Assessing the Effects of Virtual Emergency Training on Mine Rescue Team Efficacy

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ABSTRACT

To reach trapped miners, underground mine rescue teams might be required to perform a variety of non-routine tasks (e.g., fight fire, pump water, support unsafe roof) as they encounter hazardous and rapidly changing conditions. Due to risks associated with such conditions, underground mine rescue team training has traditionally been performed using live exercises in the form of competitive drills in above-ground facilities or open fields. Oftentimes these contests utilize printed paper placards to represent environmental conditions and have strict rules which were developed for comparative assessment purposes. Although widely used, these contests have undetermined 'real world' application, are low fidelity, and have limited documented evidence for effectiveness. Both miners and subject matter experts have emphasized the need for more realistic and engaging training environments to enhance the learning experience of all miners and emergency responders. To this end, the National Institute for Occupational Safety and Health (NIOSH) has developed a fully immersive dynamic virtual training environment for mine emergency responders. During training scenarios, rescue teams approach the problem and perform as they would in "real life" utilizing virtual representative equipment, with success dependent on effective communication and group decision-making. This study represents the first documented empirical attempt at evaluating the effectiveness of virtual reality training for mine rescue teams in the United States, and this paper discusses the utility of such environments for not only delivering realistic and engaging training, but for conducting behavioral research activities. Associations among psychosocial factors such as training climate, team familiarity, and team efficacy are examined and, in general, the study results support findings and recommendations found in the emergency teamwork literature. The results of this effort will add to the research base on mine emergency response training and assessment as well as provide insights into emergency response team behavior.

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INTRODUCTION

Throughout the course of the 20th century, the number of catastrophic mining events steadily declined in both number and scale. Because there was only one underground disaster in the 1990s (South Mountain Coal Company No. 3 Mine in 1992, 8 fatalities), it was possible to hold the view that emergency response no longer needed to be a top research priority. New miner and annual refresher training emphasized required routine knowledge, skills, abilities, and other attributes (KSAOs) over the non-routine KSAOs required to respond to seemingly unlikely large-scale emergencies. Then came Brookwood in 2001 (13 fatalities); followed by Quecreek (2002, 0 fatalities); Alma No. 1(2006, 2 fatalities), Sago (2006, 12 fatalities), Darby (2006, 5 fatalities), Crandall Canyon (2007, 6 fatalities), and Upper Big Branch (2010, 29 fatalities). These tragedies brought the critical need for emergency preparations back to the forefront and the mining industry and state and federal government agencies reacted. These incidents highlighted the need to balance investments that would reduce low-probability/high-severity events with those that focus on more frequent, but less severe injuries and illnesses. The Mine Improvement and New Emergency Response Act (MINER Act) of 2006 was passed in an attempt to help prevent future disasters and to specifically address and increase training requirements. This presented new opportunities for the research and development of training in non-routine KSAOs required to respond to large-scale emergencies.

The current minimum federal regulations (30 CFR Parts 49 and 75) for mine rescue team training require:

- 96 hours annually
- Participation in 2 local mine rescue contests
    - Company team – annually at each mine covered by the rescue team
    - Composite teams – semi-annually at each mine covered by the rescue team
    - Contract team – quarterly at large and semi-annually at each small mine covered by the rescue team
    - State sponsored team – annually at each mine covered by the rescue team
- Annual participation in smoke training
- 2 hours wearing breathing apparatus under oxygen every 2 months

While federal mandates for frequency of training are important for mine rescue team member skill development, the benefits are difficult to assess, and modern approaches to training in a virtual environment can offer promising potential benefits. The goal of this research effort was to assess the benefit of immersive mine rescue team training on emergency-based teamwork and its potential implications. In addition to the more concrete task-oriented knowledge and skills required for effective mine emergency response, this paper discusses other salient team-based constructs such as training climate, team familiarity, and team efficacy.

