The Conspicuity of Pedestrians at Night: Effects of Experimentally Induced Visual Impairments and Headlamp Glare

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Background

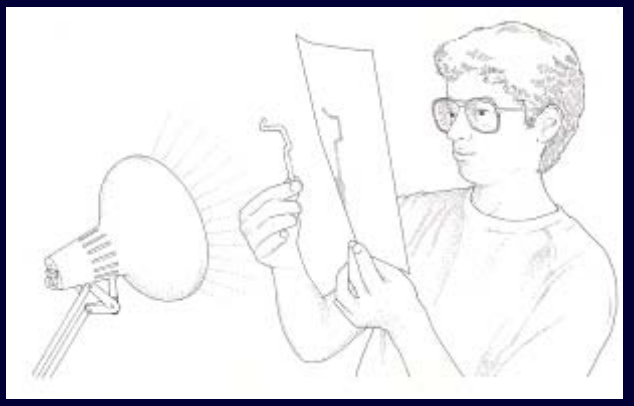
- Pedestrian fatalities are over-represented at night-time
  - Nearly 2/3 of all fatal pedestrian collisions occur at night (64%)
- Multiple factors contribute to the increased night-time fatality rate
  - Alcohol
  - Fatigue
  - Poor conspicuity - believed to be the leading cause of vehicle collisions with pedestrians, cyclists, and other low-contrast obstacles

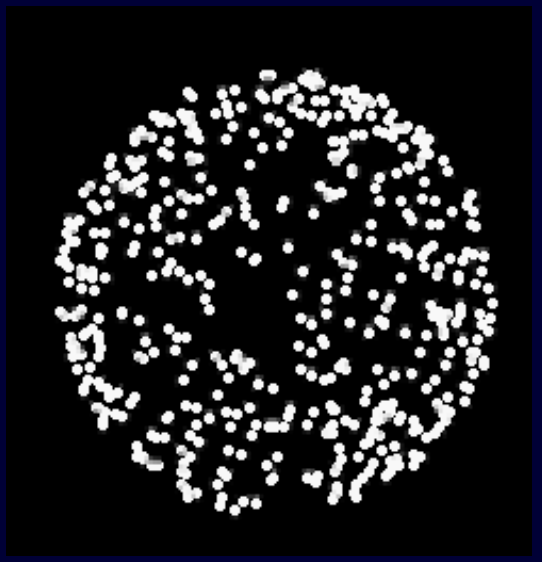
Background

- Most common clothing intervention adopted to improve pedestrian conspicuity at night is a reflective vest
- BUT studies have suggested that night-time pedestrian visibility can be better enhanced via strategic placement of reflective markers
- A particularly promising configuration: biological motion

Structure from Motion

- Biological motion is an example of Structure from Motion (SFM) - ability to derive impression of object's shape from motion (Wallach & O'Connell 1953)
  - Pipe cleaner bent into a meaningless 3 D shape
  - Light source is arranged so pipe cleaner casts shadow on paper
  - When pipe cleaner motionless shadow gives no idea of shape
  - BUT movement provides strong sense of 3 D shape

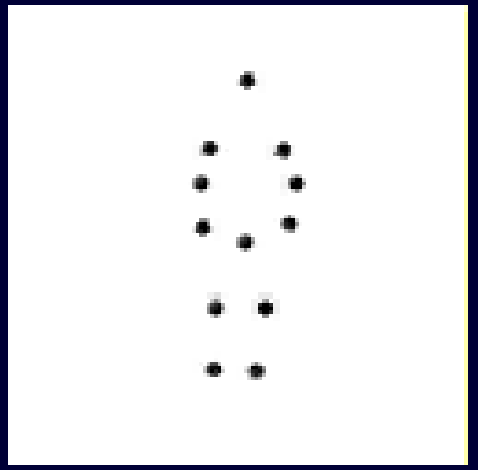




http://www.lifesci.sussex.ac.uk/home/George_Mather/Motion/

Biological Motion

- Biological motion is a class of SFM event
- Pattern of motion of living creatures is very different to that of inanimate objects



