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The effect of cap lamp lighting on postural control and stability

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Abstract

Researchers at the National Institute for Occupational Safety and Health (NIOSH) are conducting mine illumination research with the objective of improving miner safety. Slips, trips, and falls (STFs) are the second leading accident class (18.1%, n = 2,374) of nonfatal lost-time injuries at underground mines (MSHA, 2005–2009). Factors contributing to STFs include recognition of hazards as well as postural balance and age. Improved lighting may enable better hazard recognition and reduce the impact of postural balance and age. Previous research has shown that cap lamp technology that used light-emitting diodes (LEDs) has improved hazard detection. This study was an initial investigation to determine if cap lamp lighting significantly influences measures of static postural stability (displacement and velocity of center of pressure). Results of this investigation showed no significant differences in the balance measures of interest between cap lamps tested. However, balance was shown to significantly decline ($p < 0.05$) when tested in an underground coal mine compared to the laboratory testing condition. *Relevance to industry:* Underground coal mine workers wear cap lamps on their hard hats as their primary light source to illuminate nearby areas where their vision is directed. Proper illumination may improve miner safety by improving their STF hazard recognition and balance.

Keywords

Trip hazards; Visual performance; Mine safety; Illumination

1. Introduction

Approximately 619,000 people are employed, directly and indirectly, in the United States mining industry (BLS, 2009). Underground coal mining involves a hazardous, dynamic environment that includes dust, confined spaces, low reflective surfaces, low visual contrasts, and glare. The Illuminating Engineering Society of North America cites the working face of an underground coal mine as the most difficult environment in the world to illuminate (Rea, 2000). Mine workers depend on illumination for virtually every aspect of performing their jobs as well as for seeing various mining hazards. Equipment-related injuries where illumination can be a factor include pinning/striking accidents involving

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moving equipment, slips and falls during equipment ingress/egress, and accidents during maintenance and repair activities.

Mine Safety and Health Administration (MSHA) accident data for 2005–2009 indicates that STFs are the second leading accident class (18.1%, n = 2,374) of nonfatal lost-time injuries at underground mining work locations. During this period, STFs resulted in 149,002 total days lost from work (MSHA, 2005–2009). STF injuries have also plagued British coal mines in recent decades. Foster (1997) examined injuries from the British Coal Midland's Group underground coal mining accident database for 1988 to 1994. Foster concluded that STF injuries occurred more frequently than any other accident category. He suggested that better lighting could reduce the risk of STF injuries. Odendall (1996) examined accidents at South African gold and platinum mines and established that a strong relationship existed between the levels of illumination and the number of accidents. Research, specific to the lighting of underground metal/nonmetal mines, determined that increasing the illuminance could improve visual performance for detection and recognition of trip hazards (Merritt et al., 1983).

There are scant detailed mining injury data concerning STFs where illumination was a factor. One reason, in relation to U.S. mining accidents, might be that the MSHA accident database has several limitations. For instance, when reporting an injury, none of the 12 accident/injury codes from which mine operators may select include illumination or miner visual performance. Further, when given the opportunity to provide a narrative, the causes identified for the mine operator's consideration are mining equipment, protective items, compliance issues with rules and regulations, and operator issues such as job skills, training, and attitude. Thus, mine illumination is not specifically mentioned nor implied as a cause or condition from which to select or describe when reporting an injury.

Lighting can influence the performance of people in the industrial workplace by way of ten mechanisms that include visual performance, visual comfort, visual ambience, interpersonal relationships, job satisfaction, and problem solving (Juslén and Tenner, 2005), Poor lighting and reduced visual feedback decreases detection of STF hazards and has also been shown to decrease postural stability, increasing one's risks for falls. Brooke-Wavell et al. (2002) studied the effect of lighting on the postural sway of healthy older women. Subjects were asked to perform quiet standing in five environmental conditions while center of pressure (COP) measurements were taken. These conditions were normal laboratory lighting (186 lx), moderate lighting (10 lx), dim lighting (1 lx), eyes closed, and with a repeating pattern projected on the walls. Results showed that anteroposterior sway was significantly greater when standing with eyes closed than any other condition. It was also greater in dim lighting than moderate or normal lighting. Simeonov and Hsiao (2001) found that providing roofers with a close visual reference significantly decreased area of sway indicative of improved postural stability while standing on an elevated platform. Without close visual reference, the velocity of sway increased 17% when subjects were standing 3 m above the ground on a firm surface and 21% when subjects were standing 9 m above the ground on a firm surface (Simeonov and Hsiao, 2001).

