If the technology fits: an evaluation of mobile proximity detection systems in underground coal mines

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Full-text paper:

Mining, Metallurgy & Exploration, https://doi.org/10.1007/s42461-019-0056-8

Keywords: Occupational safety, Coal mining, Proximity detection, Task-technology fit, Automation

Special Extended Abstract

Proximity detection systems (PDSs) for mobile machines have the potential to decrease injuries and fatalities. Early adopters of the technology identified some challenges, which presents an opportunity to explore and improve the integration of mobile PDSs in underground coal mines. This research study applied the task-technology fit framework to investigate the fit between mobile PDS technology and mining relative to health and safety from the perspective of leaders at two coal mines. Quantitative results from the study show that mine leaders evaluated mobile PDSs favorably for training and ease of use, system feedback, user authorization and experience, and less favorably for safety, compatibility, task completion and reliability. Qualitative results reveal specific task, mine and system characteristics that may have influenced the leaders' evaluations. The study includes considerations and suggestions for safe technology integration.

Background

Striking, pinning and crushing accidents related to mobile machines continue to be a major concern in underground coal mining. The U.S. National Institute for Occupational Safety and Health (NIOSH) linked 22 of the 75 underground mine fatalities reported between 2011 and 2015 to powered haulage [1]. The U.S. Mine Safety and Health Administration (MSHA) asserts that PDSs for mobile machines could help to prevent these types of fatal injuries [2].

In 2015, MSHA announced a final rule that required continuous mining machines to be equipped with PDSs [3]. Following the final ruling on PDSs on continuous mining machines, MSHA proposed a rule that would also require mobile PDSs on machines such as scoops and coal haulers [4]. While the proposed rule requiring mine operators to install PDSs on mobile machines has not been enacted, some underground coal mines have implemented this technology. As of 2015, approximately 155 of 2,166 scoops and coal haulage machines had been equipped with PDSs [5].

Since the announcement of MSHA's final and proposed rules, stakeholders have conveyed several concerns related to the technology [6], raising questions regarding the fit between PDS technology and underground coal mining.

The current study used task-technology fit as a theoretical framework. Task-technology fit, originally introduced by Dale Goodhue and Ronald Thompson, posits that technology will aid workers in completing tasks [7, 8]. Further, users' assessments of the system determine the system's usefulness [7]. For the current study, we conceptualized task-technology fit as the degree to which mobile PDSs aided mineworkers in safely completing mining tasks (Fig. 1).

The study had three objectives: (1) to examine users' evaluations of task-technology fit for mobile PDSs, (2) to explore factors that influence the fit between mobile PDSs and underground coal mining, and (3) to offer organizational and system design recommendations that could improve the fit between mobile PDSs and underground mining. Researchers addressed the objectives through two research questions: (1) What factors positively influence the fit of mobile PDSs in underground coal mines? (2) What factors negatively influence the fit of mobile PDSs in underground coal mines?

Materials and methodology

Researchers used a convenience sampling approach to invite two bituminous coal mines using mobile PDSs to participate in the study. Researchers conducted two semi-structured focus groups at the participating mine sites during March and April of 2018. The focus group held at Mine A consisted of six mine leaders, and three mine leaders participated at Mine B. Before the focus groups, researchers asked mine leaders to complete a questionnaire, with 11 questions assessing the task-technology fit of their mine's mobile PDS. Researchers based the 11 questions on an adaptation of Goodhue's [7] dimensions for task-technology fit (Table 1) [7].

Key results

Favorable perceptions of mobile PDSs. Leaders provided positive evaluations for the training and ease of use, quality, locatability, authorization and user perspective dimensions. The following task, mine and system characteristics influenced these favorable perceptions: (1) Task characteristics: leaders' perceptions that the system reduced human-machine collision risk and improved workers' situational

Table 1 — Task-technology fit dimensions. (Original dimensions based on work developed by Goodhue and Thompson [7, 8])

Original TTF dimension	Current study TTF dimension	Description
Compatibility	Compatibility	Ability to work well with other machines, systems, and the conditions of the mine.
Production timeliness	Task completion	Ability to support miners in completing tasks.
Locatability	Locatability	Ease of identifying system information.
System's relationship with users	User perspective	Provides a positive user experience.
Training and ease of use	Training and ease of use	Easy to use and obtain effective training.
Data quality	Quality	Provides accurate information that keeps workers safe.
System reliability	System reliability	Dependability of system and components.
Authorization	Authorization	Ease of obtaining authorization to access necessary data.
—	Safety	Ability to keep workers safe.

awareness; (2) Mine characteristics: a thick coal seam, consistent conditions throughout the mine, dedicated resources, effective training, and a strong safety culture; (3) System characteristics: useful system features, vendor and manufacturer support, and the system's compatibility with mobile machines at their mine.

Less favorable perceptions of mobile PDSs. Less favorable evaluations were reported for the reliability, safety, task completion and compatibility dimensions. The following task, mine and system characteristics influenced mine leaders' less favorable perceptions: (1) Task characteristics: loading, system troubleshooting and maintenance, and safety inspections; (2) Mine characteristics: poor safety culture, low seam heights, variable environmental conditions, and training programs that foster system overreliance or misuse; (3) System characteristics: systems' overall cost, electromagnetic interference issues, false alarms, lack of compatibility with older mobile equipment, and concerns about the design and wearability of the miner-wearable components.

