



Exploring Worker Experience as a Predictor of Routine and Non-routine Safety Performance Outcomes in the Mining Industry

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Abstract

In recent years, there has been increasing interest in the role that individual factors play in health and safety (H&S) outcomes in the mining industry.

Two surveys, one measuring self-reported routine safety performance and one measuring individual perceived competence in the non-routine knowledge, skills, and abilities (KSAs) critical to emergency response, were administered to two samples of mineworkers in separate research studies over a 2-year period ($N=2,020$ and 696 , respectively). Eight demographic items were common to both surveys and their associations with each performance outcome were tested in response to a series of exploratory research questions.

Significant relationships were found between both safety outcome variables and individual factors, including the length of experience in current job, current mine, and mining industry, as well as participant workgroup and work schedule. Notably, the length of experience in the mining industry was the only variable significantly associated with both routine and non-routine safety performance.

This analysis suggests that individual factors such as length of job, industry, and mine experience are predictive of routine and/or non-routine safety performance outcomes in significant and sometimes unexpected ways.

Keywords Mining · Safety · Worker experience · Emergency response

1 Introduction

In recent years, there has been increasing interest in the role that organizational factors (e.g., health and safety management systems and safety culture) and individual factors (e.g., job role, tenure) play in health and safety (H&S) outcomes in the mining industry [1–4]. In particular, the role of mineworker experience in individual safety incidents has garnered attention and is the subject of an increasing number of questions being explored by the Mine Safety and Health Administration (MSHA) and the National Institute

for Occupational Safety and Health (NIOSH). Additionally, and in response to the NIOSH-sponsored National Academy of Sciences' (NAS) investigation, "Improving Self-Escape from Underground Coal Mines" [5], individual factors are being examined in terms of their relationship to personal emergency response preparedness in the underground coal mining industry. Although, there has been a great deal of speculation about the relationships between types of experience and safety performance, and to the authors' knowledge, there is little empirical evidence that speaks to the direction or significance of these relationships.

The results of three recent case studies by NIOSH [6] prompted researchers to emphasize the value of continuous engagement of mineworkers in H&S efforts across job tenure and levels of mine site and industry experience. In the current study, researchers further examined the datasets from two of these cases, whose surveys measured common demographic variables—one that measured self-reported routine safety performance and one that measured individuals' perceptions of their own competency in the non-routine, yet critical knowledge, skills, and abilities (KSAs) required

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to effectively respond to a mine-emergency (Table 1). These outcome variables were examined in relation to eight individual factors contained in both datasets (i.e., time in current job, time in current mine, time in mining industry, age, education, workgroup, work schedule, family mining history). The results of this examination add insight into whether and how mineworker demographics, specifically types of experience, might relate to workers' preparedness to effectively mitigate or respond to both routine and non-routine risk in the mining industry.

1.1 Mineworkers and Routine Safety Performance: Proactivity and Compliance

For this research, routine safety performance has been operationally defined as the summation of self-reported proactive and compliant safety behaviors associated with day-to-day job tasks, both of which have been found to predict safety performance [7–9]. Proactive safety behaviors are those where workers take the initiative to improve safety on the job [7] and/or voice concerns about safety [8], while compliant safety behaviors involve “adhering to safety procedures and carrying out work in a safe manner” [10, p.101] and include behaviors such as using personal protective equipment and following safety-related rules on the job [11].

1.2 Mineworkers and Competence in Non-routine KSAs: Self-escape Confidence

The authors of the aforementioned NAS report defined “self-escape” in the event of an emergency as “the ability of an individual miner or a group of miners to remove themselves from the mine using available resources” [5, p. 13]. Although significant efforts to improve self-escape training and assessment in the mining industry have been made in recent decades, it is impossible to know with any certainty whether these efforts have been effective. Industry consensus suggests that deficiencies in competence in the non-routine tasks required for effective self-escape likely remain [5, 12, 13] and NIOSH research continues to address this concern [14].

Although there is increasing interest in the degree to which individual factors such as background and experience might predict safety performance outcomes in the mining industry, there is little empirical evidence to support the existence of these relationships.