Age has also been associated with increased postural sway. Previous research has noted decreased visual performance and decreased postural control were detected as early as 40 years of age (Era et al., 1986; Howarth, 2006). Visual changes with age include the decline of the ability to focus on near objects (presbyopia) and the yellowing of the lens, which results in decreased contrast sensitivity (Howarth, 2006). During walking, visual cues are integrated with the somatosensory and vestibular systems to maintain balance. With age, the quality of these visual cues decline and may contribute to increased risks for falls. Additional deteriorations in proprioception, reaction time, and muscle strength contribute to these risks and may be apparent as early as 40 years (Era et al., 1986). The authors also noted a more pronounced rate of decline in male subjects. The reduced balance in older age may be attributed to many factors including loss of receptor cells in the vestibular organ, reduced peripheral sensation, and changes in visual function (Brocklehurst et al., 1982; Lord et al., 1991; Rosenhall, 1973). Of these factors, deterioration in visual function may be compensated for by improving the quality of lighting. There is an additional need for improved lighting due to the increasing age of the mining industry, whose median age is 45 years.

Various types of lighting are used to provide illumination for underground mines. Underground mine workers wear cap lamps on their hard hats to illuminate nearby areas where their vision is directed. The main parts of a typical cap lamp are the headpiece, battery, and an interconnecting cable. The headpiece contains the light source and is mounted on the miner’s protective helmet. Cap lamps are often a mine worker’s primary source of light needed to safely perform their job tasks and to visually detect hazards from moving equipment or to visually detect STF hazards on the mine floor (Cornelius et al., 1998). Visual detection is very important given that, some research results have indicated that reactions to visual signals are generally faster than those for auditory signals (Fion Lee and Alan Chan, 2007). Therefore, the quality and quantity of illumination are critical factors for mine workers to perform their jobs safely (Sanders and Peay, 1998). Traditionally, miner cap lamps used an incandescent bulb as the light source and a lead-acid battery. Today, LED light sources and lithium-ion batteries are gaining acceptance. Newer cap lamps are integrating the battery into the headpiece.

Previous underground mining research has shown that improving light quality decreases mining accidents by enhancing visual performance in the detection and recognition of STF hazards (Daly, 2001; Merritt et al., 1983). Most recently, the importance of human factors in the design of mining equipment was detailed by Horberry et al. (2011), where an entire book chapter was devoted to visual performance and the illumination of the mining environment. The cap lamp is an important piece of personal protection equipment in mining. Therefore, to enhance the safety at underground coal mines, NIOSH researchers have focused on developing a new LED cap lamp to improve the ability of miners to detect hazards. Historically, light beams from cap lamps have been a tightly focused (6–10°) symmetrical spot that is very similar to a flashlight—a design approach unchanged since the 1914 Edison cap lamp. Thus, traditional cap lamps create a “tunnel vision” type of visual environment where the floor is poorly illuminated and visual cues about the geometry of the mine are very limited. NIOSH researchers developed a new approach by using multiple LEDs and specialized optics to direct lighting to better illuminate STF hazards and moving machinery hazards. Human subject data indicate a 79% improvement in detecting moving hazards in the peripheral field of view and a 194% improvement in detecting STF hazards (Reyes et al., 2011).

Decreased visual performance and postural stability are associated with poor lighting as well as increased age (Brooke-Wavell et al., 2002; Daly, 2001; Merritt et al., 1983; Brocklehurst et al., 1982; Lord et al., 1991; Rosenhall, 1973). These factors likely contribute to the magnitude of STF accidents in the underground mining population. However, the influence of cap lamps on postural stability has not specifically been investigated. Although the LED-based cap lamps have been shown to improve STF hazard and peripheral motion detection, the effects of cap lamp design (if any) on postural stability are unknown. The primary objective of this study was to determine if cap lamp design affects postural stability. A secondary objective was to determine if age is a factor.