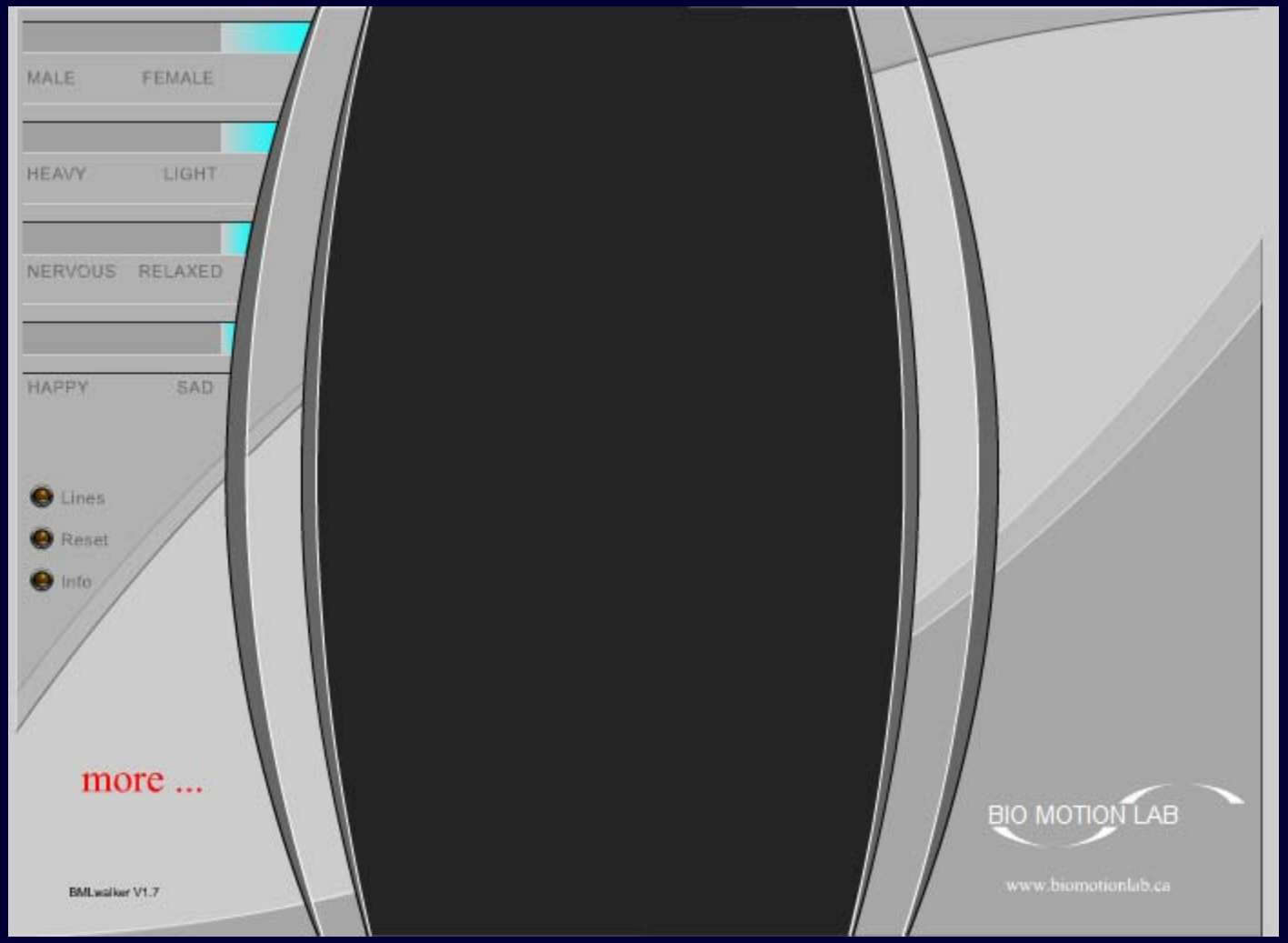
http://psych-s1.psy.vanderbilt.edu/faculty/blaker/BM/BioMot.html

Biological Motion

- Johansson (1973) first to systematically study phenomenon of biological motion
- Attached tiny light bulbs to actors hips, knees, ankles, shoulders, wrists and elbows
- Dressed in black in a completely darkened room
  - Stationary: random collection of spots
  - Moving: provides enough information to recognise human form

http://www.biomotionlab.ca/

Biological Motion



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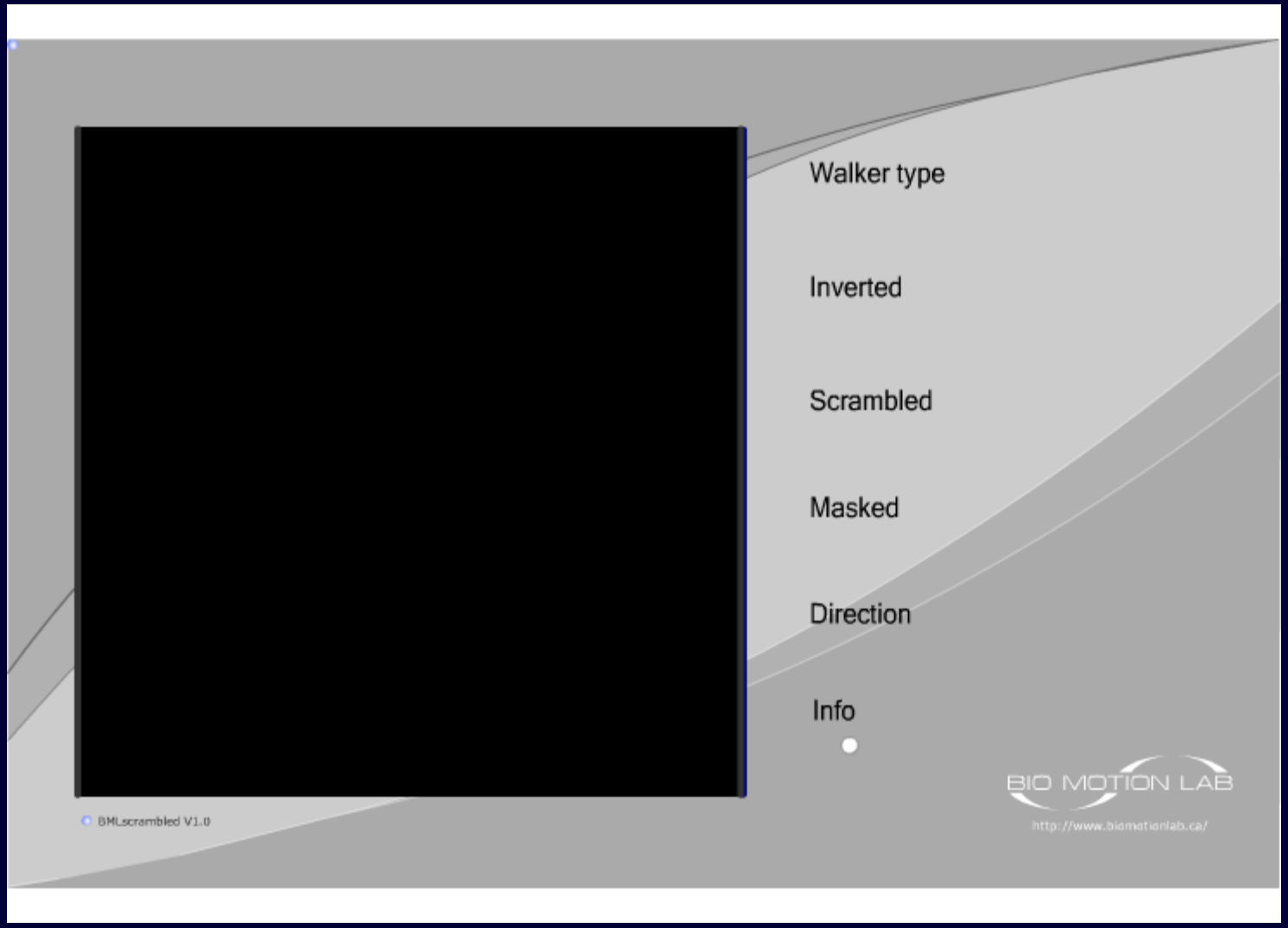
Biological Motion