2 Methods and Materials

To explore ways in which individual characteristics might predict routine safety performance and self-escape competence, an exploratory analysis of the cross-sectional results

Table 1 Individual factors measured by both surveys

	Safety performance (n, % [§])	Self-escape (n, % [*])
Time in the mining industry		
< 1 year ^{**}	205 (10.4%)	138 (19.9%)
1–5 years [†]	397 (20.0%)	292 (42.2%)
6–10 years	364 (18.4%)	113 (16.3%)
11–15 years	304 (15.4%)	60 (8.7%)
16–20 years	189 (9.5%)	89 (12.9%) ^{††}
> 20 years	521 (26.3%)	
Time on the job		
< 1 year	329 (16.4%)	83 (12.0%)
1–5 years	556 (27.7%)	247 (35.6%)
6–10 years	342 (17.0%)	237 (34.2%)
11–15 years	256 (12.7%)	77 (11.1%)
16–20 years	157 (7.8%)	29 (4.2%)
> 20 years	368 (18.3%)	20 (2.9%)
Time at the current mine/company		
< 1 year	307 (15.8%)	89 (12.8%)
1–5 years	444 (22.9%)	214 (30.9%)
6–10 years	328 (16.9%)	256 (36.9%)
11–15 years	276 (14.2%)	85 (12.3%)
16–20 years	162 (8.3%)	30 (4.4%)
> 20 years	426 (21.9%)	19 (2.7%)
Age		
18–24 years	126 (6.3%)	41 (5.9%)
25–34 years	446 (22.3%)	247 (35.6%)
35–44 years	461 (23.0%)	202 (29.1%)
45–54 years	530 (26.5%)	93 (13.4%)
55+ years	439 (21.9%)	111 (16.0%)
Education (high school [HS])		
HS or less	1382 (68.8%)	513 (73.8%)
More than HS	621 (31.2%)	182 (26.2%)
Shift schedule		
Set	1378 (69.0%)	121 (17.5%)
Rotates	620 (31.0%)	571 (82.5%)
Workgroup		
Production	1153 (57.9%)	461 (66.5%)
Maintenance	454 (22.8%)	138 (19.9%)
Other	385 (19.3%)	94 (13.6%)
Family mining history		
First generation	1270 (64.9%)	228 (33.1%)
Multigeneration	687 (35.1%)	460 (66.9%)

[§]Percentages are based on the valid percent of the sample (excludes non-responses)

^{**}These two categories (“< 1 year” and “1–5 years” of experience in the mining industry) were merged in the self-escape sample due to insufficient sample size

^{††}These two categories (“16–20 years” and “< 20 years” of experience in the mining industry) were merged in the self-escape sample due to insufficient sample size

from two separate NIOSH studies was conducted. This research was completed simultaneously over the course of 2 years: (1) to assess organizational safety climate as perceived by individual workers and its relationships to self-reported routine safety performance and (2) to measure individual workers' perceived competence (or "confidence") in non-routine self-escape KSAs.

The examination of these independent datasets allowed for the identification and exploration of trends in relationships between individual factors measured by both surveys and the routine and non-routine performance outcomes across samples. The results of this analysis may provide further insight into the usefulness of examining characteristics of individual mineworkers to design and target interventions for both high-frequency/low-severity events (e.g., near misses and injuries) and low-frequency/high-severity events (mine emergencies). To accomplish this goal, the following research questions (RQs) were addressed:

1. What individual factors measured by both surveys, if any, are significantly relate to hourly workers' self-reported routine safety performance (i.e., proactivity and compliance)?
2. What individual factors measured by both surveys, if any, are significantly relate to hourly workers' perceived self-escape competency (i.e., confidence in their own KSAs)?
3. Is there any overlap of individual factors measured by both surveys that are significantly associated with each outcome variable?

Approximately 2700 surveys from two research projects were administered to hourly mineworkers between 2016 and 2018. The two survey efforts are described below.

2.1 Routine Safety Performance

In response to broad questions surrounding safety climate and safety performance in the mining industry, NIOSH researchers developed a survey to gather and assess mine-worker demographic data, perceptions of organizational support for worker safety and health, and self-reported safety behaviors.

2.1.1 Survey Development

Worker safety performance was measured by self-reported day-to-day compliant and proactive safety behaviors as defined below.