2. Materials and methods

2.1. Subjects

Employees at the Bruceton, PA, location of NIOSH were recruited to be subjects. Subjects signed an informed consent form and were instructed about their right to withdraw freely from the research at any time without penalty. The protocol was approved by the NIOSH Human Subjects Review Board. None of the subjects were specifically involved with this cap lamp research, and most of the subjects were not familiar with miner cap lamps or had only used them infrequently. Subjects with radial keratotomy, monocular vision, glaucoma, or macular degeneration were excluded. Only the subjects that passed vision tests for. Snellen distance visual acuity of 20/40 or better, Mars Letter contrast sensitivity of 1.72–1.92 values of log contrast sensitivity, and peripheral vision of at least 80° for each eye were accepted for the study. Subjects having a balance disorder were also excluded as determined by a screening questionnaire and balance screening tests. The balance screening tests consisted of horizontal gaze nystagmus, walk and turn, one-leg stand, and Romberg tests (Khasnis and Gokula, 2003; Tharp et al., 1981).

All balance screenings were administered and scored by one researcher given the subjective nature of the tests. Following successful completion of the functional balance screening, baseline balance measurements were collected using a force plate. Balance screening and baseline testing were conducted under normal lighting conditions.

Thirty-one subjects participated: 23 male and eight female. There were 10 subjects each in the age groups of younger (18–25 years), middle (40–50 years), and older (51+ years). The average ages were 21.1 yrs, 44.8 yrs, and 55.6 yrs respectively. The age group from 26 to 39 years was not used because there are generally minimal changes in vision for those ages (Blanco et al., 2005). The average subject age was 40.5 yrs which is representative of the average U.S. mine worker’s age of 41.8 yrs (BLS, 2009). All but one subject completed the testing. That subject withdrew because of nausea experienced during testing.

2.2. Experimental design

A 3 × 2 × 3 (3 age groups, 2 visual reference scenarios, 3 cap lamps) repeated-measures randomized complete block analysis of variance (ANOVA) experimental design was used. The presentation of the six combinations of visual reference and cap lamp conditions was randomized for each subject. Age was treated as a nested-within-subjects variable. PROC GLM of SAS 9.2 was used for analysis of the ANOVA, with the RANDOM statement to indicate that the subject was nested within age categories. Type III sums of squares were used for the F-tests. Tukey's studentized range test was used (via MEANS option) for *post hoc* mean comparisons of significant factors. Separate ANOVAs were run for each dependent variable: center of pressure (COP) velocity in the mediolateral (CPVML) and anteroposterior (CPVAP) directions, the root mean square (RMS) of the COP displacement in the ML (RMSML) and AP (RMSAP) directions, and the sway area (SA).

Because the baseline measure was taken in a laboratory with a fixed visual reference, the baseline measure could not be added as a condition to compare to the cap lamp conditions. In order to compare the baseline to the cap lamps, a 3 × 4 (3 age groups, 4 lighting conditions) ANOVA was run with the baseline condition and the near conditions for each of the three cap lamps together forming the four lighting conditions. The near condition was chosen since this was closest to the laboratory setup distance from the forceplate to the wall that the subjects faced. This ANOVA allowed for comparison of the baseline conditions to underground conditions to determine if underground conditions lead to reduced postural stability. The analysis and SAS options were the same as discussed in the previous paragraph. Finally, correlations between the dependent measures and age were calculated for the baseline condition for reference comparison to findings in the literature.

3. Experiment layout and apparatus

3.1. Safety Research Coal Mine (SRCM)

This study was conducted in the NIOSH Safety Research Coal Mine (SRCM). The SRCM is located on-site at the Bruceton, PA, NIOSH campus and it has been used for decades by researchers to conduct experiments in a realistic coal mine setting. The SRCM is inactive in that no coal is mined; however, typical mine lighting and ventilation conditions are present. The entry used during testing measured 10.5 ft (3.2 m) wide by 7.3 ft (2.2 m) high and 944 ft (287.7 m) long.

3.1.1. Experimental layout—A force plate (ACCUGAIT, Advanced Mechanical Technology, Inc., Watertown, MA) was embedded into the floor flush with the walking surface of the mine at the end of a mine entry as seen in Fig. 1. From the force plate, an un-obstructed view of 944 ft (287.7 m) could be seen down the entry. All mine light sources were turned off during testing with the only light source coming from the cap lamp being tested. Typical mining machinery sounds were played during testing to further simulate the mining environment. A canvas curtain was used to simulate close field of view and was hung at a distance of 14.4 ft (4.4 m) from the force plate across the entry.

