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The concept of degraded images applied to hazard recognition training in mining for reduction of lost-time injuries☆

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Abstract

Introduction: This paper discusses the application of a training intervention that uses *degraded images* for improving the hazard recognition skills of miners. *Method*: NIOSH researchers, in an extensive literature review, identified fundamental psychological principles on perception that may be employed to enhance the ability of miners to recognize and respond to hazards in their dangerous work environment. Three studies were conducted to evaluate the effectiveness of the degraded image training intervention. A *model* of hazard recognition was developed to guide the study. *Results*: In the first study, miners from Pennsylvania, West Virginia and Alabama, who were taught with the aid of degraded images, scored significantly better on follow-up hazard recognition performance measures than those trained using traditional instructional methodologies. The second and third studies investigated the effectiveness of the training intervention at two mining companies. Data collected over a 3-year period showed that lost-time injuries at mines in Alabama and Illinois declined soon after the training intervention was instituted. *Impact on Industry*: Further exploration of the hazard recognition model and the development of other interventions based on the model could support the validity of the steps in the hazard recognition model.

Keywords: Hazard recognition; Mining; Training; Occupational safety; Perception

1. Introduction

Mining is one of the most dangerous occupations in the world. From the beginning, the removal of materials from the earth has resulted in heavy human losses. In the United States, from 1880 to 1910, mine explosions and other accidents claimed thousands of victims. The worst year in U.S. coal mining history was 1907, when 3,242 deaths occurred. Public concern about the toll of deaths, injuries, and destruction in mine accidents led the U.S. Congress to form the Bureau of Mines in 1910.

In the beginning of the twentieth century, the average death toll per year from mining was 1,500 or more. Throughout the century, this toll decreased to an average during the 1990s of less than 100 (Fig. 1). Regardless, mining, along with agriculture, construction, and transportation, continues to rank amongst the most dangerous of industries in which to work (Fig. 2). Recently, the fatality rate has "flat-lined" (Fig. 3) and as a result, researchers are now seeking new interventions, some exploring administrative controls that address modifying human behavior (such as hazard recognition training) as opposed to adding more engineering controls.

With the continued success in the reduction of mining accidents and fatalities, as well as the influence of budgetary concerns, Congress eliminated the Bureau of Mines in 1996, retaining two research laboratories and creating a Mining Safety and Health Research Division under the National Institute for Occupational Safety and Health (NIOSH). NIOSH is part of the Centers for Disease Control within the Department of Health and Human Services. The focus of the Institute continues to be on the mission of providing a safe and healthy work environment for U.S. miners through research and prevention.

The three studies reported in this paper were conducted and data collected from 1994 to 1998. The work began

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☆ A portion of this paper is contained in the proceedings of the Twenty-fifth Annual Institute on Mining Health, Safety, and Research. Blacksburg, VA 1995; in IC 9422, Information Circular, U.S. Department of Interior, 1995; and The 23rd International Congress of Applied Psychology Madrid, Spain 1994. This paper represents the first time the three studies have been reported.

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Fig. 1. Coal fatalities 1900–2001 (Office workers included starting in 1973) (Source: MSHA).

with a thorough search of the literature for psychological principles that could be applied to the task of hazard recognition. A number of concepts were identified and published in IC 9422, 1995 Bureau of Mines Information Circular, U.S. Department of Interior. This paper discusses the development, application, and evaluation of an intervention based on one of the concepts, *degraded images*. Degraded images are scenes that are viewed under less than optimal conditions, such as inadequate illumination, eccentric angles, haze, dust, or partially hidden. It concludes with a summary of follow-up training programs subsequently completed, and conclusions/recommendations for future consideration.

2. Background

In mining, as in most other production-related industries, the safety of workers is dependent upon many interrelated factors, one of which is the worker's ability to *recognize* hazards in the workplace. This ability is critical in mining because the work environment is confined, inherently dangerous, and constantly changing due to the mining process. Workers must be alert and continuously cognizant of their surroundings, particularly the condition of the immediate roof and ribs.

The information necessary to recognize conditions that are precursors of danger is often available in the form of visual

