

Ergonomics Considerations for Proximity Warning Systems

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Overview

- **What is ergonomics?**
- **Overview of key ergonomics concepts and application to proximity warning**
- **Body sizes (anthropometry), perceptual, and cognitive considerations**
 - System design
 - System selection
- **Learning, usability, and alarm design relevance to designing proximity systems**

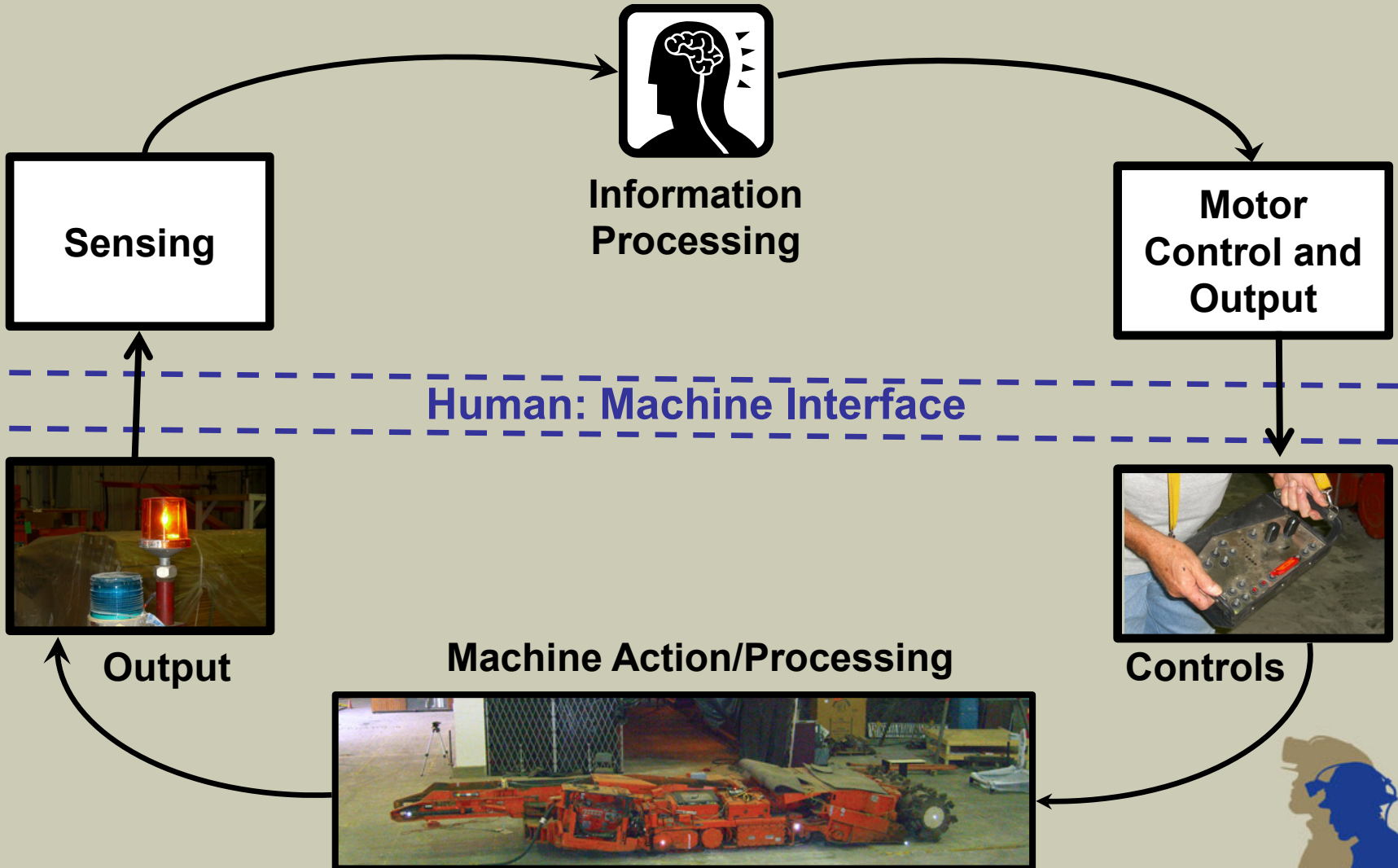


Introduction

- ***Ergonomics*** is the design and engineering of human: machine systems for the purpose of enhancing human performance (Dempsey et al., 2000)
- Human performance dimensions include:
 - Safety
 - Health
 - Error avoidance
 - Efficiency
 - Comfort