3.2. Cap lamps

Three LED cap lamps were used. Fig. 2 depicts these cap lamps on a single mounting plate that is used for laboratory measurement purposes. During the testing, a single cap lamp was mounted to the hard hat worn by the subjects. Each cap lamp was new, powered at levels for a fully charged battery, and each had a cord that connected to a power source located behind the subject. The cap lamps' electrical and photometric data are listed in Table 1. Cap lamps 1 and 2 used a single phosphor-white LED as the primary light source, along with an optical reflector to direct the light to a circular spot beam ranging from about 6 to 8° . Fig. 3 depicts the lighting distributions of two cap lamps. The lighting distribution from cap lamp 2 is very similar to cap lamp 1, except that the circular spot beam is directed an additional 4° downward to the floor area. Both were approved by the Mine Safety and Health Administration (MSHA). Cap lamp 3 was a laboratory prototype developed by NIOSH to improve the ability of miners to see mining hazards. This prototype uses multiple, phosphor-white LEDs as the primary light source along with secondary optics to better illuminate specific hazardous areas in the mine. The mine's walls are within the subject's field of view; thus they serve as a vertical frame of reference. The more the walls are illuminated, the more visible they become. The left and right wall illuminance was measured at a distance of 10 ft (3 m) ahead of the subject. For each wall, an illuminance measurement was taken at 2-ft (0.6-m) intervals starting at the floor and stopping near the mine ceiling. Fig. 4 depicts the vertical illuminance distribution for the left and right walls.

3.3. Procedure

During data collection, subjects were given standard mining personal protective equipment (hard hat, clear-framed safety glasses, a miner's belt with a cap lamp battery, self-contained self-rescuer, and steel-toed safety boots) and asked to enter the SRCM. Safety boots were standardized across subjects, with all subjects wearing the same make and model boots. The subjects were given time (about 15 min) to acclimate to the dark conditions of the mine before data collection begun. During each test, the subject was asked to stand quietly on the force plate with their eyes facing forward (down the entry). The subject's feet placement was standardized by a guide which allowed for 2-in (5-cm) inter-foot spacing (see Fig. 5). The subject then donned the appropriate cap lamp based on the randomization scheme. A series of seven trials of quiet standing (each for 60 s collected at 100 Hz) with eyes open was collected using the Balance Clinic software (Advanced Mechanical Technology, Inc., Watertown, MA). This was repeated using each of three cap lamps and the two visual reference scenarios (near-field and far-field), for a total of 42 trials. A custom-written software script (MATLAB®; The MathWorks, Inc, Natick, MA) was used to calculate CPVML, CPVAP, RMSML, RMSAP, and SA.

4. Results

The ANOVAs comparing the three cap lamps and two visual reference conditions across age categories only yielded significant differences for the effect of visual reference on RMSAP. Cap lamp condition approached significance ($p < 0.077$) for CPVML. The means of the dependent measures, collapsed across age categories and by visual reference and lighting condition, are given in Table 2, and standard deviations are listed in parentheses.

The ANOVAs comparing the lighting conditions (baseline condition and the near visual reference for three cap lamps) indicated that lighting condition significantly affected CPVAP ($p < 0.0126$), RMSML ($p < 0.0046$), and sway area ($p < 0.023$). The results of the *post hoc* Tukey tests are shown in Table 2. Age category bordered on significant for RMSAP ($p < 0.0503$); however, the data in Table 3 do not indicate that age was a significant factor.

The correlations between subject age and the dependent measures for the baseline indicated a significant correlation between age and CPVAP ($r = 0.40$, $p < 0.0275$). The other correlations were not significant, with the correlation between age and RMSAP ($r = 0.35$, $p < 0.0614$) approaching significance.

5. Discussion

Overall, the results of this pilot investigation of the role of cap lamp design on postural stability suggest that postural stability may be significantly reduced when wearing a cap lamp in a mining environment compared to a baseline lighted laboratory condition; however, the cap lamp differences studied do not significantly affect measures of static postural stability for the visual environment of the SRCM. The results have several implications for choosing cap lamps for underground use as well as for future studies, as detailed below.

5.1. Cap lamps

While the results of this study do not indicate a statistically significant difference among the cap lamps, prior NIOSH research has implied that cap lamp 3 enabled the best visual performance among LED cap lamps by comparison to cap lamps 1 and 2 as used in the current research. Human subject test results indicate that cap lamp 3 improved the ability to perceive moving objects in the peripheral visual field by as much as 79.5%, with a 194.1% detection time improvement for floor trip objects (Reyes et al., 2011) without increasing discomfort glare (Sammarco et al., 2011). Thus, it appears that with respect to safety, cap lamp 3 would enable distinct advantages in visual performance and discomfort glare without reducing postural stability when compared to the other cap lamps.