- *Safety compliance* relates to individual workers following safety rules and participating in safety-related activities, as dictated by organizational policies and procedures [10, 11].
- *Safety proactivity* (also known as safety "participation") refers to individual workers anticipating safety events, taking initiative to improve work conditions, taking charge, speaking out, and overcoming barriers to working safely rather than passively adapting to existing conditions [7–10, 15].

The safety performance scales were adapted from previously validated metrics and included four items to measure compliance with safety policies and procedures [10, 16] and five items to measure proactivity [10], respectively:

When I am at work, I...

- don't take risks that could result in an accident.
- use all necessary H&S equipment to do my job.
- use the correct H&S procedures for carrying out my job.
- always report all H&S-related incidents, and

When I am at work, I...

- try to solve problems in ways that reduce H&S risks.
- go out of my way to address potential hazards.
- voluntarily carry out tasks that help improve workplace H&S.
- make new suggestions to improve how H&S is handled.
- try new things to improve workplace H&S.

These constructs were measured using a six-point Likert scale (strongly disagree to strongly agree), with six indicating the highest levels of compliance and proactivity. In this sample, both the proactivity ($\alpha=0.875$) and compliance ($\alpha=0.851$) scales demonstrated high internal consistency [17, 18].

2.1.2 Recruitment, Data Collection, and Participants

After the approval by the Institutional Review Board (IRB) and Office of Management and Budget (OMB), the survey was pilot tested, and data collection occurred between February 2016 and March 2018. Survey administration typically occurred during pre-shift meetings or annual refresher trainings and took approximately 15 min to complete. Participants consisted of 2020 hourly mineworkers from 39 mine sites. Sixteen percent worked in underground coal, 52% in stone, sand, and gravel (SSG), and 32% in industrial minerals. The number of participants from each mine site ranged from 7 to 246 ($M=52$).

2.2 Non-routine Safety Performance

Due to the low frequency of large scale mine emergencies, there are limited data related to real-world mine emergency response effectiveness. The purpose of this survey effort was to identify potential gaps in underground coal miners' critical self-escape KSAs from the perspective of the workers themselves.

2.2.1 Survey Development

Previous research suggests that when competence is difficult or impossible to measure, “self-efficacy,” or self-reported confidence in one’s ability to perform a task can serve as a reliable predictor of performance [19], particularly in very specific task domains [20]. In this study, miners' confidence in their ability to “properly demonstrate or explain” critical self-escape KSAs was used to quantify levels of perceived competence.

Based on previous NIOSH research [12, 13], the NAS report [5], and the results of a preliminary task analysis [21], NIOSH researchers developed a 28-item self-report survey measuring perceived confidence in critical self-escape KSAs. An 11-point scale, with higher scores indicating higher levels of confidence, was used. Participants were asked to rate their level of confidence in their ability to correctly demonstrate or explain critical self-escape KSAs, such as their mine’s emergency response plan, the location of their mine’s emergency response features and apparatus (e.g., escapeways, refuge alternatives, breathing apparatus, firefighting equipment, mine maps, etc.), and where to report in the event of mine emergency.

2.2.2 Recruitment, Data Collection, and Participants

Upon receiving IRB and OMB approval, NIOSH researchers visited eight underground coal mines between October 2016 and September 2018. The survey administration typically took place during pre-shift meetings or annual trainings and took approximately 10 min to complete. Participants consisted of 696 hourly workers and the number of participants from each of the mines ranged from 16 to 213 ($M = 87$).

2.2.3 Data Analysis

Due to highly and negatively skewed distributions of both outcome variables, logistic regression analysis was used. Outcome variables were split into quartiles and then dichotomized allowing the highest (most desirable) 25% to be distinguished from the remaining 75% scores

(“high” and “lower”, respectively). Univariate analysis was used to identify which of the demographic variables common to both datasets were significantly related to the outcome variables and entered into the initial models. Backward stepwise selection procedures were used to determine each final model consisting of only those variables whose unique contributions were significantly associated with model outcomes, while controlling for the other variables.

3 Results

3.1 RQ1: What individual factors measured by both surveys, if any, are significantly related to hourly workers' perceptions of their own routine safety performance (i.e., proactivity and compliance)?

