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Translating Road Safety Research on Night-Time Visibility to the Context of Mining

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TRANSLATING ROAD SAFETY RESEARCH ON NIGHT-TIME VISIBILITY TO THE CONTEXT OF MINING

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ABSTRACT: In recent years a significant amount of research has been undertaken in collision avoidance and personnel location technology in order to reduce the number of incidents involving pedestrians and mobile plant equipment which are a high risk in underground coal mines. Improving the visibility of pedestrians to drivers would potentially reduce the likelihood of these incidents. In the road safety context, a variety of approaches have been used to make pedestrians more conspicuous to drivers at night (including vehicle and roadway lighting technologies and night vision enhancement systems). However, emerging research from our group and others has demonstrated that clothing incorporating retroreflective markers on the movable joints as well as the torso can provide highly significant improvements in pedestrian visibility in reduced illumination. Importantly, retroreflective markers are most effective when positioned on the moveable joints creating a sensation of "biological motion". Based only on the motion of points on the moveable joints of an otherwise invisible body, observers can quickly recognize a walking human form, and even correctly judge characteristics such as gender and weight. An important and as yet unexplored question is whether the benefits of these retroreflective clothing configurations translate to the context of mining where workers are operating under low light conditions. Given that the benefits of biomotion clothing are effective for both young and older drivers, as well as those with various eye conditions common in those >50 years reinforces their potential application in the mining industry which employs many workers in this age bracket. This paper will summarise the visibility benefits of retroreflective markers in a biomotion configuration for the mining industry, highlighting that this form of clothing has the potential to be an affordable and convenient way to provide a sizeable safety benefit. It does not involve modifications to vehicles, drivers, or infrastructure. Instead, adding biomotion markings to standard retroreflective vests can enhance the night-time conspicuity of mining workers by capitalising on perceptual capabilities that have already been well documented.

INTRODUCTION

The problem

Collisions between mine vehicles and other vehicles, personnel and infrastructure continue to be one of the main causes of fatal accidents in the mining industry, with reports that among the 112 fatalities that occurred in the mining, exploration and extraction industries in Australia during 1998 - 2008, vehicle collisions accounted for ~28% and claimed the lives of 31 people (Kizil *et al.,* 2011).

Collisions between pedestrians and mining equipment are a particularly high risk in underground mines, although interactions between pedestrians and vehicles also occur at surface mines.

Consequently, there has been a significant amount of research undertaken in collision avoidance and personnel location technology in order to reduce the relatively high number of incidents involving pedestrians and mobile plant equipment, given the unacceptably high risk they represent in underground coal mines. Improving the visibility of pedestrians to drivers would potentially reduce the likelihood of these incidents.

Improving pedestrian visibility

In the context of road safety, a variety of approaches have been used to make pedestrians more conspicuous to drivers at night, these have included vehicle and roadway lighting technologies and night vision enhancement systems. This has been a particular focus given that crash statistics indicate that

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when adjusted for mileage, the night-time fatality rate is two to four times higher than that for daytime (NHTSA, 2005) and night-time crashes are more severe than those occurring in the day (Plainis *et al.,* 2006). The night-time elevation in road safety risk is even greater for collisions between vehicles and pedestrians who are up to seven times more vulnerable to a fatal collision at night than in the day (Sullivan and Flannagan, 2002).
Although multiple factors, including alcohol and fatigue, may contribute to the elevated night-time fatality rate, the basic difference between night and daytime driving is the reduction in illumination at night. The increase in crash rates, particularly collisions with pedestrians, cyclists, and other low-contrast obstacles during night-time driving, has been largely attributed to poor visibility (Owens and Sivak, 1996). It has also been suggested that even the low illumination levels available from a full moon can have a positive effect on pedestrian fatalities. For example, pedestrian fatalities were 22% lower on nights with a full moon than on moonless nights (Sivak *et al.,* 2007). The problems of poor visibility at night are further compounded by drivers' misjudgment of their own visual limitations, where drivers' confidence appears to be largely based upon their lane-keeping ability at night, which is relatively unimpaired compared to the significant loss in 'focal' vision evident under low light conditions (Owens and Tyrrell, 1999, Owens, 2003).