BACKGROUND

Mine Rescue Teams

The Federal Mine Safety and Health Act of 1977 (**Public Law 91-173,** as amended by **Public Law 95-164)** required mine rescue teams for all underground mines in the United States. While all miners must prepare for emergencies, mine rescue teams form the core of the on-the-ground response when a large-scale event occurs. Rescue team members must be prepared to enter the complex and dynamic environment that exists in the aftermath of a catastrophic event. According to the Mine Safety and Health Administration's (MSHA) "Mine Rescue Teams Nationwide" webpage (http://www.msha.gov/MineRescue/MAP/ASP/minerescuehome.asp), there were 436 underground mine rescue teams (215 coal and 221 metal/nonmetal) in the United States as of March 2014, with 1875 individuals serving on underground coal teams and 2004 on metal/nonmetal teams, totaling 3879 underground mine rescue team members from 33 states.

Large mine companies sometimes form teams made up of employees, while smaller mines might contract with professional teams, rely on state teams, or come together with neighboring small mines to form composite teams. MSHA and a number universities have also assembled their own mine rescue teams. While MSHA sets the minimum standard for training, many mining companies exceed this with internal policies and standards. Due to these and many other factors, mine rescue teams possess highly variable mine emergency response experience and skills.

Mine Rescue Team Training

Mine rescue training began in the United States in 1910 and quickly evolved into local and regional competitions that are still held today. Due to the risk associated with training in dangerous environments, these contests have historically been performed in above-ground facilities or open fields like the one depicted in Image 1. While these competitions have been widely accepted by the underground mining industry and participation is mandated by law, there is little evidence to support (or controvert) their effectiveness, and the industry is lacking evidence-based guidance on how best to prepare mine rescue teams to respond to emergency situations.

Image 1. Traditional Mine Rescue Contest Field

When federal law mandated training for all mine rescue teams in the U.S. in 1977, the U.S. Bureau of Mines, then later the National Institute for Occupational Safety and Health's (NIOSH) Office of Mine Safety and Health Research, began to support the design and development of more realistic and engaging training materials and mine emergency simulation exercises. Many of these simulations were based on actual emergency events reported in formal investigations by MSHA, and on firsthand accounts of miners who were directly involved in the events. Built on unfolding narratives, training activities were designed to teach the critical problem-solving, decision-making, and other non-routine KSAOs required for mine rescue teams to effectively respond to emergencies. Most of the early exercises involved small group discussions within classroom settings and/or the use of tabletop simulations that allowed trainees to actively engage in problem solving. More recently, more advanced technologies have been introduced to add more realism to the training environment.

Technology-based Training

Extensive research on occupational safety training methods suggests that two of the most important attributes of effective training are high engagement and realism (e.g., Burke et al., 2006, Robson et al., 2012). The use of technology-based simulations to deliver realistic and engaging training is not new. In fact, the patent for the Link Trainer for pilot training was applied for in 1929 (Amico, 2009), and over a decade ago Don Johnson, a member of the Readiness and Training Unit of the Department of Defense (DoD) at the Pentagon, was quoted as saying, "In DoD, we probably have done more studies of learning technology than you will find anywhere. We've proven to ourselves that technology works. We've proven it academically, but more importantly, we've proven it operationally" (Prensky, 2001).

The mining industry has long accepted equipment simulators that incorporate virtual reality components, and virtual environments are currently being used for underground mine health and safety training in several countries. Initial indications are that this form of training adds significant realism and is working quite well for health and safety training in the mining industry (Galvin, 2008). In lieu of full-scale drills, Australia has been staging parts of mine rescue competitions in immersive 360° virtual environments since 2010 (http://www.minesrescueservices.com). Such immersive environments are supported by advanced simulations that are capable of reproducing the underground layout and physical conditions of mines and allowing for the observation and evaluation of team behavior. NIOSH established its own Virtual Immersion and Simulation Lab (VISLab) in 2012 and it is the first such facility built in the United States (see Methodology section for a brief description).

NIOSH has experienced early success using virtual technologies for simulation, and preliminary data suggest these simulated environments offer both the realism and engagement levels that are critical for effective training (http://www.cdc.gov/niosh/mining/topics/RescueTechnologiesandTraining.html). Results from the present study bolster these findings and support the argument that these environments can also be used to observe and assess team dynamics relevant to successful emergency response team function.