Three demographic variables were significantly associated with routine safety performance: time in current job ($p = 0.017$); time in the mining industry ($p = 0.022$); and workgroup ($p < 0.000$) (see Table 2). For illustrative purposes, the odds ratios for experience variables have been converted to probabilities as depicted in Fig. 1.

Table 2 Logistic regression results – demographics by safety performance ($n = 1895$)

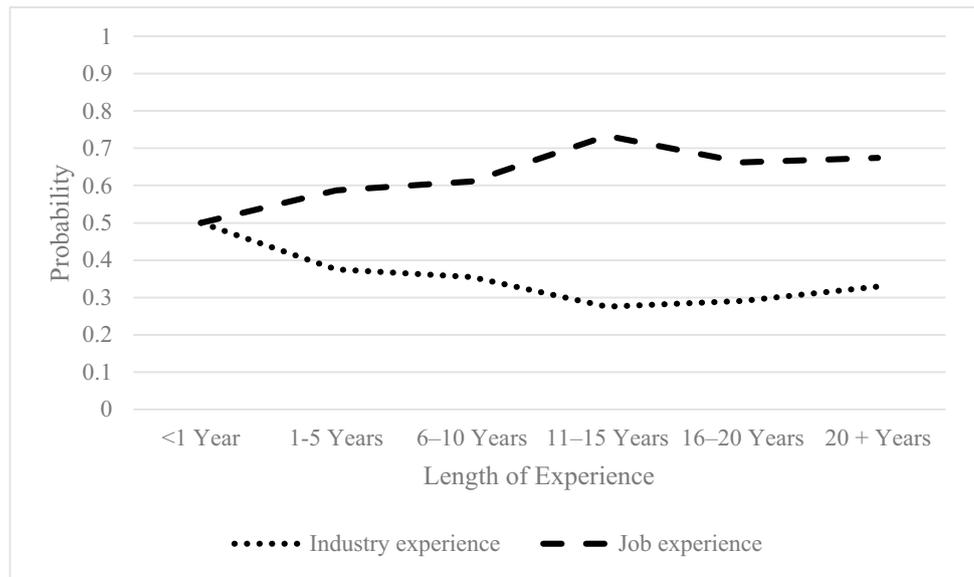
Demographics	OR*	95% CI	p-value
Time in current job			0.016
< 1 year	REF†		
1–5 years	1.42	(0.92–2.19)	
6–10 years	1.57	(0.96–2.58)	
11–15 years	2.75‡	(1.58–4.80)	
16–20 years	1.96‡	(1.05–3.65)	
20+ years	2.07‡	(1.18–3.62)	
Time in mining industry			0.030
< 1 year	REF		
1–5 years	0.60‡	(0.37–0.98)	
6–10 years	0.55‡	(0.33–0.93)	
11–15 years	0.38‡	(0.21–0.67)	
16–20 years	0.41‡	(0.22–0.76)	
20+ years	0.49‡	(0.28–0.85)	
Workgroup			0.000
Production	REF		
Maintenance	0.56‡	(0.42–0.75)	
Other	0.91	(0.69–1.20)	

*odds ratio

†reference variable

‡ $p < .05$

Fig. 1 Type of experience and probability of reporting high routine safety performance



3.1.1 Time in Current Job

While controlling for time in mining industry and workgroup, those who reported 11+ years in their current job were significantly more likely to report high safety performance than those who reported being in their current job for <1 year. Specifically, those in the job 11–15 years were almost three times as likely to report high safety performance than those with <1 year, while those with 16+ years in the current job were twice as likely.

3.1.2 Time in Mining Industry

In contrast to time in job, high routine safety performance was significantly less likely (ranging from 40 to 62% less likely) for all levels of industry experience when compared to those with <1 year of industry experience. That is, those with <1 year of industry experience were significantly more likely to report high safety performance than all others surveyed, when controlling for time in current job and workgroup.

3.1.3 Workgroup

One individual factor unrelated to experience was predictive of safety performance. Analysis of the workgroup variable showed that maintenance workers were 45% less likely to report high safety performance than those in the production workgroup ($p < 0.000$), when controlling for time in job and time in mining industry.

3.2 RQ2: What individual factors measured by both surveys, if any, are significantly related to hourly workers’ perceived self-escape competence (confidence in their own KSAs)?