Human: Machine Interaction



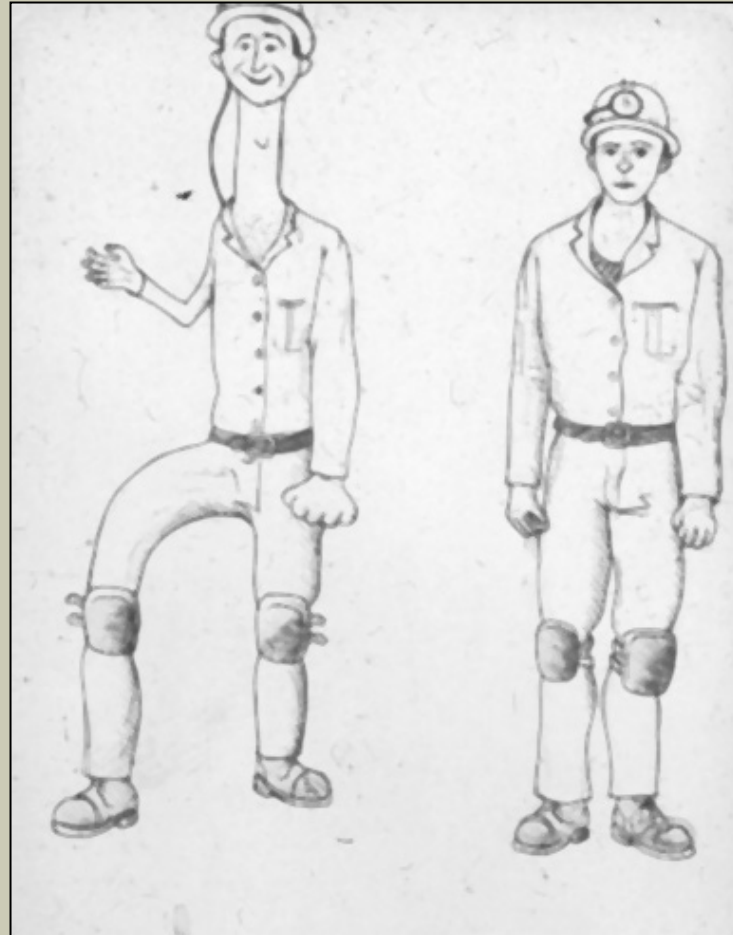
Key Ergonomics Concepts

- **“Fitting the task to the worker”**
- **Designing work so that demands do not exceed the capacities of the majority of the workforce (>95%)**
 - Anthropometric (body sizes)
 - Perceptual
 - Cognitive
 - Physiologic
 - Biomechanical
 - Organizational
 - Social



Fit Miners to Mine Equipment?

- 'Bretby Man' by Steve Mason (courtesy Tom Leamon)
- Designed miner to fit drill-loader
- Long neck to see over booms
- Short right arm to operate control panel at shoulder level
- Short left leg for 'deadman' pedal (Simpson, Horberry and Joy, 2009)



Potential Consequences

- **Three Mile Island perhaps most famous example of ignoring ergonomics design**
 - Open valve showed closed on instrument panel, releasing coolant to the drain tank
 - Too many simultaneous demands ensued
- **Russian Salyut cosmonauts**
 - Separation of control module activated pressure equalization valve, cabin depressurized
 - Manual closure of valve (intended for this purpose) from inside took longer than oxygen lasted



MSHA – Fatality July 11, 2008

- “Foreman with 40 years experience was fatally injured while preparing to tram a belt feeder to a belt tail after a belt move. When the feeder started, it abruptly pivoted pinning the victim between the feeder and the coal rib.”
- **Root causes**
 - Start switch 63” from operator’s station
 - Hydraulic control levers exposed to unexpected activation (trailing cable) to open position
 - Strain clamp aligned cable with control levers while under tension