An important challenge is to better understand the problems involved in driving under reduced light levels where there has been only limited research, despite the risk to safety, particularly for vulnerable road users such as pedestrians. In addition, there has been a widespread emergence of night vision systems and other devices which are believed to assist in night-time driving, including near and far infrared night vision systems (Tsimhoni *et al.,* 2004) and adaptive headlights. These interventions require rigorous evaluation and validation under as realistic driving conditions as possible to ensure that they actually do provide tangible safety benefits for all road users.

Research from our group and others has clearly demonstrated that clothing incorporating retroreflective markers positioned on the moveable joints that create a sensation of "biological motion" has potential benefits for improving night-time visibility. Biological motion is a compelling visual phenomenon, where based only on the motion of point-lights on the moveable joints of an otherwise invisible body, observers can quickly recognize a range of features of the moving human form (Blake and Shiffrar, 2007).

Biological motion

The effect of biological motion was first demonstrated more than four decades ago (Johansson, 1973), as an extension of psychophysical research into motion perception, where the moving point-lights on the joints of a moving person were sufficient to perceive a human form. Since that time there has been an extensive body of research that has demonstrated that such point-light walkers are able to convey information about gender (Kozlowski and Cutting, 1977), identity of walkers (Troje *et al.,* 2005), emotions (Roether *et al.,* 2008), and even to the estimation of the weight of lifted objects (Bingham, 1993).

Research to improve night-time conspicuity of pedestrians

Our research has demonstrated that clothing that incorporates retroreflective markers on the moveable joints (ankles, knees, shoulders, waist, elbows and wrists) which are illuminated by oncoming headlights produce similar visibility benefits to that of the biological motion effect of point-light walkers (Figure 1).

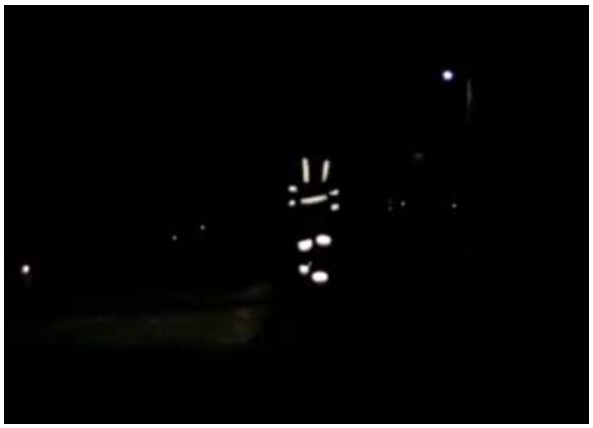

Figure 1: Example of biomotion clothing for improving pedestrian conspicuity at night

Our studies have demonstrated that retroreflective strips positioned in the full biomotion pattern provide substantial advantages for improving pedestrian visibility over and above that of retroreflective material positioned on the torso, such as retroreflective vests. In one of our closed road studies, for example, drivers using low beam headlights recognised a pedestrian walking while wearing biomotion markers at a distance that was 3.4 times greater than when the same pedestrian wore a vest that included an equal amount of retroreflective material (148m compared to 43m) (Wood *et al.,* 2005). Importantly, these studies clearly demonstrate that it is the configuration and not the amount of retroreflective material that determines pedestrian conspicuity. Our other research has also shown that the visibility advantages of biomotion configurations are relatively robust to the effects of driver age (Wood *et al.,* 2005, Owens *et al.,* 2007, Wood *et al.,* 2014a), visual impairment (Wood *et al.,* 2012a, Wood *et al.,* 2010), headlight glare (Wood *et al.,* 2012a) and the visual clutter surrounding the pedestrian (Tyrrell *et al.,* 2009). Field studies at real road worker sites have also demonstrated improvements in perceived conspicuity of roadworkers (Wood *et al.,* 2011), which are reflected in recent closed road studies (Wood *et al.,* 2014b). We have also demonstrated that an adapted form of biomotion markers attached to the ankles and knees have significant benefits for improving bicyclist conspicuity, over and above that of a standard retroreflective cycling vest (Wood *et al.,* 2012b).