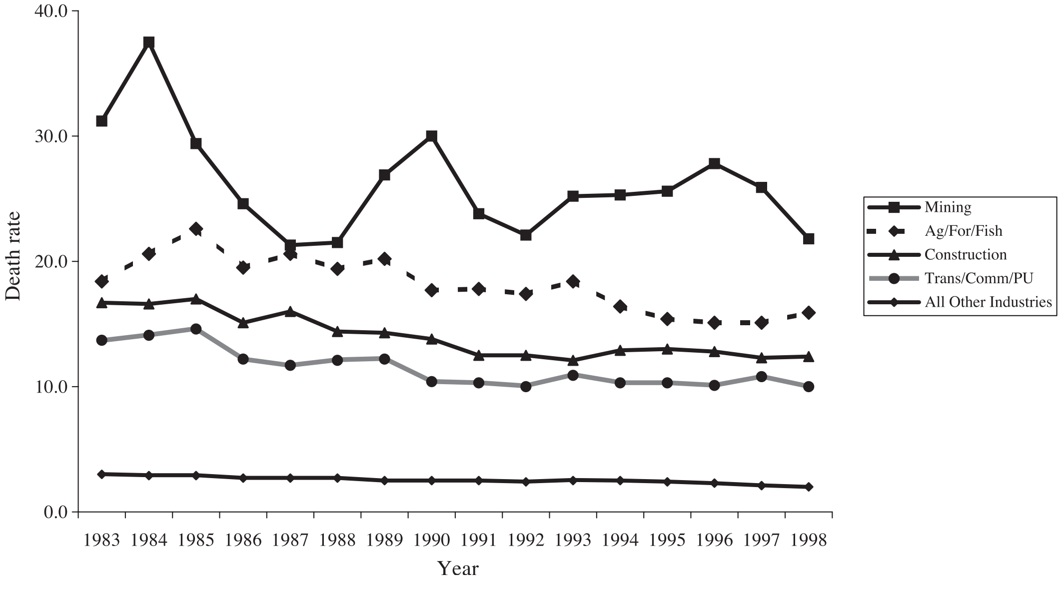

Fig. 2. Occupational injury death rates per 100,000 workers by industry division and year United States 1983–1998 (Source: CDC; data for 1998 excludes New York State).

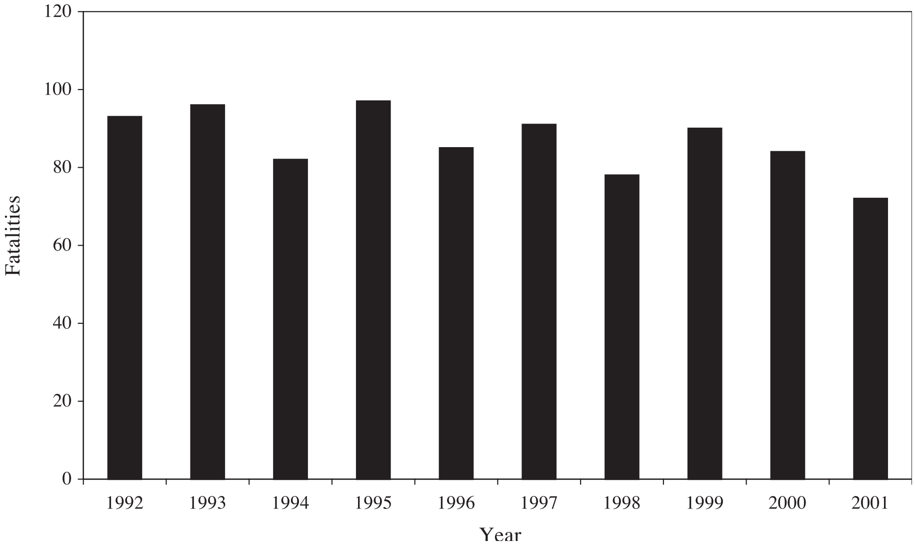

Fig. 3. United States mining fatalities 1992–2001 (Source: MSHA, 2002).

cues. However, even the “best looking” roof and rib conditions may ultimately deteriorate, sometimes dramatically. It is therefore hypothesized that the safety of miners depends, in large part, upon their individual capabilities for recognizing hazards in a timely and accurate manner. If a hazard is not recognized, response by the worker will become reactive instead of proactive, and may result in serious injury.

Mine Safety Health Administration (MSHA; U.S. Department of Labor officials, who are responsible for mine law enforcement maintains a database of accidents, injuries, and fatalities. MSHA’s descriptive accident report data have shown that “failure to perceive” a hazard consistently appears as a contributing factor leading to both fatal and non-fatal injuries. Thus, it can be argued that the ability of miners to recognize hazards is an ongoing problem.

Safety training is mandated in the United States for miners in 30 CFR Part 48 and Part 46. Hazard recognition training is one of the content areas of the mandated training. The objective of all mandated mine training is to positively affect the health and safety of all workers. It is intended not only to meet the letter-of-the-law, but to ensure that mine work activities are performed in a safe manner.

Methods of mine safety training have not changed appreciably for many years. An earlier U.S. Bureau of Mines sponsored study concluded that mine trainers tend to rely heavily on the same instructional materials year after year, and although innovative teaching techniques such as games or simulations are fairly common, by design they are usually limited to the factual recall of safety information (Cole et al., 1988; Kowalski et al., 2001).

3. Previous studies

Technical investigations of mine hazards and their effect on worker safety in the production process permeate the mine health and safety literature. However, there has been limited research on training for the *recognition* of mine hazards. In one of the few relevant studies, Blignaut (1979a) investigated hazard recognition abilities among gold miners in 1979 for the Chamber of Mines in South Africa. He concluded that visual search performance depends significantly upon individual search skills. In subsequent work, Blignaut (1979b) examined the ability of mine workers to differentiate between safe and dangerous rock. In this study, he confirmed that visual skills training significantly improved this ability. In the latter investigation, Blignaut found that skills training consisting of subjecting trainees to exercises in detection were more effective than training that provided workers only with verbal information about specific hazards. His hazard detection exercises included the use of stereoscopic (3-D) slides for depicting the ground hazards found in gold mines.