- Permits you to recognise:
  - Actor's gender, weight and emotions (Kozlowski & Cutting 1977)
  - Identity of your friends (Cutting & Kozlowski 1977)
  - Weight of unseen objects lifted by the actor (Bingham et al 1993)
- Present in babies as young as 3 months (Pavlova et al. 2001)
- Biological motion effects relatively robust to the effects of ageing (Norman et al 2004)
  - Our life-long experiences of watching other people may ensure that as we age we retain good sensitivity to biological motion

Biological Motion

- Perception of human motion increases with the number of illuminated joints (Neri et al 1998)
- Can still recognise motion under impoverished conditions:
  - Dots are blurred (Mather et al 1992)
  - Embedded in random noise (Ahlstrom et al 1997)
  - Points on wrists and ankles are crucial for detecting direction of walking (Mather et al 1992)
  - BUT not when the figure is inverted (Troje et al 2006) or in the periphery (Ikeda et al 2005)
- Cats can do it too! (Blake 1993)

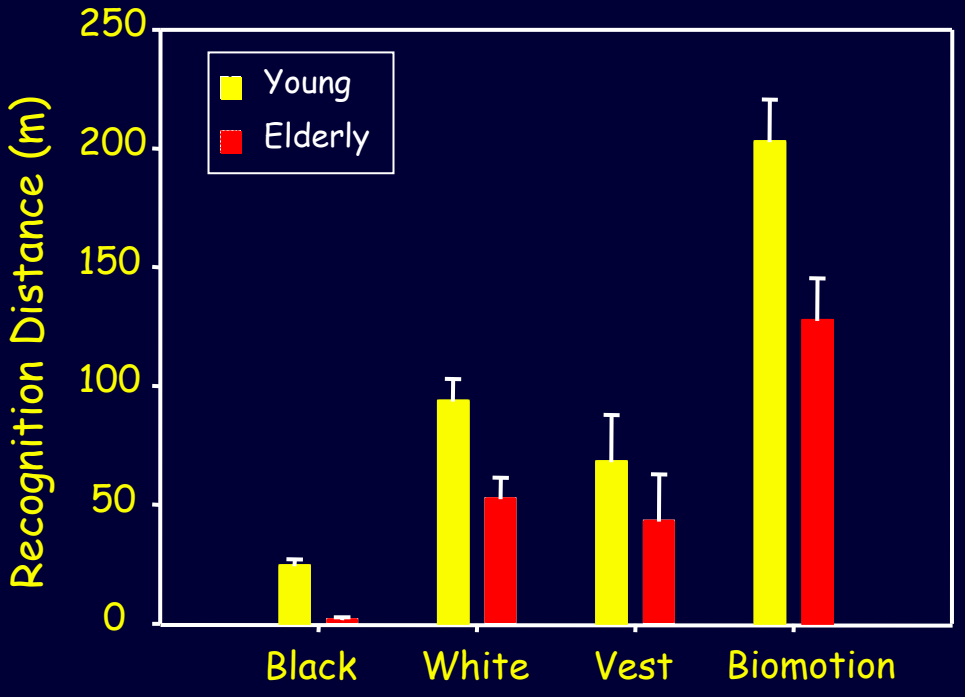
Biological Motion



http://www.biomotionlab.ca/

Application of Biological Motion

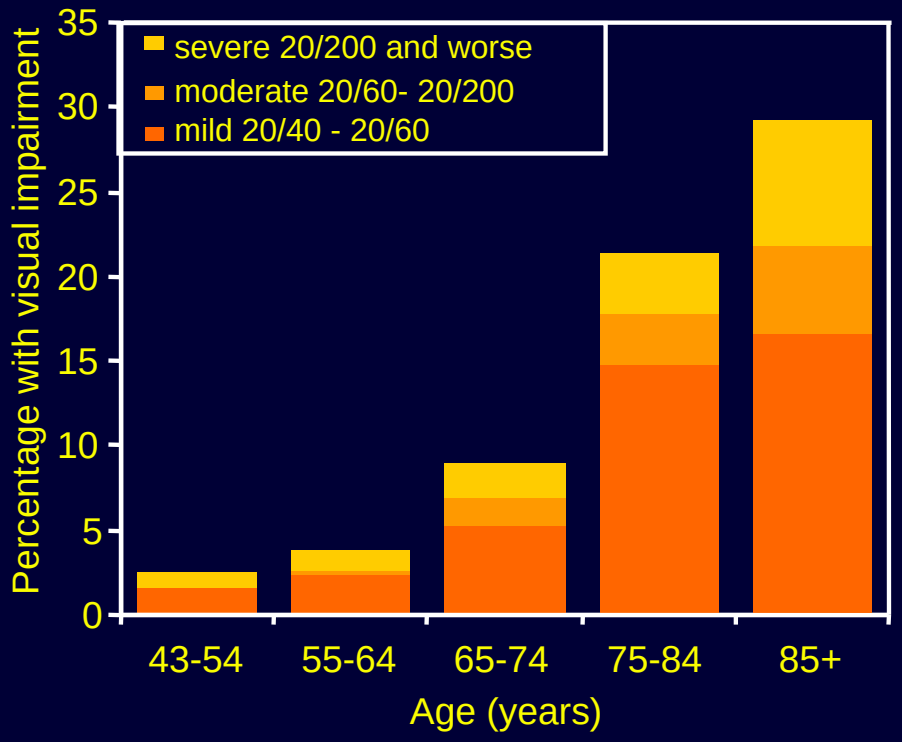
- Recent interest in applying perceptual phenomenon of biological motion to improving pedestrian visibility at night
  - Reflective strips attached to moveable joints illuminated in headlamp beam
  - Investigated using video-based representations of biomotion walkers, on closed and open road