Team Training

Schaafstal et al. (2001) summarized the role and captured the state of emergency groups and teams best: "[Emergency teams] are often faced with ill-structured problems, uncertain and dynamic environments, shifting, ill-defined and sometimes competing goals, multiple event-feedback loops, time constraints, high stakes, multiple players, and organizational norms and goals that must be balanced against the team members' personal choices" (p. 617). For this reason, a great deal of the literature on emergency groups and teams focuses on team process elements (i.e. the process that teams employ to achieve performance) that can predict performance in non-routine real-world or simulated emergency events. Schaafstal et al. (2001) explicitly emphasize teamwork over task work, arguing that tasks in emergency scenarios are highly fluid and context dependent. To this end, the authors cite US Navy research on the Tactical Decision Making Under Stress (TADMUS) training framework (e.g., Cannon-Bowers & Salas, 1998), which focuses on teamwork dimensions that can distinguish expert from novice teams, such as information exchange, communication, and supporting behavior. Similarly, Serfaty et al. (1993) call attention to the notion that a team's ability to work together and adapt to changing environmental demands is paramount for team performance, especially among emergency teams. Other evidence suggests that teams with fluid tasks achieve better performance outcomes when teams have greater group participation (Linehan et al., 2009); shared mental models, collective efficacy, implicit coordination, and adaptive strategy (Waller, Lei & Pratten, 2014); greater familiarity (Huckman & Staats, 2011) and more consistent backup behavior (Smith-Jentsch et al., 2009).

This body of literature seems to suggest that optimal training for emergency teams should focus on *teamwork* elements critical for successful performance, ideally through practice under a variety of simulated emergency conditions. As Ford and Schmidt (2000) put it, "With emergency training…the assumption that the KSAs being trained will be used or applied immediately on the job does not hold. A key issue, then, is how to design training programs and how to develop on the job activities that help individuals not only maintain current knowledge and skill levels but also enhance their knowledge and skills given limited or nonexistent opportunity to perform trained tasks directly on the job" (p. 200). Given this limitation, virtual training environments have the capacity to provide knowledge and skill acquisition opportunities and can lend themselves to the evaluation of critical non-routine KSAOs and observations of team-based dynamics that are believed to influence "real world" team performance.

METHODOLOGY

Target Population

The population for the study included underground mine rescue teams who were recruited by NIOSH OMSHR through mining organization contacts, team captains, trainers, and other stakeholder relationships. In 2014, mine rescue teams from Southwestern Pennsylvania and West Virginia visited the NIOSH Bruceton Research Site near Pittsburgh, PA, to voluntarily participate in this study. In total, 70 participants representing 10 mine rescue teams with variable composition and a wide range of experience participated.

Simulation Environment

NIOSH OMSHR's Virtual Immersion and Simulation Laboratory (VISLab) is a multipurpose training research and development lab for virtual reality applications and uses state-of-the-art technology for training and assessing miners. Through observation and the use of interaction devices, researchers have the ability to capture data within training simulations that would be impossible to replicate in real life. The facility includes a state-of-the-art 360° cylindrical projection system that uses stereoscopic 3D technology designed to provide an intuitive training experience for participants (Image 2-A). Surrounding the screen is a 7.1 channel surround sound system to aid in providing directional auditory cues as dictated by the rescue problem. An adjacent 50° curved screen display acts as a classroom environment for instructor-driven sessions and serves as a post-simulation debriefing environment for after-action reviews (Image 2-B). Room C in Image 2 serves as a fresh air base for the team briefing officer.

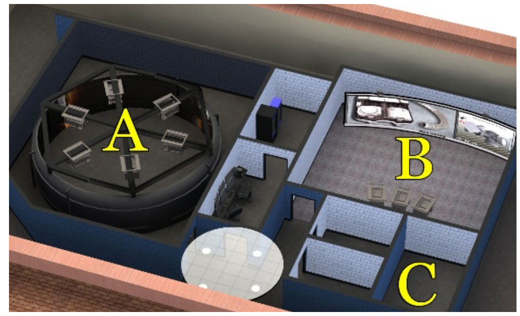

Image 2. Overhead representation of OMSHR's VISLab

Image 3. Mine Rescue Trainee under Apparatus

Image 4. After-Action Review

Instrument Development

The primary goal of this effort was to develop and assess an immersive training environment that requires trainees to utilize the technical non-routine KSAOs required for successful emergency response, while also allowing teams to practice and develop 'soft' teamwork skills and enabling researchers to examine a variety of constructs that would be difficult to measure in other settings. In general, a training assessment strategy as outlined in Holton (1996; 2005), in which the effectiveness and outcomes of the training are evaluated alongside influencing elements – such as motivation, environmental factors, and abilities – was employed. While the full details of the training evaluation model are not included here, the analysis will focus on the central teamwork elements (collective efficacy, familiarity, and training climate) of the assessment. The development of the instruments used to assess the effectiveness of the training from a teamwork perspective are described below.