5.2. Subject age

Volunteers utilized in this testing represented a wide range of ages. Although age was not a significant factor in the analyses carried out, the data in Table 3 suggest that there were trends, albeit non-significant, in the outcome measures RMSP and sway area, particularly for the oldest age group.

In accordance with the literature, baseline balance measures of this study population also imply a detriment in balance functioning with age where CPVAP ($r = 0.40$, $p < 0.0275$ was significant and RMSAP ($r = 0.35$, $p < 0.0614$) approached significance.

This study was a pilot investigation into the effect of age and cap lamp lighting distribution on postural stability; hence, only ten subjects participated in each of the three age groups. These small sample sizes increase the probability that the results could have occurred by random chance. Also, the likelihood of inadvertently increasing confounding factors increases because small groups are likely to be less diverse than large groups. Increasing the sample size in a larger study has the potential to yield significant results with respect to age as a factor.

5.3. Limitations

Testing was conducted in the SRCM. In the test area, the mine width was about 10.5 ft (3.2 m) as depicted by Fig. 1. This is about half the width of entries commonly encountered in contemporary room-and-pillar coal mines in the U.S., where the width is typically about 20 ft (6.1 m). The SRCM dates back to 1910, when the majority of the mining was conducted by older mining techniques that used drills, cutting bars, and explosives to mine the coal. Today, room-and-pillar coal mines use continuous mining machines that can cut coal in widths ranging from approximately 16 ft (4.9 m) to 22 ft (6.7 m). In these conditions, the mine wall illumination depends on the distance from the light source to the mine wall, where the illumination varies according to the inverse square law. Thus the wall illumination in a typical room-and-pillar coal mine would decrease by a factor of four given a mine width of 21 ft (6.4 m). This would reduce the illumination below that provided, for instance, by a full moon on a clear night. It is unknown if this reduced illumination would negatively affect the usefulness of the wall as a visual frame of reference. However, previous research has found that restricting peripheral vision (through wearing personal protective eyewear) is likely to affect balance negatively, and this may be comparable to walking in an area with dimly illuminated walls (Wade et al., 2004). Additional research is needed to address this potential issue.

Standing and walking are considerably different activities. However, while most falls occur during walking, the risk for falling is often determined via static standing measurements of postural stability. In the case of the current study, it was impractical to attempt dynamic measures due to the difficulty of equipping the mine and maintaining consistent walkway conditions. In general, loss of balance is commonly a triggering event for a fall accident, and postural stability measures obtained during static standing correlate well with risks for falls (Duncan et al., 1992; Simeonov and Hsiao, 2001; Topper et al., 1993).

The foot placement guide discussed in the procedure was not removed prior to testing, however the force plate was zeroed out with the guide placed on the force plate before the subject stepped onto the force plate. The effect of the guide remaining on the force plate was measured during pilot testing and it was found that the guide did not significantly affect the measurements taken, however it could have prevented the detection of very slight significant differences in the data.

Locomotion in an underground coal mine is substantially different than in many other occupational environments. Not only is there poor lighting, but miners must also wear protective eyewear and footwear in addition to other tools and safety devices attached to their belts. These protective measures may reduce peripheral vision and affect the dynamic stability of miners when walking in an underground coal mine, where they are constantly navigating the uneven mine floor terrain. Although the authors believe that the balance effects noted in this study will correlate to those experienced during walking (since all subjects wore typical mining PPE), the additional hazard recognition required during walking in a mine is a concern. Additional research would be needed to address this potential issue.

Although only LED cap lamps were studied, there are still many incandescent cap lamps in use. It is possible that including incandescent cap lamps may have resulted in greater differences within cap lamps, especially given the research mentioned previously indicating superior performance of LED over incandescent cap lamps with respect to visual performance. The results did suggest that postural stability appears to be negatively influenced by underground lighting conditions, and these differences are likely contributors to the problem of slips and falls in underground mines.

Lastly, remote control and automation is being increasingly deployed in coal mining for a number of reasons such as to remove operators from hazardous situations, improve productivity, lessen environmental impact and to mine areas that were previously inaccessible (Hoberry et al., 2011). The scope of this pilot study did not include such remotely-controlled or automated mining equipment. The illumination environment improves when remote control and automation is not used because mining equipment is in close proximity. The machine mounted lighting then helps to increase the overall illumination thus providing miners with better illumination of visual cues, hazards, and visual frames of references. Remote control and automation results in a higher dependence on the cap lamp because the equipment illumination is farther away and contributes less to illuminating the mine environment by the inverse of the square of the distance to the miners.

