Clothing for Improving Mine Worker Visibility

Queensland Mining Safety Conference

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The Problem

- Low light levels are a constant hazard in underground mines and for night-time operations at surface mines
  - Collisions between vehicles and workers are a major cause of fatal accidents in the mining industry
  - Account for ~28% of the 112 fatalities in the mining, exploration and extraction industries in Australia during 1998 – 2008 (Kizil et al 2011)
- Improving the visibility of workers to drivers of mining vehicles and equipment is one potential approach for reducing the risk of collisions and fatalities
  - This approach has been explored in the context of road safety for improving the visibility of vulnerable road users and could potentially be translated to the mining industry
Night-time Driving

• Driving at night can be dangerous
  • Crash statistics indicate that fatality rates at night are 3x higher than those for daytime (National Safety Council 1999-2004)

• The night-time elevation in road safety risk is even greater for collisions involving vehicles and pedestrians
  • Fatal pedestrian collisions are up to 7x more likely at night than in the day (Sullivan & Flanagan 2002)

• Highly relevant in general road systems, particularly at road work sites
  • 844 workers were killed at road construction sites in the USA between 1995 and 2002 (Pegula 2004)
  • Night-time construction 5x more hazardous than day-time (Arditi et al 2007)
Night-time Visibility

- Crash database analyses indicate that reduced visibility is a key factor in night-time crashes involving vulnerable road-users (Owens & Sivak 1996; Sullivan & Flannagan 2002)

- Problems of poor visibility compounded by:
  - Drivers’ underestimation of their own visual limitations at night
    - Confidence is largely based on lane-keeping ability (which is relatively unimpaired) but drivers are unaware of the reduction in their visual function at night (Owens & Tyrrell 1999; Owens 2003)
  - Pedestrians/cyclists overestimation of their own visibility (Tyrrell et al 2004; Wood et al 2013)
  - Increasing driver age with associated declines in visual function
    - Relevant in the mining industry where ~25% of mineworkers are aged 50 years and above
Age-related Vision Changes

- Pupil gets smaller (less light)
- Clouding of the lens (reduced contrast and more glare)
- Retinal/neural slowing (slowing of visual processing)
Night-time Visibility

- Retroreflective clothing is a low cost option for improving the visibility of pedestrians
  - Most common clothing intervention is a retroreflective vest
  - BUT studies show night-time pedestrian visibility is better enhanced via alternative placement of retroreflective markers
- A promising configuration is ‘biological motion’
  - Pattern of motion of living creatures – known as ‘biological motion’ - is very different to that of inanimate objects
  - Helps identification of the moving object and its action even with limited visual information

http://psych-s1.psy.vanderbilt.edu/faculty/blaker/BM/BioMot.html
Biological Motion

http://www.biomotionlab.ca/

more ...

Available on the iPhone App Store

http://www.biomotionlab.ca/
Application of Biological Motion

- Application of the perceptual phenomenon of biological motion to improve night-time pedestrian visibility
  - Retroreflective strips attached to moveable joints illuminated in headlamp beam
  - Our studies have demonstrated the visibility benefits of biomotion clothing in both closed and open road environments
Closed Road Pedestrian Studies

- Participants drive an instrumented vehicle around a closed road course at night
  - Distracter task: Call out all road signs
  - Distracter cones
  - Glare lights to simulate oncoming vehicle headlamps
  - Announce “pedestrian!” and press touch pad when they first recognise a pedestrian is present
Older drivers recognised pedestrians less often and at significantly shorter distances than the younger drivers.

- Overall, older drivers recognised only 58% of the pedestrians and at half the distance.

Clothing really matters!

- Recognition distances for biomotion 50x greater than black...
- … and 3x greater than vest!