In an attempt to create a theoretical model that might summarize the structural and process needs of teams, Salas, Sims, and Burke (2005) proposed a "Big Five" framework (hereafter referred to as "Big 5") for teamwork which aims to condense teamwork activities into five core concepts (team leadership, mutual performance monitoring, backup behavior, adaptability, team orientation) as well as three supporting coordinating mechanisms (shared mental models, closed-loop communication, mutual trust), with the general understanding that – regardless of task type – teams that are successful across these process dimensions are more effective and productive when compared to their counterparts. Salas et al. (2005) argue that theirs is the first model, derived from an extensive review of the previous 20 years of research on teams that attempts to comprehensively capture teamwork. Although the framework certainly has appealing face value, the empirical benefits of assessing the Big 5 are unclear given the unique and diverse nature of emergency teams, and the reality that emergency teamwork behavior can be difficult to assess.

One solution comes from Collins and Parker (2010), whose research distinguishes team *outcome* efficacy and team *process* efficacy, in which the former is the team's belief that it can achieve some level of desired outcome; whereas the latter is the team's belief that it can successfully engage in the processes that are necessary to achieve this outcome. Although self-report methodologies come with limitations, there is the potential for assessing an emergency team's teamwork KSAOs using a *process* efficacy approach. To our knowledge, no previous study has attempted to quantitatively assess teamwork in emergency teams using Salas et al.'s (2005) Big 5 framework, and survey items were developed with this in mind. Survey methodology espoused by Hinkin (1995; 1998) was used as a general framework to develop the Team Process Efficacy scales. Items were generated by reviewing the Big 5 of teamwork as described by Salas et al. (2005), as well as a review of the teamwork taxonomy literature (e.g., Marks, Mathieu, & Zaccaro, 2001). Items were reviewed by internal scale development and mining engineer subject matter experts to determine adequate fit and face validity. A list of ten items was logically derived and covered all five teamwork dimensions and three coordinating mechanisms (see Table 1). Efficacy response scales as reported by Collins and Parker (2010) were added to the survey, and study participants were asked to describe their sense of efficacy in the team by assigning a percentage between 0 and 100 percent to indicate the degree of confidence they had in their team's process and ability to achieve desired outcomes. All efficacy measures were collected before and after the training in order to detect any potential effect of training on team efficacy.

Two additional constructs (Familiarity and Training Climate) relevant to this analysis and believed to moderate gains in perceptions of team efficacy as a result of training were added to the assessment. It was hypothesized that mine rescue teams who reported more familiarity with one another would have a greater sense of team efficacy. Team cohesion literature suggests that teams with members who are highly familiar with one another appear to perform better in ambiguous circumstances (Gruenfeld, Mannix, Williams, & Neale, 1996). To measure familiarity, three items were created which asked trainees how often their team members see each other at work or outside of work and how often training across team roles occurs. Familiarity items were administered on a five-point frequency scale, from "*Not at all*" to "*Frequently or always.*" In addition, given the importance of both organizational climate and individual attitudinal measures on training effectiveness (e.g., Salas & Canon-Bowers, 2001), participants also responded to items from the Mine Emergency Preparedness Climate scale (Bauerle & Mallett, 2013). For this analysis, the focus is on the Training Climate subscale which aims to assess the degree to which organizational and environmental supports exist and represent the enacted values of miners' respective mine sites.

Research Protocol/Design

Upon arrival, all trainees were asked for their voluntary consent to participate in a mine rescue training scenario in the VISLab's 360° theater and to participate in IRB-approved assessments of their knowledge and skills, levels of confidence, their perceptions regarding the realism of the scenario and the environment, and their level of engagement with the problem.