6. Conclusions

The aim of this research was to provide initial quantification of the effects of improved lighting on postural stability which can be a contributing factor for STF accidents in underground mining. Vision plays a large role in preventing STF accidents and serves two purposes: 1 – it exposes the presence of objects allowing them to be evaded and 2 – it reveals changes in the environment that necessitate a change in locomotive action (Howarth, 2006). Previous research conducted by NIOSH has demonstrated the ability of LED-based cap lamps to improve hazard detection. Results of this study did not find a significant difference in postural stability between different designs of LED-based cap lamps, but did show a significant decline in postural stability when moving from a fully lit laboratory to an underground coal mine. Future studies, such as those by Reyes et al. (2011 , in press), will be necessary to determine the gain in other performance measures for reducing STF accidents realized with improved cap lamp technology.

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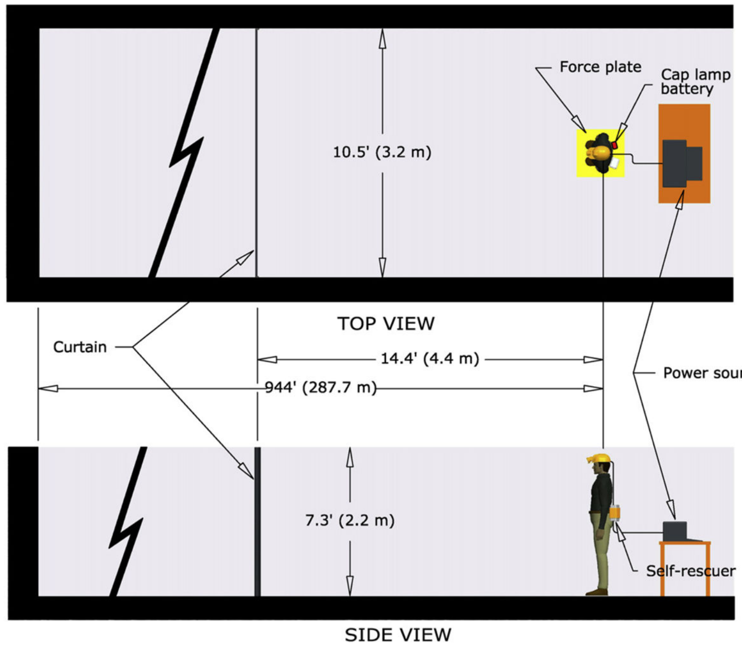

Fig. 1.

The test layout within the Safety Research Coal Mine. The curtain was lowered and raised for the near-field and far-field visual reference scenarios, respectively.

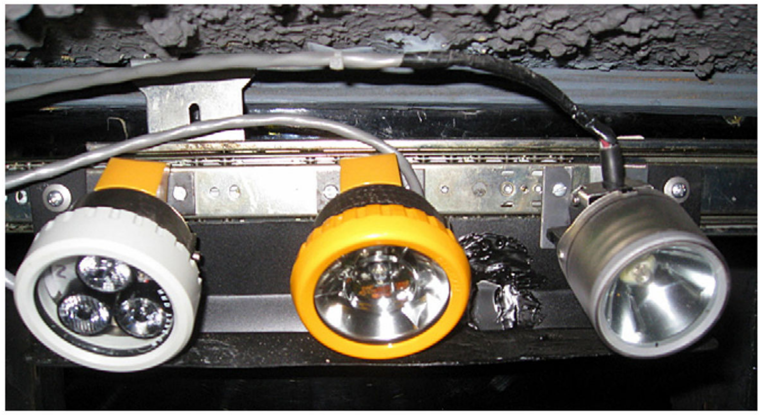

Fig. 2.
Cap lamps 3, 2, and 1 (left to right) mounted on a bracket used for laboratory measurements.