Overall, the findings show that mobile PDSs have the potential to be an effective safety technology for U.S. mines. However, to ensure their safe integration, industry stakeholders should consider the critical task-technology fit issues that emerged from this study. Therefore, the following suggestions are provided:

For mine operators. (1) Evaluate mine conditions that may pose challenges. (2) Identify how a mobile PDS may change specific tasks and mitigate any associated risks. (3) Develop training programs for workers, including more specialized training for maintenance workers. (4) Assess, secure, and dedicate time, personnel and financial resources for mobile PDS implementation. (5) Evaluate the mine's existing safety culture and address any issues. (6) Identify ways to manage worker frustration and align organizational practices and policies to deter unsafe behaviors.

For researchers and equipment designers. (1) Further identify and address the electromagnetic interference issues related to mobile PDSs. (2) Provide resources and forums to help share common challenges and best practices. (3) Consider ways to improve wearability of the miner-wearable components. (4) Explore additional system features and functions that will allow mines to meet specific needs through system customization. ■

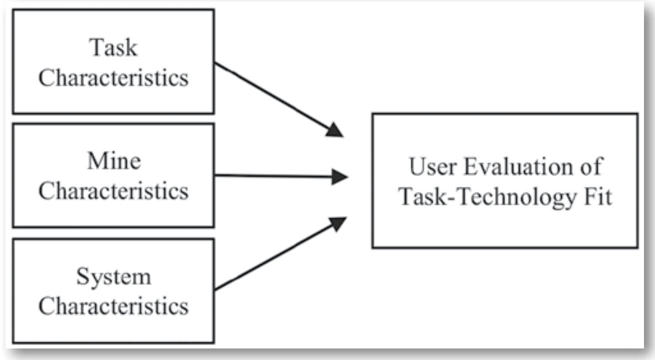

Fig. 1 Adapted version of Goodhue's [7] task-technology fit model.

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 any company or product does not constitute endorsement by NIOSH.

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Associations between whole-body vibration exposure and occupational and personal factors in drill operators in Indian iron ore mines

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Full-text paper:
Mining, Metallurgy & Exploration (2019) 36:495–511, https://doi.org/10.1007/s42461-019-0061-y

Keywords: Whole-body vibration exposure, Drill operators, Predictors, Frequency-weighted RMS acceleration, VDV

To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Heavy earth-moving machineries used in openpit mines intensively expose drill operators to whole-body vibration and shocks, and thus to musculoskeletal disorders. The roles of individual, machine and rock-related factors in their exposure remain poorly understood. This cross-sectional study investigated their roles in 39 drill operators from Indian iron ore mines. It shows that 70 percent of the operators were exposed to high levels of vibration, above the limit values recommended by ISO 2631-1 (1997). Multiple linear regression models showed that the whole-body vibration and shock exposures were strongly associated with operator's age, drill-machine model and rock hardness, uniaxial compressive strength and density. The role of body mass index was close to significance (p = 0.08). Univariate analyses found the drill's age, seat-pad thickness and seat backrest height were also strong predictors. These results help in identifying risky operators, materials and occupational situations, and in implementing appropriate prevention and intervention strategies to reduce and monitor the exposures and health risk. In addition, during the planning stage of acquisition of new equipment, anthropometric data of the operators should be considered for the ergonomic design of the seat.

Introduction

Whole-body vibration (WBV) exposure negatively influences the health and safety of exposed mine operators. Many studies indicate that WBV contributes to the development of musculoskeletal disorders of the spine among workers exposed to a vibration environment [1-4]. Mining equipment operates on rough surfaces under harsh operating conditions that produce WBV and mechanical shock [2,4,5-9]. Among heavy earth-moving machineries operations, blast-hole-drill machine operations potentially result in high WBV because they involve continuous rotation and percussion on irregular hard surfaces [10]. However, WBV, including shock exposures of drill operators, remain poorly understood. This study aimed to determine the WBV and mechanical-shock exposures of drill operators and to explore how physical, machine and rock-related characteristics may influence the WBV exposures of the drill operators.

Methods

This cross-sectional study was conducted for a period of 120 days covering all the seasons during May 2013 to May 2015 in six iron ore mines in India. All 39 participants were male, aged 22 to 60 years. Twelve blast-hole drill machines of three models — IDM30, IDM30E and ROCL6 — manufactured by two manufacturers — Atlas Copco and Ingersoll Rand — were used. Data collection consisted of face-to-face interviews using a questionnaire to record personal factors, collection of drill-machine-related data, collection of rock samples from drilling sites for laboratory investigation of hardness, uniaxial compressive strength and density of rock, and measurement of WBV.

Data were collected based on observational study design, a scientific investigation in which neither the study subjects nor any of the variables of interest are controlled. Vibration data were collected using a three-channel-vibration meter (model Nor 133). The vibration measurements consisted of estimations of root-mean-square acceleration, crest factor and vibration dose value in three orthogonal (x-, y- and z-) axes [9]. Total vibration value (vector sum) and