Numerous other studies in the literature suggest that perceptual judgments are susceptible to training. The most extensive base of information that ties training with the improvement of visual skills appears in military studies on target detection (Farnsworth, Malone, & Sexton, 1952; Jones, Freitag, & Collyer, 1974; Leibowitz, 1967). In other visual search studies, performance of subjects’ visual skills was shown to change both qualitatively and quantitatively with extended training (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). These researchers applied a two-process theory of human information processing to detection, search, and attention phenomena. The two-process theory includes *automatic* processing (not demanding of attention) and *controlled* processing (demanding of attention). Schneider and Shiffrin demonstrated that the learning of these processes improves search performance.

The need for classroom simulations of real conditions has long been recognized among training practitioners.

Gibson (1969), for example, suggested there should be training devices that would simulate particular dangers while allowing subjects to act safely or unsafely. As a general rule, providing perceptual experience in recognizing visual cues during hazard recognition training should lead to a desired response in actual underground situations. This precept was investigated by the Bureau of Mines in determining the feasibility of improving a miner's ability to recognize roof and rib conditions (Barrett, Wiehagen, & Peters, 1989; Barrett & Kowalski, 1995).

In the above simulation, it was shown that stereoscopic (3-D) slides are an effective instructional aid for illustrating ground hazards in the mine environment. These slides are a high-fidelity medium that realistically simulates underground conditions, and as such, are an excellent proxy for miners to learn to recognize the characteristics of unstable mine roof and rib. Additionally, the effectiveness of providing perceptual experience in recognizing visual cues during training was investigated, as workers' performance on a hazard recognition task was measured in the workplace using actual mine roof and rib conditions. It was concluded in these studies that, indeed, perceptual skills of miners in recognizing hazards could be improved in the classroom through simulation.

When hazard recognition is discussed, several knowledge bases are implicated. Hazard recognition is viewed as a complex task, with sensory, perceptual, and cognitive components. Consequently, information from many sources is applicable. Research on transportation safety, military target acquisition, and operator vigilance in industrial settings initially appear concerned with superficially dissimilar perceptual problems and environments. However, the underlying perceptual processes addressed by investigators in these seemingly disparate areas are often analogous to those involved in underground hazard recognition. For the purposes of these studies, researchers developed a model of hazard recognition based on these various areas of research. The model of hazard recognition in mining also benefited from basic laboratory research into human information processing and studies of the development of expertise in complex tasks (Perdue, Kowalski, & Barrett, 1995).

In a study conducted by Bureau of Mines, researchers' interviews with coal miners revealed that nearly two-thirds of the miners had either been injured or startled by rockfall at least once during a 12-month period (Peters & Wiehagen, 1987). The miners apparently did not perceive the danger until it was too late to avoid it. Numerous Mine Safety and Health Administration (MSHA) accident investigation reports note that the failure of miners to recognize hazardous roof conditions has contributed to many accidents. In one example, undetected areas of loose rock in the mine roof ("rolling roof") fell and caused fatal injuries to a worker. Another fatality occurred when an "undetected" horseback formation fell as a worker was scaling the mine roof. The direct cause of these accidents was reportedly the failure to detect the hazardous rock conditions at these locations.

4. A model of hazard recognition[1]

Although many different ways of conceptualizing the process of hazard recognition have been considered, a comparatively simple model was developed for this study (Fig. 4). The researchers posit that in order to respond appropriately to danger from potential mine hazards, an individual must perform the following:

1. **Detection of sensory cues**: *Detect* the presence of potentially relevant sensory cues or features in the environment. Often this takes the form of discriminating "figures" from the other stimuli serving as "ground." In terms of signal detection theory, the hazard "signal" must be discriminated from the extraneous "noise" of mine operations. Factors that may influence the sensory discrimination of hazard features include illumination levels, apparent color and brightness contrast of the features with the surrounding environment, "embeddedness" of the hazard, and acuity of the observer.
2. **Attentional selection**: Selectively *attend* to a subset of those features either overtly or in an automatic fashion, favoring them with further processing. The amounts of sensory input that can be attended to will generally be limited by the automaticity with which the observer is functioning, the ability of the observer to time-share cognitive resources between tasks, and the mental workload experienced.
3. **Recognition of the hazard**: Correctly *recognize* the pattern of features that identify a particular hazard. Experience or training provides the information that cues have been differentially associated with the presence of hazards in the past and thus are "diagnostic" of that hazard. In addition, the degree to which the often degraded "real-world" image of the hazard is consistent with the observer's cognitive representation of the hazard will influence the speed and accuracy of recognition.
4. **Confirm or disconfirm the hazard**: *Test* the initial hypothesis of the recognition or denial of a hazard by searching further for confirming or disconfirming evidence, the search being guided by some mental representation or schema of the nature of the hazard and the general environment of the underground mine. Since people seem generally reluctant to disconfirm any tentative hypothesis they hold (Watson, 1968), the efficacy of this stage will be determined by the ability of the observer to avoid a simple "confirmatory bias."

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[1] Source: U.S. Bureau of Mines IC 9422, 1995. U.S. Department of Interior.