Previous research has also demonstrated that a key element of the visibility problem of vulnerable road users, including pedestrians and cyclists, is their failure to appreciate the extent of the problem and their tendency to overestimate their own visibility to oncoming drivers (Tyrrell *et al.,* 2004b, Wood *et al.,* 2013). In the only study that sought to alter pedestrians' estimates of their own visibility, it was demonstrated that a lecture-based delivery of information on night-time visibility effectively changed subsequent judgments of visibility by pedestrians in an on-road situation (Tyrrell *et al.,* 2004a). This research provides reason for optimism about translating the findings from our research into safety benefits for workers over and above the benefits gained by using biomotion. We have recently developed a video-based intervention that similarly outlines the problems of the conspicuity of pedestrians under low light levels, highlighting the need to be aware of difficulties that drivers have in seeing pedestrians at night-time, particularly older drivers and those with visual impairment, and the utility and value of biomotion markings in relation to other clothing configurations. There is potential application for effective and easily implementable interventions like this in the context of mining organisations, which have the potential to change both knowledge and behaviour of workers with ultimate benefits for workplace safety.

Low illumination levels are a constant hazard associated with underground mines, and are also associated with night-time operations at surface mines. The importance of retroreflective markings on clothing is recognized by the mining industry and is a standard on all sites. Some sites also mandate reflective strips on upper and lower body. The location of these retroreflective markings to coincide with the anatomical joints in the biomotion pattern constitutes a relatively low-cost modification to these standards.

CONCLUSIONS

The adoption of retroreflective markers in a biomotion configuration has the potential to be an affordable and practical way to provide a sizeable safety benefit in the mining context. It does not involve modifications to vehicles, drivers, or infrastructure; instead, adding biomotion markings to standard vests can enhance the night-time conspicuity of workers by capitalising on perceptual capabilities that are already well established.

REFERENCES

Bingham, G P. 1993, Scaling judgments of lifted weight: Lifter size and the role of the standard, *Ecological Psychology,* 5**,** 31-64.

Blake, R and Shiffrar, M. 2007, Perception of human motion, *Annual Review of Psychology,* 58**,** 47-73.

Johansson, G. 1973, Visual perception of biological motion and a model for its analysis, *Perception & Psychophysics,* 14**,** 201-211.

KIZIL, G. V, BYE, A and JOY, J. 2011, Development and Application of Risk-Cost-Benefit (RCB) Decision Support Framework and Analytical Tools, RCBGEN and RCEMETHOD, for the Minerals Industry, *Technical Report, ACARP 17014*.

Kozlowski, L T and Cutting, J, 1977. Recognizing the sex of a walker from a dynamic point-light display. *Perception and Psychophysics,* 21**,** 575-580.

Nhtsa. 2005, *Motor Vehicle Traffic Crash Fatality Counts and Injury Estimates for 2004* [Online]. Washington, D.C. Available: http://www.nhtsa.dot.gov.

Owens, D. A. 2003, Twilight Vision and Road Safety: Seeing More Than we Notice but Less Than We Think. *In: IN J.T. ANDRE, D. A. O., & L.O. HARVEY (EDS.) (ed.) Visual Perception: The Influence of H.W. Leibowitz*, Washington, D.C: American Psychological Association.

Owens, D A and Sivak, M. 1996, Differentiation of visibility and alcohol as contributors to twilight road fatalities, *Human Factors,* 38**,** 680-689.

Owens, D A and Tyrrell, R A. 1999, Effects of luminance, blur, and age on nighttime visual guidance: A test of the selective degradation hypothesis, *Journal of Experimental Psychology:Applied,* 5**,** 115-128.