  - Effects useful for both young and older drivers
  - Effects of visual impairment have not been explored



Wood et al HF 2005

Visual Impairment and Age

- Normal ageing:
  - Lens (lens opacities, increase in refractive errors, presbyopia)
  - Pupil (reduced retinal illumination)
  - Retinal/neural changes (slowing of visual processing)
- Eye disease
  - Most common eye diseases:
    - Cataracts
    - Glaucoma
    - Age-related Maculopathy



Attebo et al., 1996

Normal

Cataract

Glaucoma

Age-related Maculopathy

Aims

- To better understand how drivers' ability to recognise pedestrians at night is affected by visual impairment (blur and simulated cataracts) and in the presence or absence of headlamp glare

Main Causes of Visual Impairment

- Refractive blur and cataracts are two of the leading causes of visual impairment in developed countries

	No in group	% attributed to: Refractive error	AMD	Cataract	Glaucoma	Diabetes
Low vision (<6/18–3/60)						
75–79	312	46.5	18.0	23.7	5.1	2.9
80–84	360	41.7	26.7	25.3	8.1	2.5
85–89	349	32.7	33.5	32.3	7.5	2.0
90+	155	25.8	44.5	30.3	4.5	0.7
Blindness (<3/60)						
75–79	35	0	51.4	8.6	17.1	11.4
80–84	90	1.1	70.0	5.6	13.3	3.3
85–89	82	0	72.0	15.9	13.4	0
90+	43	0	88.4	9.3	14.0	0

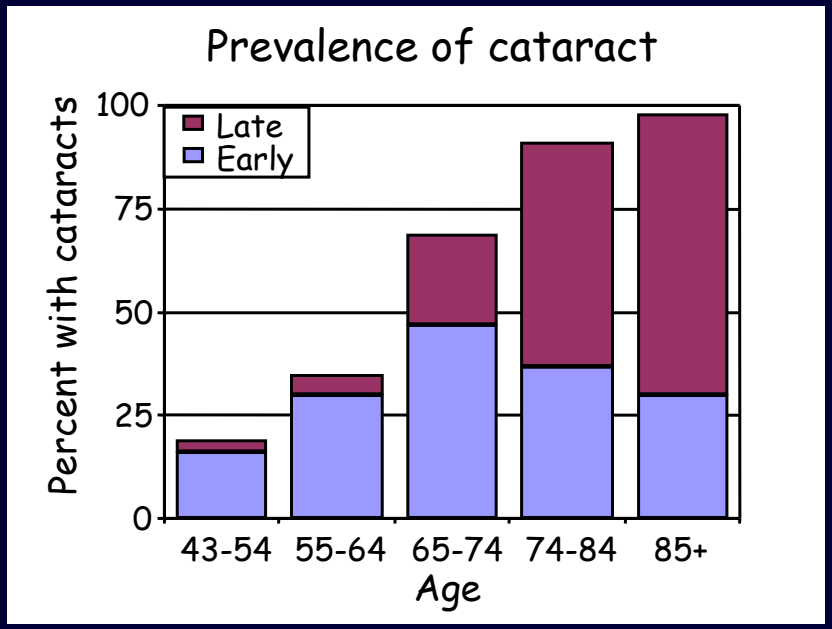
Evans et al 2004

Refractive Blur

- Refractive blur is a major cause of reversible visual impairment arising from:
  - Uncorrected refractive error (not wearing spectacles)
  - Wearing out of date spectacles