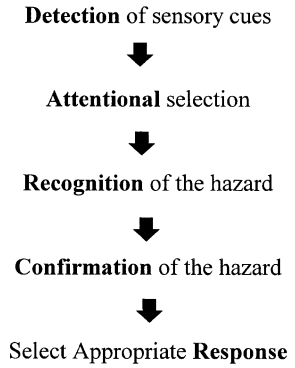

Fig. 4. A Model of Hazard Recognition (Source: NIOSH, 1995).

5. **Select appropriate response**: Consider and select an appropriate *response* to identified hazards. To a certain extent this depends upon the subjective evaluation of risk by the observer – simply because a potentially hazardous condition has been identified does not mean that the observer views it as a personal threat that compels avoidance. Objective danger does not always elicit an appropriate response if there is no personal, subjective assessment of danger (Benda & Hoyos, 1983).

4.1. Mining application of the model

An example of the application of this model to mining might be a situation where an underground shuttle car operator in the process of transporting coal from the mining face may be driving at high speed under varied lighting conditions. The operator at some point may *detect* a presence in the path of the shuttle, perhaps initially simply as a glimmer of reflected light or the impression of movement ahead. The operator may then focus more *attention* on the stimulus, either consciously or automatically attempting to discern the nature of the object: What is its shape? its size? its speed?

The initially ambiguous sensory impressions (a faint outline, a gleam of light) may be interpreted as the presence of reflective tape or a swaying cap light on a human form, and thus the mental picture emerges of a miner walking across the path of the shuttle car. The operator has then *recognized* that these cues signal a potentially hazardous event: a collision with a worker. Presumably the operator will continue to attend to the hypothesized "worker" ahead, *testing* his or her interpretation by searching for more confirming (or disconfirming) details. Once the operator has achieved a necessary amount of confidence in the interpretation of a hazard, there are a variety of *responses* to consider, depending on the proximity of the miner, the miner's behavior, and the braking capabilities of the shuttle. Of course, all of these "stages" in responding to a hazard are likely to be accomplished swiftly and perhaps with little conscious awareness of discrete steps in the process.

5. Training with degraded visuals

As noted earlier, it has been shown in Bureau studies that hazard recognition skills of miners can be improved through training conducted in the safety of the classroom. This finding was followed by an extensive literature search of fundamental psychological principles on perception. Concepts were identified and an innovative hazard recognition training program for miners was adapted from techniques used to train military observers in the identification of camouflaged targets (Perdue et al., 1995; Kowalski, Fotta, & Barrett, 1995).

In general, underground mining environments could be said to offer the miner who is attempting to recognize possible hazards a selection of consistently *degraded* visual targets, in that identifying features may be poorly illuminated, minimally distinguished by contour or contrast, masked from direct view, or embedded within a confusing array of competing features. In Fig. 5, the features present in this degraded scene are typical of degraded visual environments in underground mines. In fact, it is unusual to find an environment underground that is not visually degraded.

5.1. Advantages of degraded training

Laboratory research suggests that visual degradation of a stimulus hinders its correct identification by slowing both the initial stimulus encoding process and the search for that stimulus in memory (Sternberg, 1986). The perceiver finds it more difficult (and takes a longer time) to construct an intact or "cleaned up" mental representation of the target stimulus in the first place. In addition, when subsequently the mental representation of the stimulus is compared with the contents of memory for identification, each comparison operation takes longer to carry out because of the degradation still present in the mental representation. Thus, training that cultivates degraded mental representations and creates content for memory identification could shorten the time necessary to identify and thus react to hazards.

Fig. 5. A degraded scene in underground coal mine.

Fig. 6. Highlighted image.

Another explanation for the advantage of training with "degraded" targets may be attributed to the variability of the training stimuli. To facilitate information processing, individuals often store mental representations of typical targets or situations, often referred to as "prototypes." These mental prototypes are often arrived at by abstracting the defining or most typical features of the targets (Franks & Bransford, 1971; Posner & Keele, 1968). Generally, the observer has a variety of related experiences that are somehow "averaged" into a prototypical experience, or what may be thought of as the best composite example of those experiences. Thus, training for hazard recognition using visually degraded stimuli will present a more representative sample of the natural variation in appearance likely to be observed in the actual environment. The observer will tend to abstract or construct a more useful representative prototype that can be used to facilitate the identification of new stimuli.

It could be expected that in training miners to recognize hazards and dangerous situations in their highly variable and often visually degraded environment, it would be desirable to give them experience with equally variable representations of these hazards in the training presentations. Thus, practice with a series of normally distributed variations on common hazards should stimulate trainees to actively generate their own prototypical mental models of these hazards. This would tend to be useful as their expertise develops and they become proficient at matching these mental models to new conditions in the mine. On the other hand, exposing trainees to a limited set of professional well-lighted photographs or slides of hazards taken at close range would unlikely provide them with a sense of the variation they are likely to see on the job, would limit their ability to abstract a usefully complete prototype of the hazard, and would deprive them of the realistic contextual and background features that facilitate real-world hazard identification.

With these principles in mind, NIOSH researchers tested the hypothesis that miners trained using degraded training materials (slides) would be more proficient at identifying hazards than miners trained using more traditional or highlighted training materials. Examples of a highlighted slide and a degraded slide are shown in Fig. 6 (highlighted) and Fig. 7 (degraded).

