairly unlikely	Average likelihood	Fairly likely	Very likely
Overall risk	Very low	Low	Medium	High	Very high

2.4 Statistical Analysis

Multinomial population-averaged statistics were used to determine the effect of the inclusion of a person as a part of a STF hazard image on risk assessment controlling for experience across the mining population. For the performed statistical analysis, all risk assessment rating data was assumed to be ordinal. To do so, each dimension of the risk assessment was modeled using generalized estimating equations (GEE) with a multinomial distribution, cumulative logit link function, and an independent correlation structure. GEE were selected because they are deemed to be more robust to variable or unknown correlations [23]. The laboratory data was modeled as a full factorial interaction between group (student, inexperienced, experienced, safety professional) and the inclusion of a person (person, no person). Interaction effects with hazard type (fall to walk way or working surface, fall from equipment) were initially included in the model, but were removed once they were found to be insignificant. Odds ratios were calculated for any significant effect with safety professional and person as the references. Similarly, the training data was modeled using a full factorial interaction between years of mining experience (0–2, 3–10, 11–20, 21–30, 30+) and the inclusion of a person (person, no person). All data was analyzed using IBM SPSS Statistics Software (Cary, NC). Alpha was 0.05.

3 Results

3.1 Laboratory Study

The GEE models of the laboratory data indicate that participants rated the accident probability of a hazard without a person significantly lower ($p = 0.030$) (Fig. 3). There was also a significant group effect for both risk ($p = 0.035$) and severity (0.009).

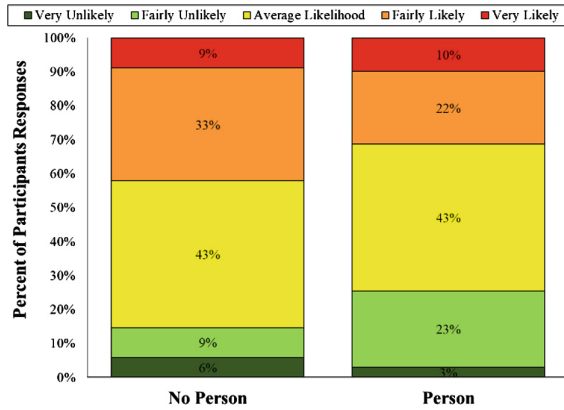


Fig. 3. Graph depicting the accident probability ratings breakdown from the laboratory study, where participants rated hazards without people significantly higher.

The parameter estimates from the GEE models reveal the following significant relationships. The odds of participants rating hazard images *without people* with a *higher probability* of occurring was 2.66 (95% CI 1.15 to 6.16; $p = 0.023$) times that of hazards with people. Figure 3 displays this significant difference through the breakdown of the accident probability ratings. The results also indicate that the odds of students rating STF hazards as *less risky* than safety professionals was 3.60 (95% CI 1.35 to 9.52; $p = 0.010$). Figure 4 displays the group effect and the general trend of risk increasing with experience. Lastly, the model estimated that the odds of students rating STF hazards as *less severe* than safety professionals was 5.59 (95% CI 2.00 to 15.90; $p = 0.001$). Severity similarly increases with experience level in the laboratory study.

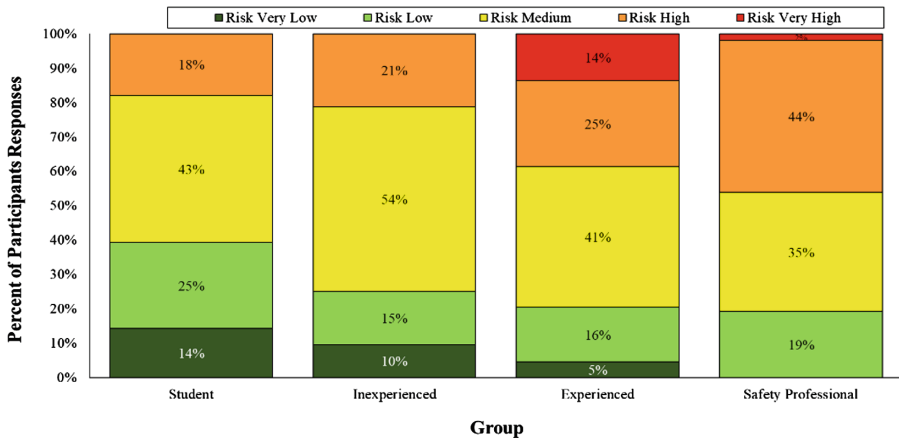


Fig. 4. Graph depicting the overall risk ratings breakdown across experience groups for the laboratory study, where the students rated risk significantly lower than safety professionals.