Using backward selection procedures for RQ2, three demographic variables were significantly associated with self-escape confidence: time in the mining industry ($p = 0.023$); time at

Table 3 Logistic regression results for demographics by average self-escape confidence

Demographics	OR*	95% CI	p-value
Time in mining industry			0.023
0–5 Years	REF†	REF	
6–10 Years	2.59‡	(1.33–5.05)	
11–15 Years	2.99‡	(1.35–6.62)	
16–20 Years	3.73‡	(1.42–9.82)	
20+ Years	3.45‡	(1.44–8.27)	
Time at current mine/company			0.044
<1 year	REF	REF	
1–5 years	0.86	(0.45–1.62)	
6–10 years	0.43‡	(0.23–0.82)	
11–15 years	0.58	(0.25–1.37)	
16+ years	0.26‡	(0.08–0.86)	
Work schedule			0.014
Set schedule	REF	REF	
Rotates/Shiftwork	0.53‡	(0.32–0.88)	

* odds ratio

† reference variable

‡ $p < .05$

current mine ($p=0.044$); and work schedule ($p=0.014$). See Table 3 and a brief summary of these relationships below. For illustrative purposes, the odds ratios for experience variables have been converted to probabilities, as depicted in Fig. 2.

3.2.1 Time in Mining Industry

Because of the small number of participants with < 1 year of industry experience (1.7%), the 0–1 and 1–5-year groups were combined into one categorical variable (0–5 years). As shown in Table 3, those who reported 6 + years in the mining industry were significantly more likely (from 2.6 to 3.5 times) to report high confidence in their self-escape competency than those with less experience in the industry (0–5 years), when controlling for time in current mine and work schedule.

3.2.2 Time in Current Mine

When controlling for time in the mining industry and work schedule, two significant differences were found among experience levels for time at current mine. Those who reported being at their current mine for 6–10 years and 16 + years were, respectively, 57% and 74% less likely to report high confidence in their self-escape competency when compared with those who reported for < 1 year at current mine. All other experience groups were statistically similar.

3.2.3 Work Schedule

When controlling for time in mining industry and time in current mine, mineworkers who did not work a set schedule were 47% less likely to report high confidence than those who did work a set schedule.

3.3 RQ3: Is there any overlap of individual factors measured by both surveys that are significantly associated with each outcome variable?

Three of the five significant predictors of the safety performance outcomes were related to experience (time in mining industry, time in job, time at mine) and only time in mining industry was found to be significantly predictive of both.

3.3.1 Time in Mining Industry

Time in the mining industry was significantly associated with both routine safety performance and self-escape confidence among mineworkers, however, in opposite directions. All groups with > 1 year of industry experience were less likely (from 40 to 62% less likely) to report high routine safety performance when compared to those with < 1 year of industry experience. Conversely, those groups who reported being in the mining industry for over 5 years were 2.6 to 3.5 times more likely to report high average self-escape confidence than those with 5 or fewer years. That is, when controlling for other factors, length of industry experience was negatively related to routine safety performance and positively to non-routine safety performance. For illustrative purposes, odds ratios have been converted to probabilities as depicted in Fig. 3.

4 Limitations

There are several limitations to this study. First, several known pitfalls associated with logistical regression analyses warrant caution in interpreting these results [28]. For example, inherent in the experience variable categories are arbitrary cutoffs and dichotomization of the highly skewed

Fig. 2 Type of experience and probability of reporting high non-routine safety performance