Fig. 6 shows a miner's foot positioned within a trailing cable loop on the mine floor. This type of highlighted scene is traditionally used by trainers to explain the potential dangers of tripping or the sudden response of a cable to tension from the take-up reel. Fig. 7 is a degraded scene showing several potential hazards. The most obvious one (highlighted in Fig. 6) is the miner's foot in the cable loop. More subtle, but equally important, potential hazards in Fig. 7 include working in a confined area between equipment and rib, working without gloves and safety glasses, and placing tools on equipment where they could be knocked off and injure a worker.

5.2. Military observations

The natural visual degradation of important features in underground mines would appear to have implications for the training of miners. Military research on target identification suggests that if eventual target stimuli are to be searched for and identified under degraded conditions, observers should be trained to recognize them using training stimuli that are similarly degraded. Cockrell (1979) conducted an experiment and confirmed that observers attempting to recognize targets in naturalistic settings must get accustomed to seeing these targets under less than optimal (degraded) conditions such as the target being partially hidden from view, observed from an eccentric angle, viewed through haze or dust, or inadequately illuminated. In his experiment, observers were asked to correctly identify slides of model cars that had been degraded to some extent by obscuring significant portions of the cars. Observers who had also been trained using degraded views produced the most consistently accurate identifications. Observers trained using clear, complete photographs of the cars suffered a reduced ability in their identification performance when confronted with the partially obscured stimuli in testing.

Fig. 7. Degraded image.

Thus, the author concluded that training that specifically camouflaged or degraded stimuli proved to be advantageous in accuracy of later identification.

Cockell's study suggests that training stimuli should be similarly masked, embedded in a cluttered background, or presented in highly variant forms. During the extensive literature review, it was noted that the military had discovered that flight observers who were trained with less than ideal pictures (degraded) as compared to ideal pictures (highlighted) of their targets had a higher score on a subsequent target identification exercise. Degraded pictures refer to pictures where the target was partially hidden by cloud cover, rain, or camouflage. Traditional, or highlighted pictures refer to pictures where the hazard is clearly visible. Individuals trained using degraded pictures increased their skill level, resulting in greater success in identifying and accurately striking a target.

5.3. Clutter

Another concept with direct application to hazard recognition in mining and related to the degraded concept is *clutter*. Many of the geologic features indicative of roof instability may be harder to detect because of the high degree of clutter in the background against which they are to be detected. In the visual search literature, the term "clutter" is usually employed to denote the presence of multiple, superficially similar stimuli in proximity to the target (Williams & Borow, 1963). Clutter provides a "noisy" background in which a target is difficult to detect. An analogous clutter can be seen in the complexity or variability of the rock surfaces and geological features found in an underground mine. For example, the very dangerous slab of loose roof rock (entry top, right side) shown in Fig. 7 may not be apparent to a miner, at least not on the most important first look, because of significant clutter existing in the entry. Clutter in this scene consists of soft clay bottom, water, and loose top. In the language of signal detection theory, clutter may be thought of as the "noise" from which the perceiver must isolate the potential hazard, the "signal." Often the crucial features that are diagnostic of the presence of roof instability are partially masked by the superposition of mine equipment, the irregularity of the rock face, poor illumination, or other elements obstructing the line-of-sight of the observer.

6. Degraded hazards investigations

6.1. Study A

Control (highlighted hazards) and experimental (degraded hazards) training modules were developed for use in mandated Part 48 underground coal annual refresher training class. Slides were selected for the modules based upon whether the targeted hazard was conspicuous or whether it was visually degraded in some way. Eighty-two mine workers were recruited from 10 separate annual refresher training classes in cooperation with mining companies in three states: Pennsylvania, West Virginia, and Alabama. Four of the classes consisted of miners working in track (haulage) mines in Pennsylvania, another four classes from belt mines in Alabama, and the remaining two classes of miners from various belt mines across West Virginia. Participants were requested to report their age, the number of years of experience they had in mining, and their current job classification. The first two columns in Table 1 present a breakdown of the experimental and control group subjects with regard to: (a) their distribution across the three states; (b) the type of mine in which they work; (c) their job classifications; (d) the reported ages of the miners; and (e) their years of experience in mining. The third column in Table 1 summarizes this same information for the overall sample.

The number of miners recruited from each class varied from a minimum of five persons to a maximum of 12. Although the classroom instruction was considered part of their annual refresher training and all attendees received this instruction, participation in the post-instructional test phase of the study was voluntary and several miners declined participation. Assignment of subjects to either the control (highlighted) group or the experimental (degraded) group was accomplished by alternately designating an entire class of subjects at each site to receive instruction using either the

Table 1
Frequencies and descriptive statistics of demographic information for experimental group, control group, and overall sample

Description	Experimental group	Control group	Overall sample
State of mine location:			
PA Track mines	16(40%)	16(38%)	32(39%)
WV Belt mines	12(30%)	9(21%)	21(26%)
AL Belt mines	12(30%)	17(41%)	29(35%)
Total	40(100%)	42(100%)	82(100%)
Job classification:			
Production:			
Longwall	3(7.5%)	3(7%)	6(7%)
Continuous Miner	6(15%)	14(33%)	20(25%)
Management	3(7.5%)	0	3(4%)
Subtotal	12(30%)	17(40%)	29(36%)
Support:			
Maintenance	7(17.5%)	7(17%)	14(17%)
General	18(45%)	16(38%)	34(41%)
Management	3(7.5%)	2(5%)	5(6%)
Subtotal	28(70%)	25(60%)	53(64%)
Total	40(100%)	42(100%)	82(100%)
Age of workers:			
Mean	41.1	40.2	40.6
Std. Dev	6.56	7.35	6.94
Years Mining Experience:			
Mean	17.1	15.8	16.4
Std. Dev	4.46	5.61	5.10

traditional slides of highlighted hazards (control group) or the degraded hazard views (experimental group).