Cataract

- The eye lens becomes cloudy and opaque
- Most common cause of reversible visual impairment in older adults
  - In adults >75yrs, 50% have early cataract and ~25% have late cataract



Mitchell et al., 1997

Research Questions

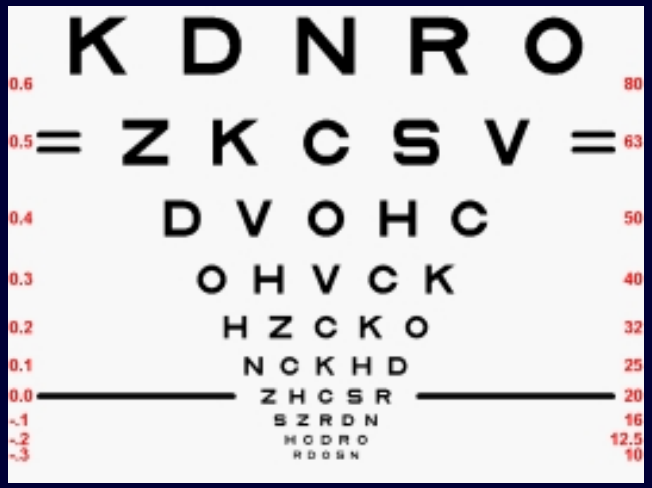
- How is pedestrian visibility affected by the visual status of drivers?
- Does headlamp glare exacerbate the effects of visual impairment on pedestrian visibility?
- Are clothing configurations which have been shown to improve pedestrian conspicuity robust to the effects of visual impairment?

Participants

- Twenty eight young visually normal participants
  - M=27.6 yrs ± 4.7 yrs; 20-36 yrs
  - 14 male, 14 female
  - 20/20 or better
- All licensed drivers
- Mild visual impairment was simulated using modified goggles:
  - Cataracts: frosted lenses
  - Blur: acuity matched to cataract condition
  - Normal: full distance refraction

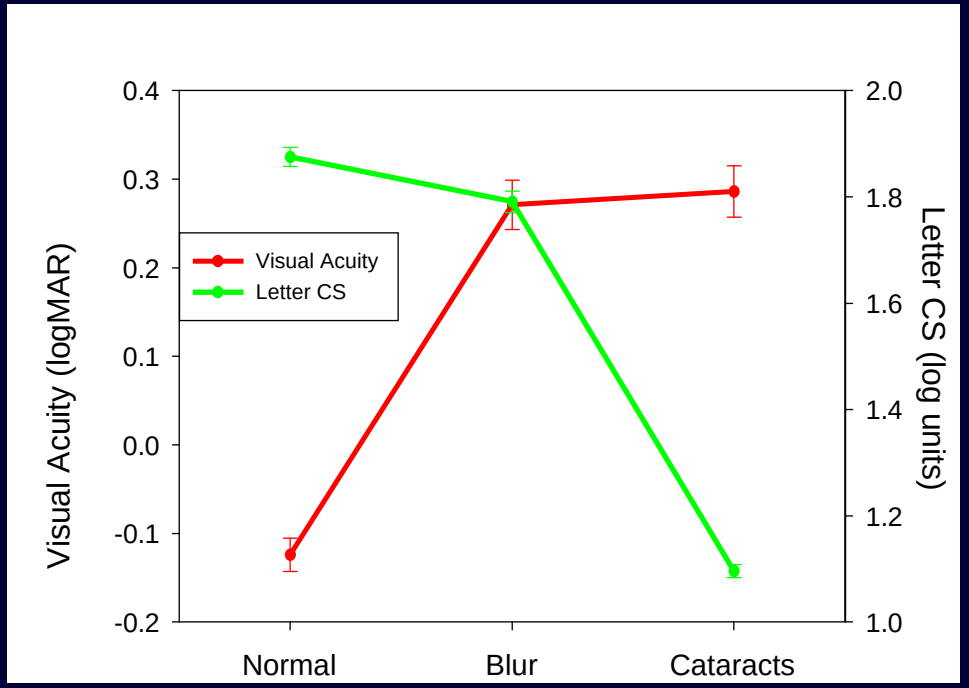
Vision Testing

- High contrast visual acuity and Pelli-Robson Letter CS measured under all 3 visual conditions



Vision Testing

- High contrast visual acuity and Pelli-Robson Letter CS measured under all 3 visual conditions
  - Cataracts and blur impaired acuity to 20/40
  - Mean lens power required to match acuity of cataract condition was +1.29D ± 0.31D



Methods

- 1.8 km closed road circuit
  - Glare lights to simulate oncoming vehicle headlamps
  - Clutter zones at various locations
  - Distracter cones