3.2 Training Study

The GEE models of the training data indicate that participants rated the accident probability of a hazard without a person significantly lower ($p < 0.001$) and the severity significantly higher ($p < 0.001$). However, there was no significant person effect on the overall risk ratings ($p = 0.794$). The results also showed that there was a significant experience ($p = 0.001$) and person-experience interaction effect ($p = 0.021$) for severity.

The parameter estimates from the GEE models reveal the following significant relationships. The odds of participants rating hazard images *without people* with a *higher probability* of occurring was 1.62 (95% CI 1.17 to 2.27; $p = 0.004$) times that of hazards with people. Table 3 presents the coefficients and odds ratio of probability model, where the significant person effect is just over 0.5. Figure 5 displays the probability response breakdown for hazards with and without people. The difference in ratings between the hazards appears larger than observed in the laboratory study (Fig. 3).

Table 3. Training study probability parameter estimates

	Coefficient			Odds ratio		
	Estimate	95% CI		Estimate	95% CI	
Experience						
30+	-0.16	-0.58	0.26	0.85	0.56	1.30
21-30	-0.34	-0.73	0.06	0.72	0.48	1.06
11-20	-0.23	-0.57	0.11	0.79	0.56	1.11
2-11	-0.16	-0.47	0.16	0.86	0.62	1.17
0-2	Reference					
Person						
Person	-0.54*	-0.83	-0.25	0.58*	0.44	0.78
No Person	Reference					
Interaction Effects						
30+ x Person	0.05	-0.39	0.50	1.06	0.68	1.64
21-30 x Person	0.42	-0.03	0.87	1.52	0.97	2.38
11-20 x Person	0.01	-0.38	0.41	1.01	0.68	1.50
2-11 x Person	0.06	-0.30	0.43	1.07	0.73	1.54

* Indicates significance at $\alpha = 0.05$

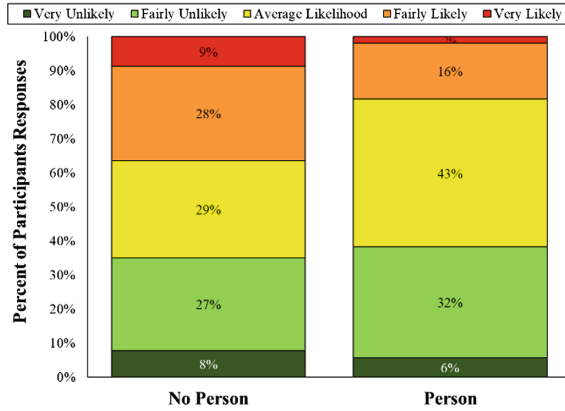


Fig. 5. Graph depicting the accident probability ratings breakdown from the training study, where participants rated hazards without people significantly higher

The results also estimate that the odds of participants rating hazard images *without people* as *less severe* was 2.54 (95% CI 1.90 to 3.40; $p < 0.001$). However, this effect appears to decrease as experience increases as demonstrated by the coefficients in Table 4. In fact, the odds of participants with 30+ years of mining experience rating hazard images *without people* as *more severe* than those with 0–2 years of experience was 2.24 (95% CI 1.35 to 3.75; $p = 0.002$), but there was no significant difference in the severity rating of participants with 30+ years of mining experience between hazards with and without people. Figure 6 displays this interaction effect for severity in the training study through the ratings breakdown across experience and between hazards with and without a person.

Table 4. Training study severity parameter estimates

	Coefficient			Odds ratio		
	Estimate	95% CI		Estimate	95% CI	
Experience						
30+	1.09*	0.66	1.52	2.98*	1.94	4.58
21–30	0.61*	0.22	1.01	1.85*	1.24	2.76
11–20	0.43*	0.07	0.79	1.54*	1.08	2.20
2–11	0.26	−0.07	0.59	1.30	0.93	1.80
0–2	Reference					
Person						
Person	0.93*	0.64	1.225	2.54*	1.90	3.40
No Person	Reference					
Interaction Effects						
30+ x Person	−0.81*	−1.32	−0.30	0.44*	0.27	0.74
21–30 x Person	−0.40	−0.84	0.04	0.67	0.43	1.04
11–20 x Person	−0.26	−0.67	0.15	0.77	0.51	1.17
2–11 x Person	−0.12	−0.49	0.24	0.88	0.61	1.28