Wood et al 2005
Clutter & Motion

- 5 clothing configurations: all pedestrians wore black and all except black wore the same amount of retroreflective material.
Clothing & Clutter

- Limb markings recognised more often
- Clutter effect not significant
Clothing & Motion

- Benefit of motion greatest when limbs are marked

Tyrrell, V
Tyrrell et al 2009
Roadworker Open Road Road Study

- Conducted at 2 road work sites:
  - Suburban & freeway - prepared according to standard work site guidelines
- 20 participants: seated at range of distances
  - Rated conspicuity of 4 road workers walking in place wearing 4 different clothing configurations at 3 distances at each site
  - Standardised rating scale

Standard (fluorescent orange shirt and navy blue work pants, plus fluorescent orange vest with silver retro-reflective strips)

Thigh (standard configuration plus retro-reflective strips worn around each thigh, midway between hip and knee joint)

Ankles & Knees (standard configuration plus retro-reflective strips worn around ankle and knee joints)

Biomotion (standard configuration plus retro-reflective strips around elbow, wrist, ankle and knee joints)
Effects of Roadworker Clothing

- Overall rankings
  - Suburban & freeway sites

- Ranked 1\textsuperscript{st} by 95\% of people
- Ranked 2\textsuperscript{nd} by 95\% of people
- Ranked 3\textsuperscript{rd} by 95\% of people
- Ranked 4\textsuperscript{th} by 100\% of people

- Significant main effect of clothing
  - Biomotion > ankle & knee > thigh > standard

- Pattern of effects were apparent at both work sites

Wood et al 2011
Effects of Roadworker Clothing

- Overall rankings
  - Suburban & freeway sites

- Study undertaken on the closed road confirmed these ranking results

Wood et al 2013
Interventions

- Key element of the pedestrian and cyclist visibility problem is their tendency to overestimate their own visibility to oncoming drivers (Tyrrell et al 2004; Wood et al 2013)
Interventions

- A lecture on night-time visibility improved subsequent judgments of pedestrians own visibility in an on-road situation (Tyrrell et al 2004)

- This approach has potential for translating the findings from biomotion research into safety benefits for workers
  - In addition to those already gained by biomotion clothing

- Recently developed video-based intervention outlines the problems of conspicuity of pedestrians under low light levels
  - Highlights the need to be aware of difficulties that drivers have in seeing pedestrians at night
  - Demonstrates the value of biomotion markings in relation to other clothing configurations
• Viewing of this intervention had a significant impact on participants’ perceptions of their own visibility at night.
Potential Translation

• Low illumination is a hazard in underground mines and for night-time operations at surface mines
  • Importance of retroreflective markings on clothing is recognised by the mining industry and is standard on all sites
  • Some sites mandate reflective strips on upper and lower body
• Biomotion clothing has the potential to be a low cost and practical way to provide safety benefits in the mining industry
• Does not involve modifications to vehicles, drivers or infrastructure
  • Capitalises on well-documented human perceptual sensitivities
  • Road safety research demonstrates that biomotion clothing is relatively robust to the effects of age, eye conditions, clutter, glare and other factors encountered in mine sites
Potential Translation

• Potential application for an effective and easily implementable custom-based video intervention in the context of mining organisations
  • Potential to change both knowledge and behaviour of mine workers (both drivers and pedestrians) with ultimate benefits for workplace safety
• BUT important that visibility research is undertaken in representative mining environments
  • To further explore the unique visual challenges presented in underground mines and surface mines at night
  • In order to optimise the visibility and hence safety of mine workers in low light conditions
Acknowledgments

• Funding agencies: ARC Linkage, ARC Discovery

• Mt Cotton Driver Training Centre

• Researchers: Vision and Driving team

• Collaborators: Richard Tyrrell, Fred Owens
Age-related Visual Function Changes

- **Visual acuity**
  - Ability to see fine detail

- **Contrast sensitivity**
  - Ability to see faint images

![Graph showing visual acuity and contrast sensitivity changes with age](image)
Age-related Visual Function Changes

- **Glare sensitivity**
  - Ability to see objects in the presence of bright light sources

- **Motion sensitivity**
  - Ability to detect and identify the direction of movement of objects