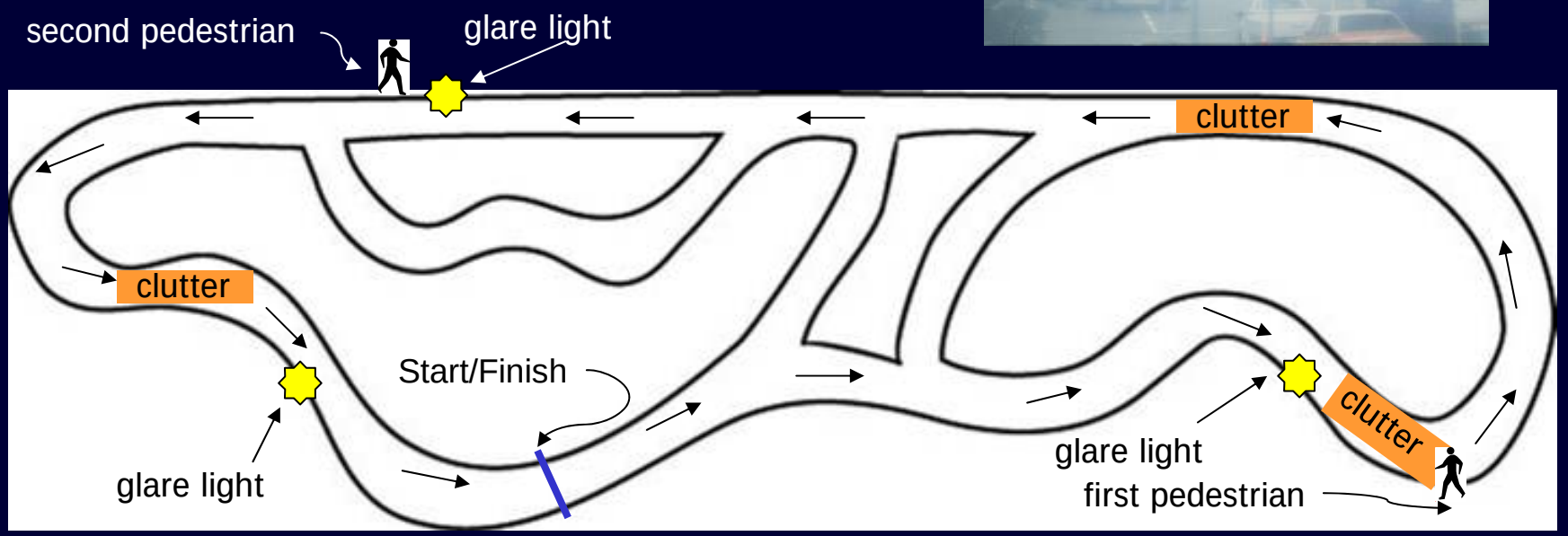
- Instrumented vehicle with twin digital video cameras mounted on roof rack

Measuring System

- Cameras linked to dash-mounted response pad
- Visibility distances derived off-line by interpreting parallax between the two images