<http://www.msha.gov/FATALS/2008/FTL08c16.asp>

<http://www.msha.gov/FATALS/2008/FAB08c16.asp>



Anthropometric Considerations

- **Placement of wearable sensor will influence protection**
 - Head-mounted sensor could be 6+ ft away from lower legs
 - Low seam mines will potentially increase sensitivity since more varied postures are expected
 - Depending on interaction required, placement will influence visual information transmission
 - Design for extreme
- **Additional equipment on miner who may already have comm/tracking, SCSR, tools, etc.**



Perceptual Considerations

- **Warnings before shutdown need to be detected**
 - These will increase usability
 - Nuisance alarms should be avoided
 - Potential for training mode
- **In harsh auditory environments, visual warning signals are superior to auditory**
 - Vibro-tactile warnings are possible, but visual preferred
 - If more than one light or color are used, red and green most prone to color blindness, followed by blue and yellow



Visual Warning Considerations

- **Visual warnings need to be within typical field of view**
 - Bartels et al. (2009) concept of visual attention locations (VALs) is one approach
 - VALs are discrete points or areas regularly scanned by operators
 - Near edge of continuous mining machine was common VAL for tramming and cutting
- **Other light sources may interfere**
- **Dust, other miners and equipment may interfere** (Bartels et al. 2009)
- **Person-wearable warnings may not be seen**