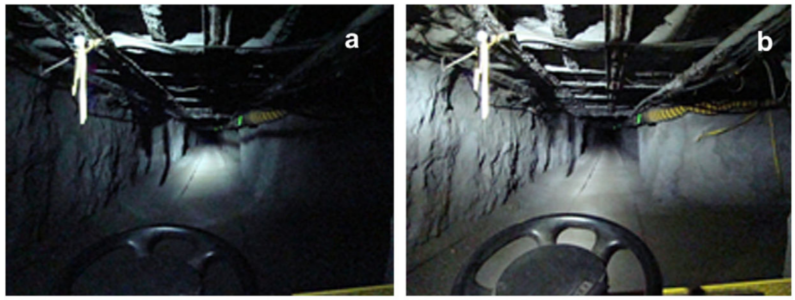

Fig. 3.
The light distributions from cap lamps a) 1 and b) 3.

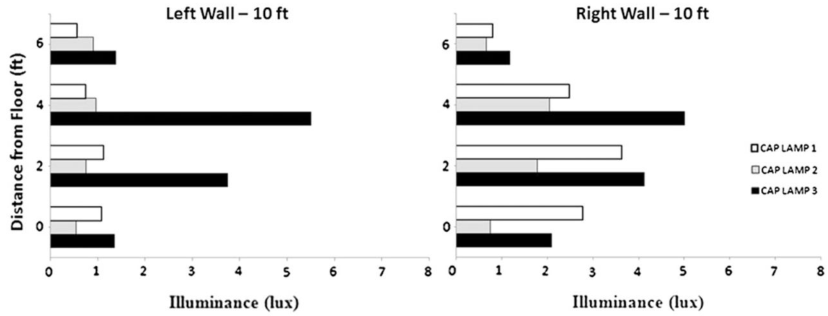

Fig. 4.
Vertical illuminance at a distance of 10 ft (3 m) ahead of the subject at: a) the left wall; b) right wall.

Fig. 5.
Force plate showing placement of the feet and T-shaped separator.

Table 1

Cap lamp electrical and photometric data.

Cap lamp (nm)	Electrical characteristics			Photometric characteristics	
	Supply voltage (Vdc)	**Supply current (ma)**	**Supply power (watts)**	**Peak wavelength**	**Correlated color temp. (K)**
1	4.00	760	3.04	452	8039
2	3.95	530	2.09	456	6603
3	2.96	450	1.33	448	6356

Table 2

Means (standard deviations) of postural sway by visual reference and lighting (3 camp lamps, baseline laboratory) conditions.

	Dependent measure									
	CPVML (mm/sec)		CPVAP (mm/sec)		RMSML (mm)		RMSAP (mm)		Sway area (mm^2)	
	Visual reference		Visual reference		Visual reference		Visual reference		Visual reference	
Lighting	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
Baseline (Lab)	0.22 (0.03)	–	^{b}0.32 (0.04)	–	^{b}0.10 (0.04)	–	0.17 (0.07)	–	^{b}0.31 (0.21)	–
Cap lamp 1	0.23 (0.04)	0.22 (0.03)	^{a,b}0.35 (0.07)	0.35 (0.05)	^{a}0.12 (0.04)	0.11 (0.04)	0.19 (0.07)	0.16 (0.05)	^{a}0.43 (0.36)	0.35 (0.21)
Cap lamp 2	0.23 (0.04)	0.23 (0.04)	^{a}0.35 (0.06)	0.37 (0.09)	^{a}0.12 (0.04)	0.12 (0.05)	0.17 (0.06)	0.16 (0.05)	^{a,b}0.40 (0.25)	0.42 (0.42)
Cap lamp 3	0.23 (0.05)	0.23 (0.04)	^{a}0.35 (0.05)	0.37 (0.09)	^{a}0.12 (0.04)	0.12 (0.05)	0.17 (0.05)	0.16 (0.05)	^{a,b}0.38 (0.25)	0.42 (0.42)

^{a,b}Means with the same letter are not significantly different.

Table 3

Means (standard deviations) of dependent measures by age categories collapsed across visual reference and lighting conditions.

Age group	Dependent measure				
	CPVML (mm/sec)	**CPVAP (mm/sec)**	**RMSML (mm)**	**RMSAP (mm)**	**Sway area (mm^2)**
18–25	0.23 (0.03)	0.33 (0.06)	0.11 (0.03)	0.16 (0.04)	0.34 (0.16)
40–50	0.22 (0.04)	0.35 (0.06)	0.10 (0.05)	0.15 (0.05)	0.32 (0.32)
51+	0.23 (0.04)	0.36 (0.07)	0.12 (0.04)	0.20 (0.07)	0.49 (0.33)