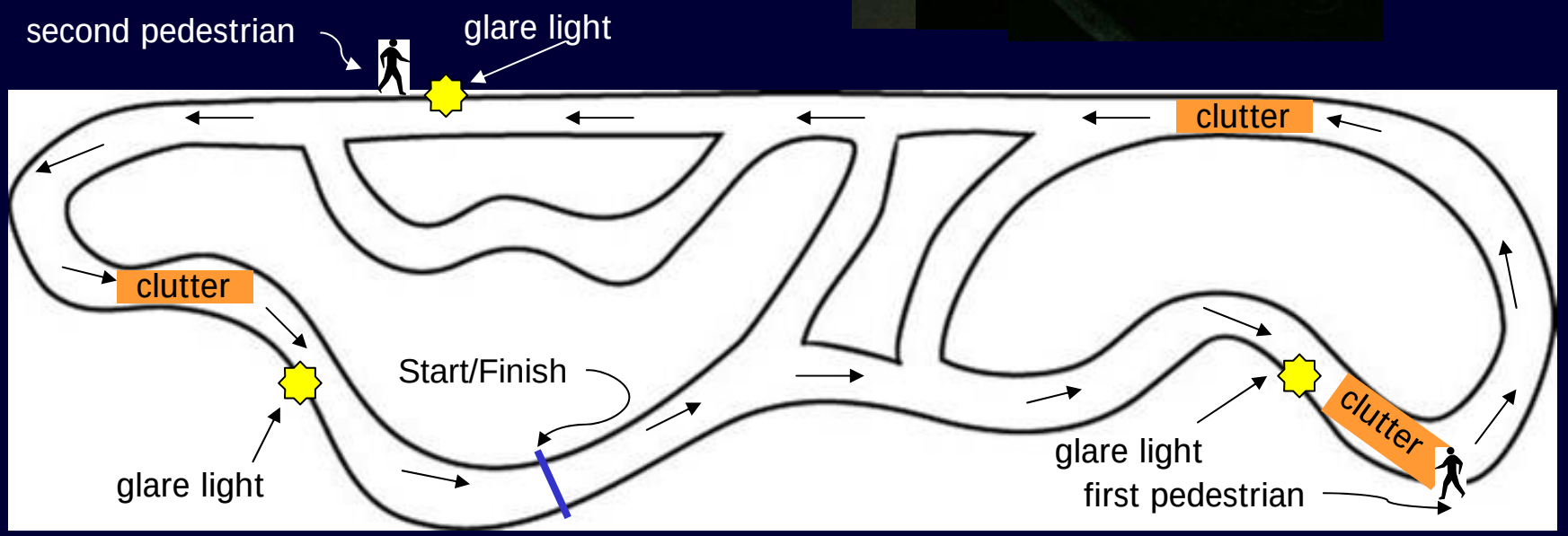
Experimental Design

- 3 visual conditions:
  - Normal
  - Blur
  - Cataracts



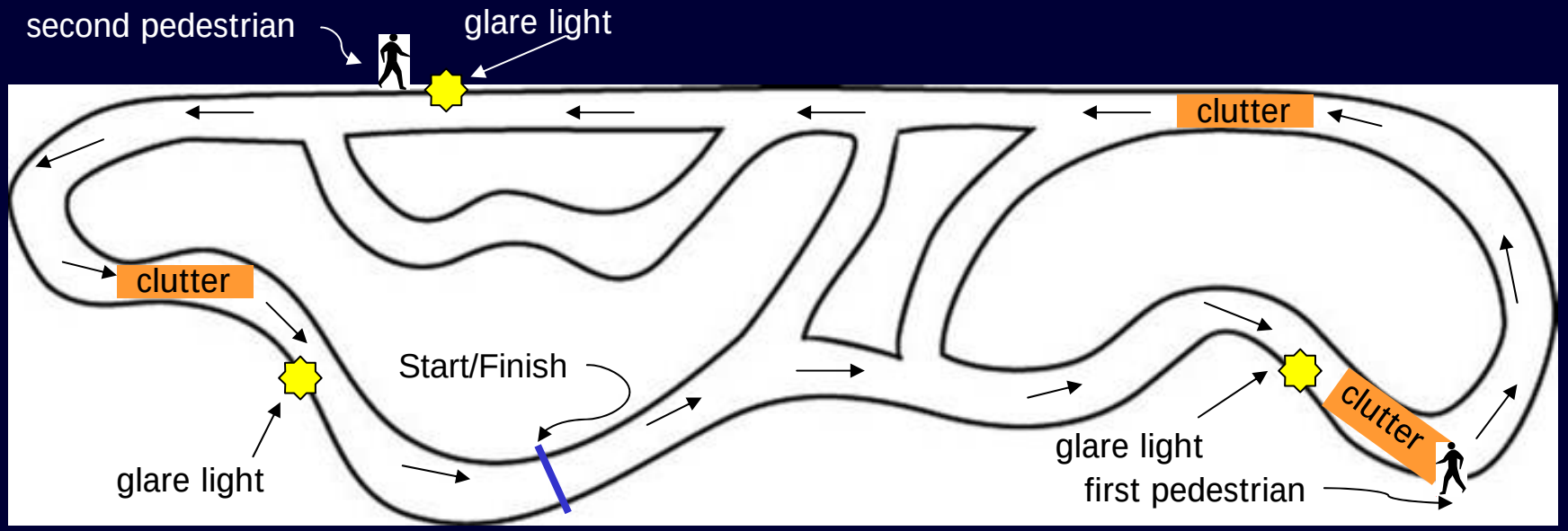
Experimental Design

- 3 clothing manipulations
  - Black, Vest, Biomotion
  - Equal area of reflective material in vest and biomotion

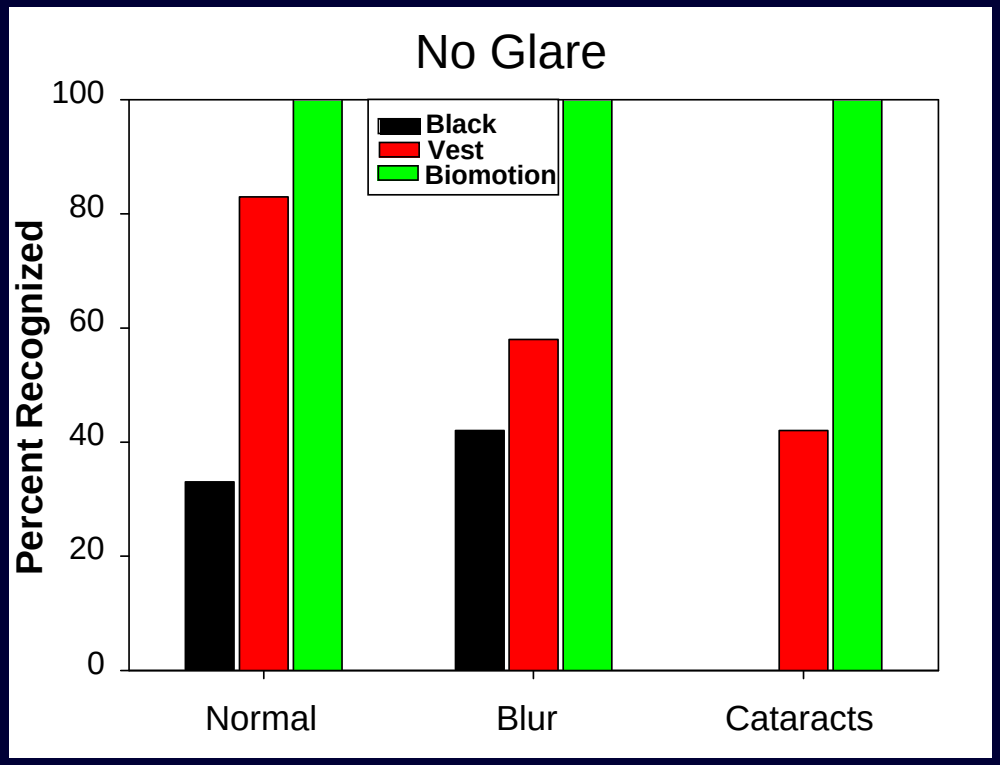


Experimental Design

- Within subjects: visual status (3), pedestrian clothing (3)
- Between subjects: presence (n=16) or absence (n=12) of glare
- Total laps: 9 clothing x vision combinations (in a random order) plus a trial where no pedestrian was present
- Total of >500 opportunities for a driver to see a pedestrian