After a short orientation program and ample opportunity to become familiarized with the virtual environment and interaction devices, teams were formally briefed by an experienced mine rescue trainer. The briefing included information about the virtual mine including details about the mine environment (e.g., mine layout, ventilation, escapeway routes, locations of refuge alternatives and self-contained self-rescuers (SCSRs), etc.). Teams participated in one of two training modules, each designed within common underground coal mining environments (i.e. room and pillar and longwall methods). Following the briefing, team roles were assigned as they are for actual exploration to include a captain, map man, gas man, stretcher bearer, and tail captain. A sixth team member, known as a briefing officer, remains in a fresh air base and interacts through two-way radio with the team captain to track the team's location and advise team movement. Once inside the room, participants navigated through the mine while accessing and utilizing virtual items such as fire extinguishers, SCSRs, gas meters, tether lines, and other equipment while remaining in radio contact with the briefing officer. The simulation typically lasted between 60 and 90 minutes, depending on the module and the strategies the participants chose to employ while working through the problem.

After completion of the virtual mine rescue scenario, participants underwent a 30-minute after-action debriefing session during which the mine map was projected on the 50° curved screen display. This allowed the mine rescue trainer to review the actions and exploration paths taken by the teams, the decisions that were made, and to ask questions and promote discussion surrounding the team's strategy. Following the debriefing, subjects were administered questionnaires designed to capture their thoughts and feelings about the face validity of the training exercise as well as training-specific attitudes and their reaction to the training. Participants also completed a similar questionnaire before briefing in order to compare pre- and post-test responses. In total, participants were administered three brief questionnaires: one administered before briefing ("pre-training"), one immediately after the simulation ("post-simulation"), and one after debriefing ("post-training"). Participants were also asked to complete pre- and post-training knowledge questionnaires. Time was also allowed for trainees to express their opinions about their experience, in general, and for research staff to address any questions or concerns raised by trainees. Overall, each of the mine rescue training sessions including the pre- and post-assessments took between 3 and 4 hours.

RESULTS AND ANALYSIS

Sample Characteristics

Seventy participants from 10 underground mine rescue teams consisting of 6 company teams, 3 composite state teams, and 1 university team participated. Due to the relatively small number of teams in the study, results are presented with the individual as the unit of analysis. The participants were almost exclusively male (98.6%) and ranged in age from 21–58 with a mean age of 33.22 (*SD* = 10.02). Participants reported an average of 9.54 (*SD* = 8.26) years of experience in mining and an average of 4.13 (*SD* = 5.24) years of experience on a mine rescue team. Of this group, 32.9% reported having experienced a virtual reality environment before participation in this study.

Participant Reactions

Based on survey results, most of the participants reacted positively to the training environment. A majority of participants agreed or strongly agreed that the training included relevant content to mine rescue team members (100%), was a good supplement to existing mine rescue training (97%), and made them more confident in correctly responding to a real mine emergency (94%). Furthermore, on a 7-point Likert immersion scale, most of the participants reported above the median rating (i.e. > 4) regarding feeling immersed in the virtual environment (68.9%), being engaged in the virtual reality experience (77%), and being involved in the exercise to the extent that they lost track of time (56.5%). Finally, 82.5% of participants reported at or above the median rating that the virtual simulated environment was consistent with that of an actual underground coal mine.

Scale Development

Due to the exploratory nature of this study, principal components analysis (PCA) with varimax rotation was used to investigate solutions for both the process efficacy and climate measures (Fabrigar, Wegener, MacCallum & Strahan, 1999). A final two-factor solution was discovered (Table 1) from the initial 10 team efficacy items, which accounted for 72% of the variance and closely mirrored Salas' framework, with one factor representing the 'Big 5' processes (α= .88) and the other factor representing 'Coordination Mechanisms' (α = .85). Likewise, a parsimonious four-factor model was discovered for Mine Emergency Preparedness Climate which accounted for 78% of the variance, and the Training Climate factor (α = .83) included the following items:

- *Our mine rescue training has opportunities for constructive feedback from instructors.*
- *Our mine rescue training includes practice using the equipment we would use in a real emergency.*
- *Our mine rescue training is usually realistic and "hands-on".*