Owens, D A. Wood, J M and Owens, J. M. 2007, Effects of age and illumination on night driving: A road test. *Human Factors,* 49**,** 1115-1131.

Plainis, S, Murray, I J and Pallikaris, I G, 2006. Road traffic casualties: understanding the night-time death toll, *Injury Prevention,* 12**,** 125-138.

Roether, C L, Omlor, L and Giese, M A. 2008, Lateral asymmetry of bodily emotion expression. *Current Biology,* 18**,** R329-30.

Sivak, M, Schoettle, B and Tsimhoni, O. 2007, Moon phases and nighttime road crashes involving pedestrians, *Ann Arbor, MI: University of Michigan Transport Research Institute*.

Sullivan, J M and Flannagan, M J. 2002, The role of ambient light level in fatal crashes: inferences from daylight saving time transitions, *Accident Analysis & Prevention,* 34**,** 487-498.

Troje, N F, Westhoff, C and Lavrov, M. 2005, Person identification from biological motion: effects of structural and kinematic cues, *Perception & Psychophysics,* 67**,** 667-75.

Tsimhoni, O, Bargman, J, Minoda, T and Flannagain, M J. 2004, Pedestrian detection with near and far infrared night vision enhancement, *Ann Arbor, MI: University of Michigan Transport Research Institute*.

Tyrrell, R A, Patton, C W and Brooks, J O. 2004a, Educational interventions successfully reduce pedestrians' overestimates of their own nighttime visibility, *Human Factors,* 46**,** 170-182.

Tyrrell, R A, Wood, J M and Carberry, T P. 2004b, On-road measures of pedestrians' estimates of their own nighttime conspicuity, *Journal of Safety Research,* 35**,** 483-490.

Tyrrell, R A, Wood, J M, Chaparro, A, Carberry, T P, Chu, B S and Marszalek, R P. 2009, Seeing pedestrians at night: visual clutter does not mask biological motion, *Accident Analysis & Prevention,* 41**,** 506-12.

Wood, J, Chaparro, A, Carberry, T and Chu, B. S. 2010, Effect of simulated visual impairment on nighttime driving performance, *Optometry & Vision Science,* 87**,** 379-86.

Wood, J M, Lacherez, P and Tyrrell, R A. 2014a, Seeing pedestrians at night: effect of driver age and visual abilities, *Ophthalmic & Physiological Optics,* 34**,** 452-8.

Wood, J M, Marszalek, R, Lacherez, P and Tyrrell, R A. 2014b, Configuring retroreflective markings to enhance the night-time conspicuity of road workers, *Accident Analysis & Prevention,* 70**,** 209-14.

Wood, J M, Tyrrell, R A and Carberry, T P. 2005, Limitations in drivers' ability to recognize pedestrians at night, *Human Factors,* 47**,** 644-653.

Wood, J M, Tyrrell, R A, Chaparro, A, Marszalek, R P, Carberry, T P and Chu, B S. 2012a, Even moderate visual impairments degrade drivers' ability to see pedestrians at night, *Investigative Ophthalmology & Visual Science,* 53**,** 2586-92.

Wood, J M, Tyrrell, R A, Marszalek, R, Lacherez, P and Carberry, T. 2013, Bicyclists overestimate their own night-time conspicuity and underestimate the benefits of retroreflective markers on the moveable joints, *Accident Analysis & Prevention,* 55**,** 48-53.

Wood, J M, Tyrrell, R A, Marszalek, R, Lacherez, P, Carberry, T and Chu, B S. 2012b, Using reflective clothing to enhance the conspicuity of bicyclists at night, *Accident Analysis & Prevention,* 45**,** 726-30.

Wood, J M, Tyrrell, R A, Marszalek, R, Lacherez, P, Chaparro, A and Britt, T W. 2011, Using biological motion to enhance the conspicuity of roadway workers, *Accident Analysis & Prevention,* 43**,** 1036-41.