In both testing conditions, 11 instructional slides (depicting a combined total of 35 hazards) were displayed to the class for five seconds per slide, after which a Mining Industry Specialist reviewed the slides and discussed the multiple hazards depicted in each. The procedure for the training phase was similar for both the control and experimental groups, except for the manner in which hazards were pictured in the training slides.

After the training phase, participants in both control and experimental groups were tested individually on an assessment task that presented them with a sequence of 10 slides illustrating a total of 36 known hazards. Subjects examined each test slide for five seconds and then reported any hazards identified to the experimenter. Scores were computed by tallying the number of correctly identified unsafe conditions. The highest possible score a participant could receive by identifying each hazard as well as recognizing the one slide depicting no hazardous condition was 37. Subsequent to the study, an item review, conducted as part of the overall analysis, revealed a possible bias on the assessment task with regard to three items, all of which depicted a miner not wearing safety glasses. As part of the degraded training, the experimental group had observed two instances of miners not wearing safety glasses while the control group observed no such hazard as part of the highlighted instruction. This difference may have given the experimental group an unfair advantage in performing the tasks, and consequently these three items were deleted from the assessment task, reducing the highest possible score to 34.

6.1.1. Results for study A

The results indicate that scores on the assessment task for the experimental group were statistically significantly higher than scores for the control group. Means and standard deviations were computed on the scores for the experimental (degraded) and control (highlighted) groups. Differences between the means were analyzed using the independent sample's *t* test. Since the expectation was that the experimental group would obtain a higher score than the control group, a one-tailed *t* test was performed. The computed statistics are reported in Table 2.

A summary of the average scores obtained on the task by demographic subgroupings of miners within the overall sample is provided in Table 3. These subgroupings represent a breakdown of the overall sample relative to the state in which the miners worked and their job classification as listed previously in Table 1. The first two columns of Table 3 list the mean scores for the subgroups within the experimental and control groups, respectively. The third column lists the mean scores for the subgroups within the overall sample. Comparing the means between the two groups, the average scores for the experimental group exceed those obtained by the control group in all but two of the subgroupings.

Table 2
Means, standard deviations (SD), and results of t test for examining differences in performance scores between the control and experimental groups

Group	Instructional method	Number of miners	Mean score	SD	*t*-value
Control	Highlighted	42	11.8	4.0	2.57*
Experimental	Degraded	40	14.0	3.8	

* $p < .01$.

Table 3
Score means and standard deviations (in parentheses) by demographic groupings of the experimental group, control group, and overall sample

Description	Experimental group	Control group	Overall sample
State of mine location			
PA Track mines	16.5 (3.3)	13.3 (3.0)	14.9 (3.5)
WV Belt mines	11.7 (3.4)	9.7 (4.1)	10.8 (3.7)
AL Belt mines	13.1 (3.2)	11.5 (4.3)	12.2 (3.9)
Job classification			
Production	13.2 (5.3)	12.1 (4.7)	12.6 (4.9)
Longwall	11.0 (1.7)	14.3 (5.1)	12.7 (3.9)
Continuous Miner	11.5 (5.4)	11.6 (4.7)	11.6 (4.8)
Management	18.7 (4.0)	–	18.7 (4.0)
Support	14.4 (3.1)	11.6 (3.5)	13.1 (3.3)
Maintenance	14.3 (3.7)	12.0 (2.7)	13.7 (3.7)
General	14.3 (3.1)	11.2 (3.4)	12.8 (3.6)
Management	15.3 (1.5)	13.5 (7.8)	14.6 (4.2)

Note that a comparison for the production managers could not be made since there were no production managers assigned to the control group. However, for miners classified by job under Longwall Production and under Continuous Miner Production, the average scores were higher in the control group than in the experimental group, suggesting that the effectiveness of the degraded training varies across job categories. Although the study was not designed to examine differences across job categories, a closer scrutiny of the data offers some explanation for the observed discrepancies in the outcome. In the case of one set of production miners, given the small number of persons (n = 3) within each of the groups, a meaningful interpretation of any computed difference in the means is not realistic.

The intent of providing the information listed in Table 3 is to address the concern that the experimental group was predisposed to performing better than the control group by initial differences between the groups in their ability to recognize hazards rather than by differences in the type of instruction provided. Although time constraints prevented researchers from pretesting participants on their hazard recognition abilities, the demographic information obtained is useful in determining whether miners were more or less evenly distributed across the two groups on relevant demographic variables. As mentioned previously, there were no production managers in the control group, and as may be seen in Table 3, the three production managers assigned to the experimental group had the highest average score (20.3) of all the subgroupings. However, when the overall sample was reduced by eliminating these three managers, the resultant *t*-value (2.14) remained statistically significant (df = 77, $p < .05$).