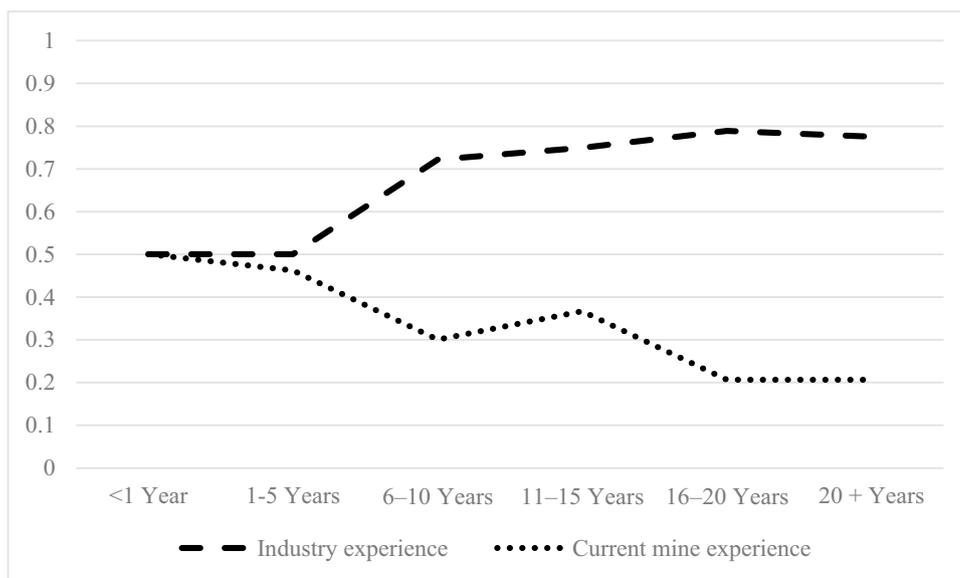
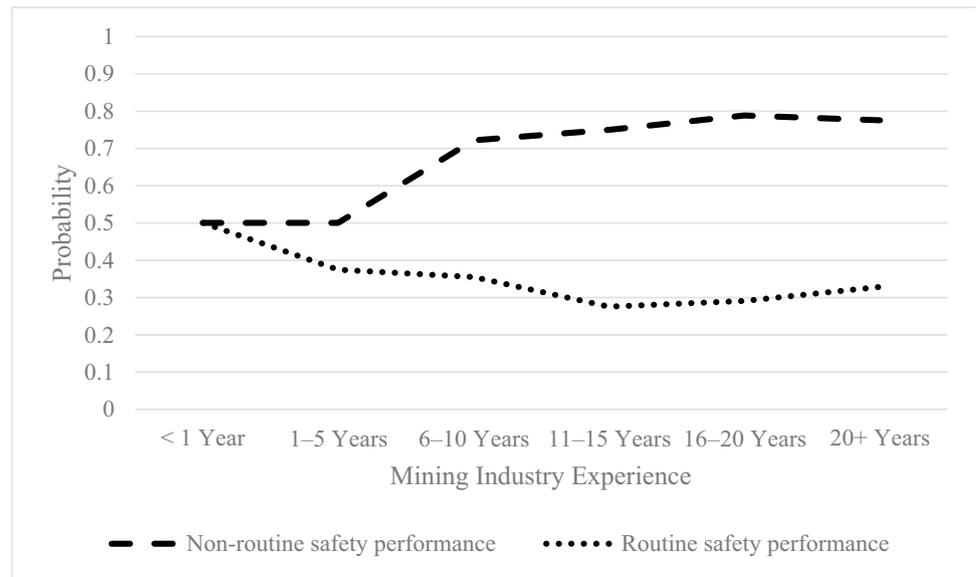


Fig. 3 Mining industry experience and probability of reporting high routine and non-routine safety performance



outcome variables could potentially result in the loss of important information. Additionally, these models do not account for extraneous individual and organizational influences on safety performance, such as job satisfaction, training adequacy, sector, and organizational climate. By design, the projects targeted similar, yet distinct, populations. One focused exclusively on underground coal mining and the other included a variety of mining sectors representing both surface and underground operations. Convenience sampling was used to recruit participating mine sites, and individual mineworkers who volunteered to participate in the survey efforts and self-selection in both cases could negatively impact the generalizability of results. Both research efforts utilized a self-report survey method, which presents known challenges related to social desirability, acquiescence, and concerns about confidentiality, all of which could influence responses. Finally, all data were collected to answer specific research questions unrelated to those asked here, so there is likely insufficient information to draw any definitive inferences from this analysis, nor was this the goal of this exploration.

5 Discussion

The purpose of this study was to identify individual factors that are potentially predictive of routine and non-routine safety performance and to consider the scientific plausibility of these relationships. Results of this analysis found that five of the eight individual factors measured by both surveys were significantly associated with at least one of the outcome variables studied. Of these five individual factors, three were related to levels of experience in either the job, the industry, or the mine, and will be the focus of this discussion.