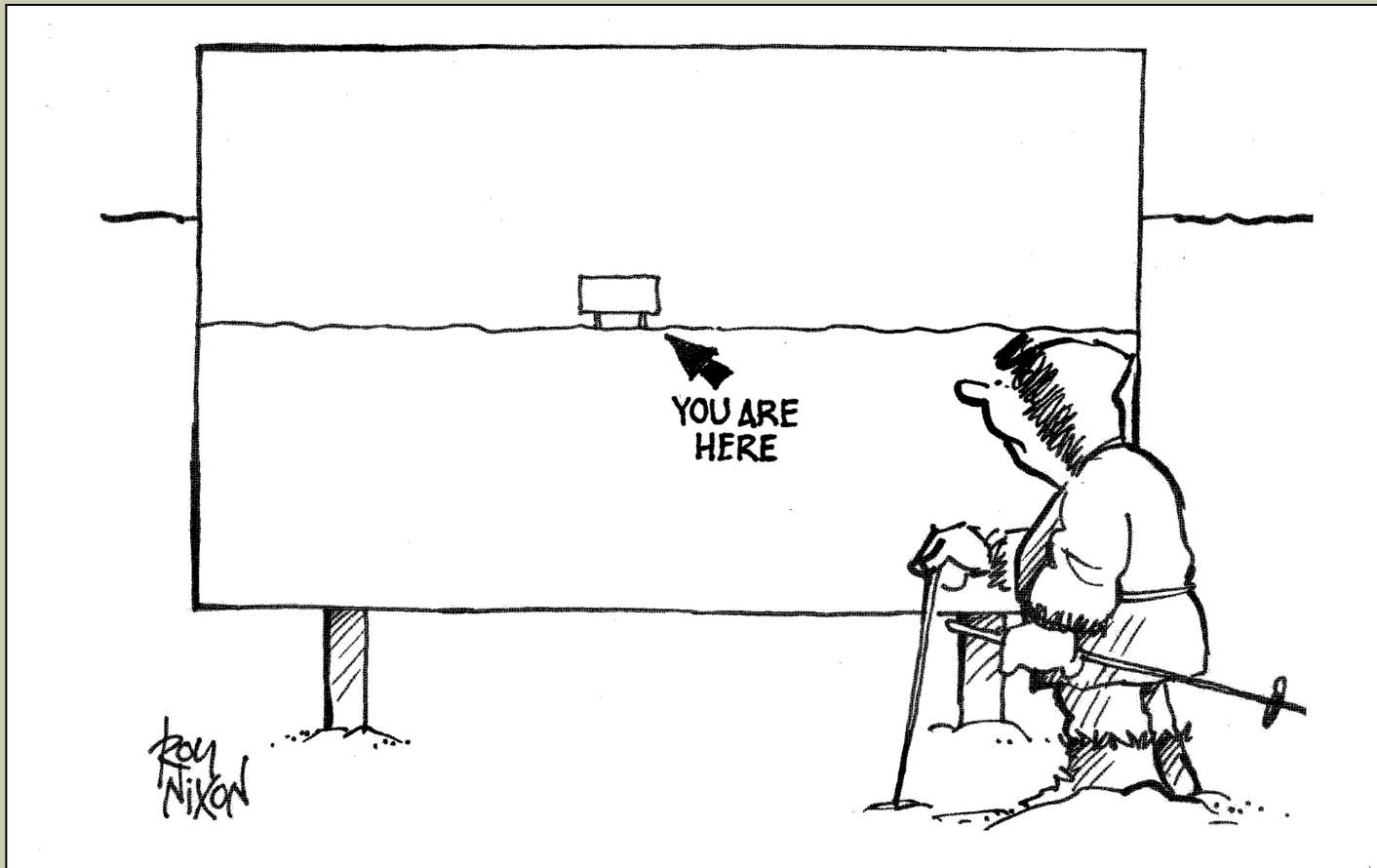


Visual Warning Considerations

- **Size (+), luminance (+) and exposure time influence detectability**
- **3 to 30 Hz recommended, lower end better for attracting attention**
- **With high signal-to-background brightness contrast, color is less important**
- **Background lights suggest flashing warning light**
(Sanders and McCormick, 1987)



Cognitive Considerations



Stereotypes

- ***Population stereotypes*** refer to expectations regarding movement relationships among the **general public** (Sanders and McCormick, 1987)
 - ‘Up’ implies ‘On’ for a light switch, counter-clockwise opens a valve, etc.
 - For mining equipment, stereotypes are complicated and are not universally applicable (Simpson and Chan, 1988)
- **It is likely that operators will develop certain stereotypes about systems**
 - Shape/size of field, warnings before shutdown, etc.
 - Uniform warning zones and related operational characteristics can minimize transfer issues



Learning and Transfer

- If the same stimulus is present on two different systems (e.g. warning light), there can be positive or negative transfer of learning depending on the response required
- Different responses to the same stimulus could be required on two systems causing negative transfer
 - e.g. Differently shaped warning zones could cause continuous miner operators to move in different directions to avoid shutdown when warning occurs at a given spot



Usability

- ***Usability***: the extent to which a product can be used to achieved specified goals with effectiveness, efficiency, and satisfaction (ISO 9241-11: 1998)
- It is easier to measure difficulties than it is to measure ease of use (Chapanis, 1981)
- ***Effectiveness***: proximity warning protects miners
- ***Efficiency***: proximity warning should not impede productivity
- ***Satisfaction***: miner operators are happy (at least content) with proximity system



Alarms and Vigilance

- ***Nuisance alarm*** is a signal that attempts to direct attention to an event but frequently one that does not warrant a shift in attention (Woods, 1995)
- Nuisance alarms lead to operators ignoring the alarms or attempting or succeeding in disabling the alarms
 - Deepwater Horizon audible alarms disabled to avoid waking sleeping workers
- Warning zone alarms can be of significant value if they warn operators appropriately



Additional Considerations

- **Unanticipated and even anticipated situations may require rapid over-ride**
- **Equipment may continue to move even after shutdown**
- **There is a history of mismatches between designers' intentions and users' actions**
 - Even well intentioned designs have led to creative uses
- **Humans adapt to systems, the possibility of miner operators adapting to proximity systems is high**



Conclusions

- **Proximity warning systems are complicated systems overlaid on an existing system**
- **Need to understand users and how they will use the system**
- **Design systems to optimize human performance**
- **Ergonomics analysis should not be an afterthought**
 - The cost of implementing ergonomics is minimized at the design phase



The findings and conclusions in this presentation are those of the authors and do not necessarily represent the views of NIOSH



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