Additionally, eliminating management from the sample also eliminated any advantage the experimental group may have had in terms of the previously observed differences in age and years of mining experience. Any other differences in the distribution of miners with regard to state (and type of mine haulage) or job classification appear to be negligible or to favor the control group. The conclusion is therefore that miners instructed using the degraded hazard approach were able to identify more hazards on a hazard recognition task than miners instructed by the traditional highlighted approach as a result of the type of instruction they received.

6.2. Study B

One of the subject companies from study A, located in Alabama, worked with NIOSH researchers to develop a Degraded Hazard Recognition program for its workers. The goal was to look at lost-time injuries for one year, incorporate the degraded hazard recognition intervention program the next year, followed by a no-intervention year (no degraded hazard recognition intervention taught), then compare the three years data on lost time injuries - pre, during, and post intervention. The program was incorporated into the company's Part 48 training program with more than 2,300 miners participating each year over the three-year period — 1994 through 1996.

The subject company operated four underground coal mines. Fig. 8 shows the monthly incident rate for all four mines for the years 1994 through 1996. It can be seen from the figure that the incident rate oscillates, but the peak values of each subsequent oscillation are less than the previous peak. It appears that there is a downward trend in incident rates during the three-year period. The latter was confirmed by computing a Spearman correlation coefficient to determine if there is an association between the incident rate and time. The coefficient showed a moderate negative correlation ($r = -0.53$) with a highly significant p-value (0.0009). A Poisson regression model was then used to test for a trend over time (Ely, Dawson, Lemke, & Rosenberg, 1997). The slope coefficient β was calculated to be -0.015 with a p-value of < 0.0001. Clearly, because β is negative and statistically different from zero, there is indeed a significant downward trend in incident rates from 1994 through 1996 at the Study B mine.

Table 4
Study B - Alabama Mine total accident, total employee-hours, and incident rate per 200,000 employee hours 1994–1996 (Source: NIOSH, 2002)

Year	Total accidents	Total employee-hours	Incident rate
1994	366	3,876,560	18.88
1995	346	4,030,116	17.17
1996	273	4,420,960	12.03

The program was evaluated by the company to be a success at the end of 1995, the intervention year, and the company requested a continuation of the degraded methodology for 1996 because it was already convinced that the method of training was a contributing factor in the reduction of injuries. This decision interrupted the study as originally designed but provided data to draw some conclusions. The degraded training continued into the third year; thus, the miners received two years of the degraded training. Table 4 shows the total accidents, total employee-hours, and average incident rate for 1994 through 1996. The incident rate decreased from 18.88 to 17.17 to 12.03. The drop in incident rates was 9.06% from 1994 to 1995 and 29.94% from 1995 to 1996 – a significant decrease after the training

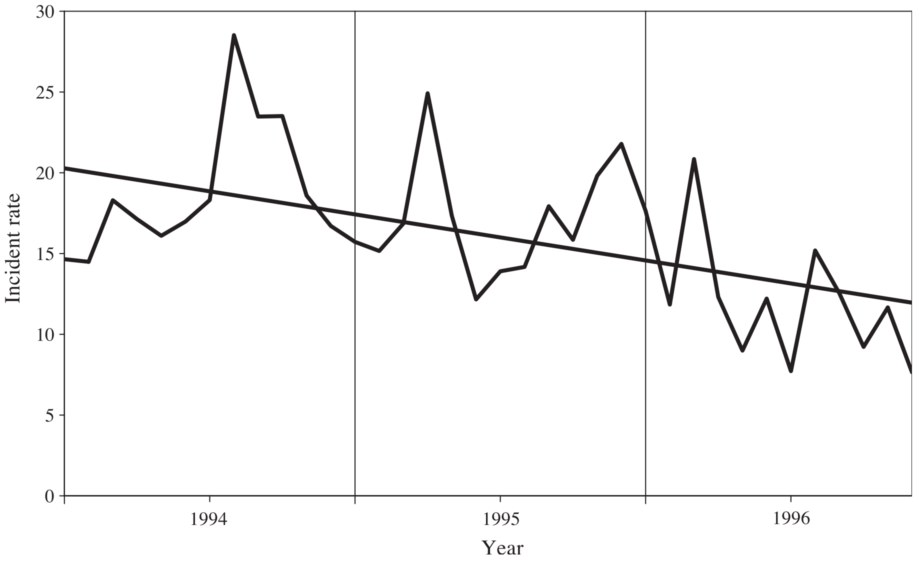

Fig. 8. Study B - Alabama Mine monthly incident rate per 200,000 employee hours with trend line (Source: NIOSH, 2002).