Based on speculation and wide support within the existing literature [22–25], one might conclude that length of experience is logically and positively related to safety performance, in general. However, while not definitive, this analysis suggests that more complex relationships between both levels and types of experience and the safety performance outcomes studied here exist.

For example, it is generally accepted that job experience is directly associated with job performance because, over time, workers tend to gain job specific KSAs which can lead to more effective performance [22]. Not surprisingly, this analysis showed a significant positive relationship between job experience and routine safety performance. More specific to safety performance outcomes, as time on the job increases, perhaps so does the likelihood of workers witnessing or experiencing work-related injuries and/or near-miss incidents, which could result in workers' increased ability to perceive, identify, and proactively respond to risks [23]. However, the finding of no significant differences in safety performance among the three groups of mineworkers with < 10 years of job experience was unexpected due to increasing speculation that mineworkers with < 1 year of job experience—both at mine and on the job—experience higher rates of injuries than more experienced miners. Given the widely accepted theoretical association between leading safety indicators and safety outcomes [10, 11, 24, 26], further research into reportable injury and fatality rates across experience levels and types is warranted. Interestingly, length of job experience was not significantly related to self-escape confidence which might be explained by the fact that all rank-and-file underground coal miners, regardless of specific job duties, require the same non-routine KSAs, which are largely unrelated to specific job tasks.

Interestingly, time in the mining industry was the only demographic variable common to both surveys that emerged as a significant predictor of both outcomes. Consistent with the case study results [6], these findings support the idea that length of industry experience is negatively associated with routine safety performance but is in direct contrast to the relationship between job experience and routine safety performance. Those with < 1 year of experience in the industry were significantly more likely to report high safety performance than any other experience group examined in this study. Considering this result, it is plausible that the longer workers perform the same job tasks, the more comfortable and knowledgeable they become about job-specific risks and how to effectively manage them, regardless of how long they have been in the mining industry. These findings suggest that among this sample of mineworkers, job-specific experience is a stronger predictor of routine safety performance than industry-specific experience.

On the other hand, and exclusively among underground coal miners, length of industry experience was positively and significantly associated with self-escape confidence, while length of job experience was not. Due to stringent regulation (i.e., 30 CFR Part 48), the underground coal mining sector has very specific annual self-escape training requirements which could lead to a cumulative effect of training over time and lead to high confidence in self-escape KSAs. Again, the lack of relationship between job experience and self-escape confidence could be attributed to that fact that self-escape KSAs are generally unrelated to routine job-specific KSAs. That is, while job experience may be logically and positively related to routine job performance, in general, the same might not be true for performance outcomes related to KSAs that are not routinely used on the job. That industry experience was the only individual factor associated with both routine and non-routine safety performance, and in opposite directions, suggests these constructs have very different relationships to experience and deserve further exploration.

The finding that no significant relationship between time at current mine and routine safety performance was detected does not support the limited data that exists for similar relationships within the mining industry. Specifically, a 1986 US Bureau of Mines study examined the relative risk of injuries in coal mining by age and experience [27] and found that experience at the present “company” was the most significant predictor of injury rates. Among this group of mineworkers, those with < 1 year of experience suffered a disproportionate number of injuries when compared to all other experience groups and all other experience groups combined [27]. As previously mentioned, MSHA has speculated that the number of injuries suffered by mineworkers with < 1 year of experience in the job or at the mine have higher rates of injuries than all other groups, and these findings support

the need for more contemporary exploration into this group of inexperienced miners and their relative susceptibility to work-related injuries. Given this finding, further examination of relationships between leading (e.g., self-reported safety performance) and lagging (reportable injuries and fatalities) safety indicators in the mining industry is also warranted.

Further distinctions among types of experience as they relate to the outcomes became apparent as results suggested that time in current mine is negatively, not positively, associated with self-escape confidence. Also consistent with the aforementioned case study [6], mineworkers with < 1 year of experience at their current mine were more likely to report high confidence than any other group. One potential explanation could be that those new to a mine site might have received more recent mine-specific training, refresher training, emergency response training, and/or more focused attention from trainers and supervisors during the onboarding process than those who had been with the mine for longer periods. It can be inferred from the data that confidence levels might tend to adjust over time and remain relatively stable as time at the mine increases, which could have implications for refresher training timing and frequency.