A repeated measures ANOVA (Table 2) determined that both the Big 5 ($F(1,57) = 26.01$, $p < .01$, $\eta^2 = .31$) and Coordination ($F(1,57) = 10.86$, $p < .01$, $\eta^2 = .16$) aspects of perceived team efficacy improved for trainees as a result of training. Furthermore, with regard to the Coordination subscale, team familiarity significatly interacted with efficacy over time ($F(1,57) = 4.02$, $p < .05$, $\eta^2 = .07$), such that members from highly familiar teams had greater gains in efficacy during post-test assessment (Figure 1). Additionally, for the Big 5 indicator of team efficacy, a significant three-way interaction was found between efficacy, team familiarity, and training climate ($F(1,57) = 7.31$, $p < .01$, $\eta^2 = .11$). As expected, members from teams with a supportive training climate and high member familiarity had the highest pre- and post-test efficacy ratings, while the converse was true for members from teams with low scores on training climate and low member familiarity. Tukey post-hoc comparisons indicated mean Big 5 efficacy scores for the low familiarity high training climate group did not differ significantly from the high familiarity high training climate or for the low familiarity low training climate groups at pre- or post-test. However, the high familiarity low training climate group mean score 70.29 (*SD* = 14.49) did differ significantly at from the high familiarity high training climate group mean score 85.62 (*SD* = 12.8) at at pre-test and this difference became statistically non-significant at post-test (Figure 2).

Item Text	Salas' Framework	Construct	1	2
Readapt team strategy in response to unexpected changes in the environment.	Adaptability	Big 5	**.86**	.30
Make quick and effective decisions	Team Effectiveness	Big 5	**.84**	.34
Agree on solutions to difficult problems encountered.	Team Orientation	Big 5	**.79**	.35
Maintain clear and efficient communication.	Closed-Loop Communication	Big 5*	**.72**	.42
Monitor each other's work to catch mistakes and provide feedback.	Mutual Performance Monitoring; Back-Up Behavior	Big 5	**.66**	.51
Assist with each other's responsibilities.	Mutual Performance Monitoring; Back-Up Behavior	Big 5	**.65**	.13
Maintain a shared understanding of each other's responsibilities.	Share Mental Models	Coordination	.30	**.84**
Maintain coordination in performing the tasks at hand.	Coordinating Mechanisms	Coordination	.42	**.79**
Consider teammate input before making an action.	Mutual Trust	Coordination	.16	**.77**
Maintain a level of trust and confidence in each other.	Mutual Trust	Coordination	.45	**.74**

*This item was assigned to construct based on theoretical justification.

Table 1. Final Rotated Solution for Pretest Team Process Efficacy

Effect	*SS*	*df*	*MS*	*F*
Big 5	615.03	1	615.03	26.01**
Team Familiarity	183.25	1	185.25	7.75**
Training Climate	97.09	1	97.09	4.11*
Team Familiarity * Training Climate	172.90	1	172.90	7.31**
Error	1347.95	57	23.65	
Coordination	1221.69	1	1221.69	10.86**
Team Familiarity	452.62	1	452.62	4.02*
Training Climate	81.81	1	81.81	0.73
Team Familiarity * Training Climate	129.99	1	129.99	1.16
Error	6414.61	57	112.54	

Note: * $p < .05$ ** $p < .01$

Table 2. One-Way Repeated Measures ANOVA with Pre- and Post-test Team Process Efficacy

DISCUSSION

There are limited opportunities for mine rescue teams to practice coordinated use of the critical non-routine KSAOs required for an effective mine emergency response. Traditional full-scale drills can be cost- and resource-prohibitive and mine rescue team contests are strictly judged under relatively unrealistic conditions. The study results demonstrate that NIOSH's VISLab offers realistic and engaging training environments for mine rescue teams to practice solving problems as they would in "real life." This added element requires team members to communicate and make critical decisions about actions to take without regard to competitive scoring.

As the literature shows, team training in immersive environments is important for the development of teamwork efficacy, and this sense of team efficacy is related to better training outcomes. Results from this study indicate that teams with high familiarity among members report higher team efficacy scores than low familiarity teams both pre- and post-training, with greater gains in coordination efficacy after training. When considering training climate with team familiarity, results were similar for Big 5 process efficacy.

Not surprisingly, teams reporting both low training climate and low familiarity also reported the lowest levels of process efficacy at pre- and post-training, and those teams reporting both high training climate and high familiarity reported the highest process efficacy scores. Interestingly, the greatest gains in Big 5 process efficacy were observed in groups that reported high familiarity and low training climate. This might suggest that high familiarity teams can overcome other limiting factors more quickly and dramatically than their counterparts in their development of team-efficacy. All teams reported an increased sense of team efficacy post-training.