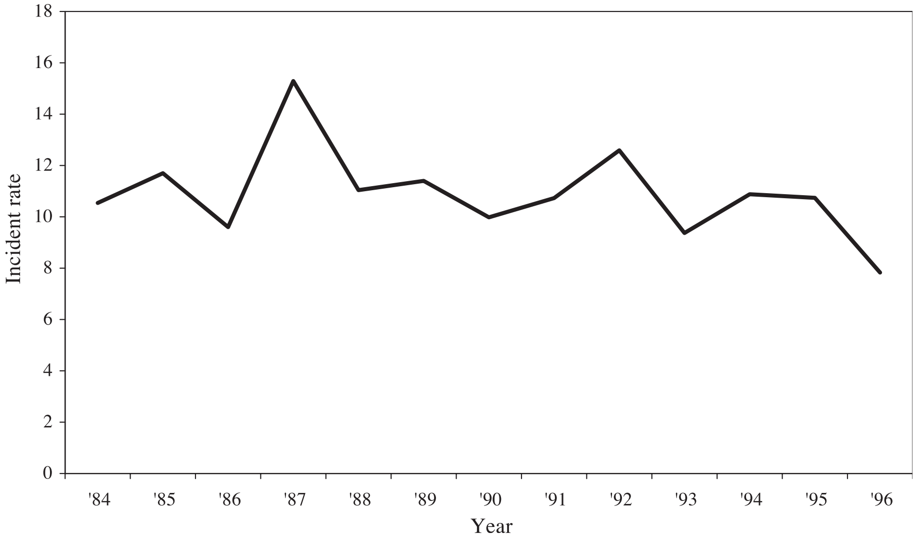

Fig. 9. Study C - Illinois Mine average yearly incident rate per 200,000 employee hours 1984–1996 (Source: NIOSH, 2002).

intervention. It is also important to note that company management at all levels became more involved in safety at approximately the same time. In this case, it is not possible to determine the separate effects of the training and the management involvement.

One of the four mines did not show a significant decrease in incident rates over the three-year period. For 1994 the incident rate was 16.1, for 1995 it was 17.0, and for 1996, 15.8. The reasons for this occurring are not known. It does mean that if this mine is not considered in the analysis, the decrease in the incident rate over the 3 years and the slope of the time trend line would be even more significant.

6.3. Study C

NIOSH researchers worked with an underground coal mine in southern Illinois to develop a degraded program as a supplemental safety program for 550 workers. Fig. 9 shows the yearly incident rate for 1984 through 1996. The incident rates increase, decrease, and increase again. Table 5 shows the total accident, total employee-hours, and incident rate for this mine for the years 1994 through 1996. Conclusions that can be drawn from the Illinois mine data include the fact that the 1996 incident rate is the lowest since the opening of the mine in 1984. It represents a 27.10% drop from 1995 to 1996. The degraded program along with a flex-and-stretch program (begun in 1994) is credited with a substantial decrease in average incidence rates and the lowest lost-time injury rate since the mine opened in 1984. This mine was experiencing serious low morale problems for internal and external reasons. Many mines in the area of the state were closing and communication was poor, yet the injuries went down. It is important to note that the safety incentive program at this mine was consistent (a reward program) throughout the last 4 years, which further documented the positive results of the degraded hazard recognition program in conjunction with the flex-and-stretch program.

Table 5
Study C - Illinois Mine total accident, total employee-hours, and incident rate per 200,000 employee hours 1994–1996 (Source: NIOSH, 2002)

Year	Total accidents	Total employee-hours	Incident rate
1994	63	1,158,380	10.88
1995	64	1,191,550	10.74
1996	52	1,328,780	7.83

7. Conclusions and recommendations

The perceptual skills of miners can be improved in the classroom using degraded visuals. Further, this type of hazard recognition training has transfer potential for improving miners' ability to recognize hazards in underground coal, and a potential for limestone and surface sand and gravel operations. The initial study, Study A, showed an increase in miners' ability to recognize hazards. Studies B and C showed that the incident rates dropped significantly after the intervention in Alabama (29.94%) and in Illinois (27.10%). In each case, there was another factor introduced by the company at approximately the same time – management involvement in Alabama and a flex-and-stretch program in Illinois. This confounding of the results makes it impossible to determine how much of the drop in incident rates was due to the training itself. However, in interviews with the trainers, their observations credited the degraded hazard recognition program with a major part of the decrease in rates.

The authors recommend further study of the use of degraded image training to improve hazard recognition skills of workers at a variety of work sites and industries. In addition, further exploration of the hazard recognition model and the development of other interventions based on the model could support the validity of the steps in the hazard recognition model.

8. Follow-up report on additional programs and applications

In the past several years, mining industry and MSHA training personnel have developed numerous programs using the degraded method. A training module including a video, slides, overheads, and instructor's manual was produced in cooperation with the State of Illinois, Department of Natural Resources, and Eastern Illinois Community Colleges. In addition, the method was used to develop a hazard recognition program for underground limestone and surface sand and gravel, and in a program focused on falls in construction.

The hazard recognition method has been presented to a number of audiences, but this paper represents the first publication of the combined data from the three studies. The literature review was presented at the International Applied Psychology Conference in July 1994 in Madrid, Spain. The Degraded Method of training was presented to participants at the National Mine Instructor's Conference in October 1994 and again in October 1995. Training programs developed for the mining industry based on the degraded image concept are available at www.cdc.gov/niosh/mining/training.

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