In this sample of mineworkers, two factors unrelated to length of experience—workgroup and work schedule were found to be predictive of routine and non-routine safety performance, respectively whether mineworkers reported working a “set schedule” or “rotating schedule/shiftwork” significantly related to self-escape confidence. Mineworkers who reported rotating schedule/shiftwork were almost 50% less likely to report high self-escape confidence. Although negative impacts of shift work on mineworkers’ job performance [28, 29], situation awareness [30], and health [31] have been documented in the literature, this finding should be interpreted with some caution. First, the majority of mineworkers surveyed about self-escape confidence were shift workers, and of the roughly 17% who worked a set schedule, a large majority (87%) were spread over just three of the eight mines surveyed. Still, more formally examining shift work as it relates to non-routine safety outcomes in the mining industry could provide insight into whether and how work schedule relates to mineworkers’ levels of emergency response preparedness.

Workgroup membership (i.e., production vs. maintenance workers) was significantly associated with routine safety performance, with those in the production workgroup being significantly more likely to report high safety performance than those in the maintenance workgroup. Again, while preliminary, this finding could have important implications for further study comparing the specifics of the job tasks, inherent risks, levels of supervisor support, etc. that might provide support for this finding.

6 Conclusion

This analysis explored how mineworkers' individual characteristics relate to both routine and non-routine H&S outcomes. Results suggest that significant differences in relationships between individual factors and the outcome variables of interest exist and that both length and type of experience could be relevant to safety performance outcomes in the mining industry. Given these relationships, it might be concluded that the relationship between experience and H&S outcomes in the mining industry is more complex than practitioners and researchers might expect.

Furthermore, the differences in 3.1.2 between outcome variables raise questions as to whether the constructs themselves are fundamentally different. While taking into consideration the limitations of this study, these findings could provide a foundation for further study in the areas of individual differences, safety performance, and emergency preparedness. Although some of the variability in the data is likely attributable to organizational factors such as safety climate, mine-specific training, and assessment practices, or other confounding variables, the feasibility of considering individual mineworker differences in targeting specific health and safety interventions should be examined along with whether and how this might be accomplished through modifications to existing routine and non-routine risk management strategies.

Finally, although individual variables such as self-efficacy, proactivity, and compliance are widely accepted as leading indicators, it is necessary for researchers to examine the role and interplay that other individual factors, specifically experience, play in H&S outcomes in the mining industry. These results also further support the need for further research in this area, such as current NIOSH work designed to examine relative risk for injuries and fatalities among inexperienced miners [33]. NIOSH researchers have begun a quantitative analysis of MSHA data and NIOSH surveillance data to better characterize the role that inexperience plays in safety outcomes across levels and types of experience. Subject matter experts are also being interviewed by NIOSH researchers to investigate current practices and identify effective strategies for transitioning miners into new workplaces or job tasks.

In the meantime, the findings from the exploratory analysis described in this paper, though not definitive, lend credence to the idea that mine safety and health professionals should avoid taking a “one size fits all” approach to routine and non-routine risk management or assuming that experience, in general, is necessarily positively related to H&S outcomes. Further research is necessary and warranted to better understand these relationships and their implications for targeting training, reinforcement, and assessment efforts in the mining industry.

Author Contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Cassandra L. Hoebbel, Emily J. Haas, and Margaret E. Ryan. The first draft of the manuscript was written by Cassandra L. Hoebbel and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data Availability Due to the federal governmental procedures, participant organizations were granted certificates of confidentiality which preclude the public sharing of the datasets.

Code Availability Not applicable.

Declarations

Ethics Approval This research was approved by the National Institute for Occupational Safety and Health (NIOSH) and Human Subjects Review Board (HSRB) under NIOSH protocol numbers 14-OMSHR-08XM and 16-OMSHR-01XM .

Consent to Participate All human subjects provided informed consent to participate in the research activities described within this manuscript as documented in the approved protocols listed above.

Consent for Publication All authors have consented for this work to be published.

Conflict of Interest The authors declare no competing interests. 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 (NIOSH), Centers for Disease Control and Prevention. Mention of company names or products does not constitute endorsement by NIOSH.

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