* Indicates significance at $\alpha = 0.05$

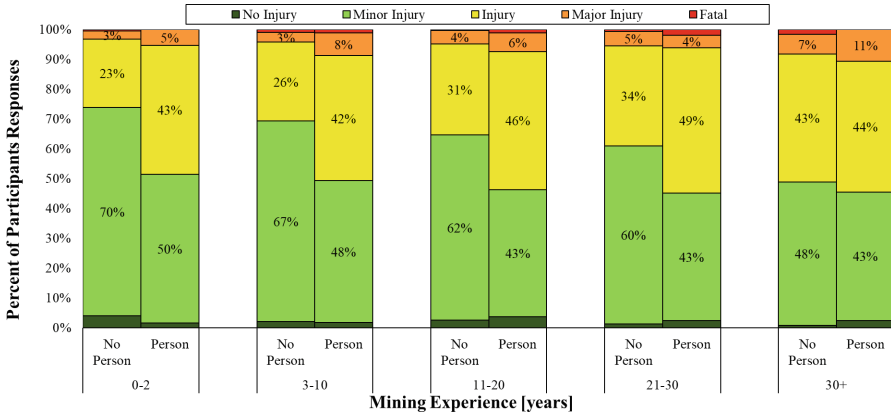


Fig. 6. Stacked plots depicting the severity ratings breakdown across experience from the training study for the hazards with and without a person. The significant interaction effect is apparent by the difference between no person and person for each experience level except 30+ years.

4 Discussion

Research from adult education, social marketing, and public health education suggest that the inclusion of a person in the context of hazards as a part of hazard recognition training materials may improve its knowledge transfer, but it is unclear how this difference affects risk assessment. Researchers are exploring data from two studies to characterize this effect. The results suggest that the inclusion of a person in the context of a hazard has roughly equal and opposite changes in probability and severity ratings but no change in overall risk. Additionally, the results indicate that there may be a confounding effect of specific types of experience.

Overall, participants in both studies rated the probability of hazards without people significantly higher than those with people. This result suggests that there may be a tradeoff between hazard situational specifics and an increase in incident possibilities. Having a person in the midst of a hazard may suggest that the person is closer to safety, leading to the lower accident probability ratings. Alternatively, mineworkers may be experiencing projection bias [24] or false consensus bias [25] in that they are assuming the person in the image has the same increased visibility or awareness of the hazard as they do as observers, again decreasing the probability of an accident. Mineworkers should be careful of attributional biases and avoid allowing them to affect their perceptions. Risk assessment is intended to be “objective estimations based upon well-defined criteria, relating to the probability of an event, its potential consequences, and levels of exposure to these consequences” as opposed to subjective risk perception [20].

The results of this study also suggest that for the training participants, less experienced mineworkers rated the severity of hazards without people lower. The decrease in severity may be due to the lack of clear definition of the hazardous situation without

a person. This makes the hazard outcome less salient that is, less cognitively available and thus participants tended to rate the severity lower [26]. However, this effect is not present in more experienced participants. One possible reason for the difference is that experienced participants tend to be older. Older adults may be more sensitive to STF hazards because they tend to be more risk adverse [27]. Alternatively, the increased morbidity and mortality of falls for older adults [28] and the increased likelihood of a previous personal injury may have an amplification effect on their severity perception [26].

Another interesting finding was that the results from the laboratory and training studies differ on severity and risk. This difference suggests that there may be a difference between general experience and safety-specific experience as has been demonstrated previously [7–9]. Despite similarities in years of mining experience, safety professionals have a different focus and type of experiences than experienced mineworkers. Furthermore, the laboratory study included mining students that lack any practical experience that even an inexperienced mineworker would have. It is also important to note that the age and experience makeup of the laboratory study is lower than that of the training study.

Lastly, the results indicate that for the training participants, the opposite changes in probability and severity appeared to offset each other, resulting in no change in overall risk. However, it is unclear whether the magnitude of the changes in probability and severity are hazard specific.

As a secondary analysis, this paper explores the changes in participants risk perceptions based on the context of hazard images. Though the primary focus was the inclusion of a person, this study is limited in that exact matching hazards were not used. It is possible that the effect observed in this analysis were due to other differences between the images. Specifically, tripping on pipe is different than falling off a bucket. Additionally, the number and type of hazards included in this study was small. This study only included two sets of two types of STF hazards. Researchers should conduct an additional directed study using a tighter comparison design with additional hazard types and hazard classifications.

The generalizability of the laboratory and training data may be limited by the convenience sampling. Participants for the laboratory study self-selected to participate and the training recruitment was limited to the clientele of the fourth and fifth authors. Furthermore, the cultural background of the participants is unknown. As suggested in the literature, cultural relevance can influence perception in positive and negative ways [20]; additional studies should control for this.

5 Conclusions

Overall, the results of this work indicate that the context of a hazard can alter trainees' risk perceptions. These results begin to suggest that the inclusion of a person in hazard images may reduce probability ratings and increase severity ratings. More work is needed to directly attribute these findings. However, this does not mean that adding in workers no longer has the potential to improve training materials. Including context and variability in training material is an important aspect to building up trainees'

exposure and understanding. The results also highlight the differences across hazards and experience levels. Together, this underscores the importance of standardizing and objectifying risk assessment.

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.

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