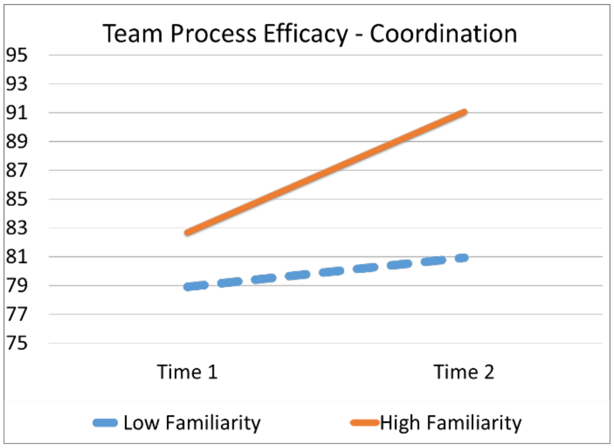

Figure 1. Team Familiarity and Pre- and Post-Training Team Coordination Process Efficacy

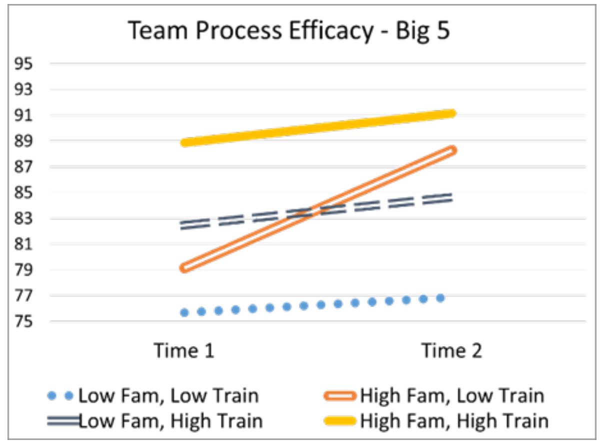

Figure 2. Team Familiarity and Training Climate and Pre- and Post-Training Team Big 5 Process Efficacy

Limitations

Due to accessibility issues with this population, it is sometimes difficult to recruit teams to visit a research laboratory. For this reason, follow-up data collection was not part of this study design. We acknowledge the limitations this presents in terms of measuring any sustaining effect of the training and recognize that the extent to which performance in a simulated environment successfully transfers to real-world emergencies cannot be quantified. Additionally, the study lacks a random sample at both the mine site and the individual level. Participating mines and individual team members volunteered to participate and self-selection in both cases could lead to results that may not be generalizable across the industry. Finally, the individual data presented in this analysis was self-reported, and therefore, responses were subject to biases such as social desirability and acquiescence, or could be otherwise inaccurate due to concerns about confidentiality of responses.

Implications & Future Directions

The results of this study suggest several important considerations for training emergency response teams. First, on a broad level, we confirm the importance of distal indicators of training effectiveness in an emergency team training context. Indeed, teams who come from organizations with unsupportive training climates or teams who are less familiar with one another may not receive the same training benefits as their better-supported, highly familiar counterparts. Secondly, team familiarity emerged as a salient moderator in team efficacy gains as a result of training. As noted in the federal regulations, mandated training frequency varies across team composition. While additional research is needed to confirm these findings, these results suggest that teams may benefit from time spent together *outside* of training with increases in confidence in their team's ability to accomplish team tasks and incorporate new experiences into the team dynamic. Finally, this study provides an instrument development foundation upon which other emergency team training evaluation efforts can be based. Future research efforts may consider other ways to conceptualize the Big 5 and Coordinating Mechanisms and/or measure the differential impact of various efficacies on various team tasks.

NIOSH OMSHR plans to develop more portable modalities (e.g., desktop applications, oculus rift, etc.) that may help to mitigate the accessibility issues leading to higher sample sizes, more in-depth analysis, and opportunities for longitudinal analysis. In addition to the benefits these technologies bring to research, increased accessibility can create opportunities for teams to interact more frequently, thereby strengthening the team processes believed to be so critical to successful team performance.

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