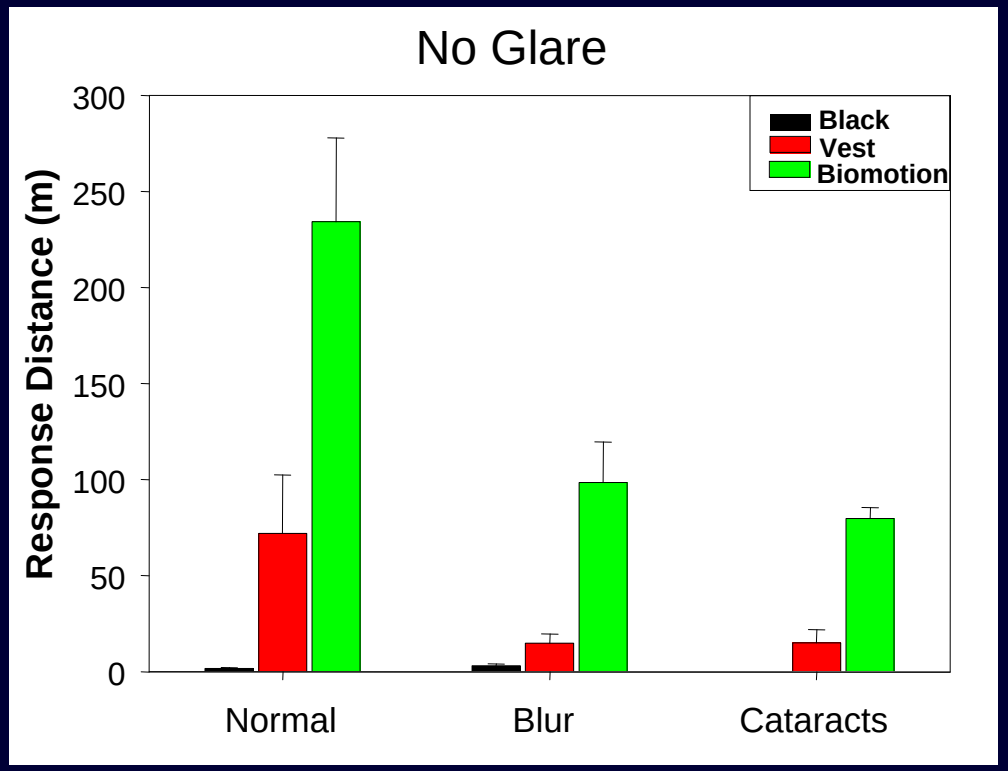
Results: Vision & Clothing



% seen

- In absence of glare:
  - Normal vision: Pedestrians wearing black seen on only 33% of trials
  - Blur: 42% seen
  - Cataracts: NEVER seen!
- Pedestrians wearing biomotion were seen on 100% of trials for all 3 visual conditions

Results: Vision & Clothing

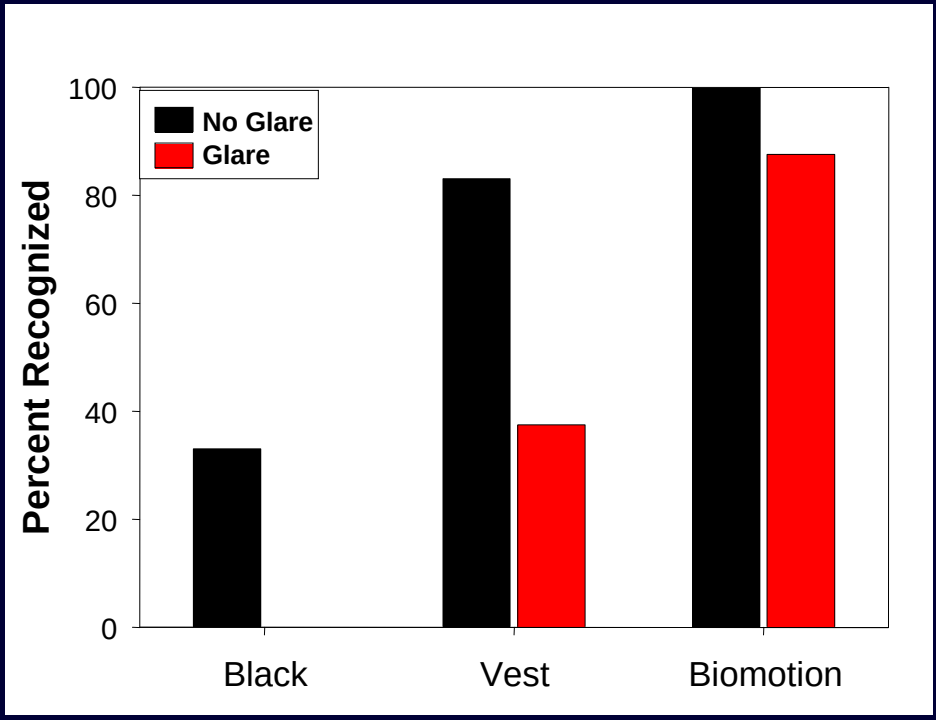


Response distance

- In absence of glare:
  - Black clothing: 0.0 to 3.1 m
  - Vest: 15 to 72 m
  - Biomotion: 80 to 234 m
- And:
  - Normal vision: 1.7 to 234 m
  - Blur: 3.0 to 99 m
  - Cataracts: 0.0 to 80 m

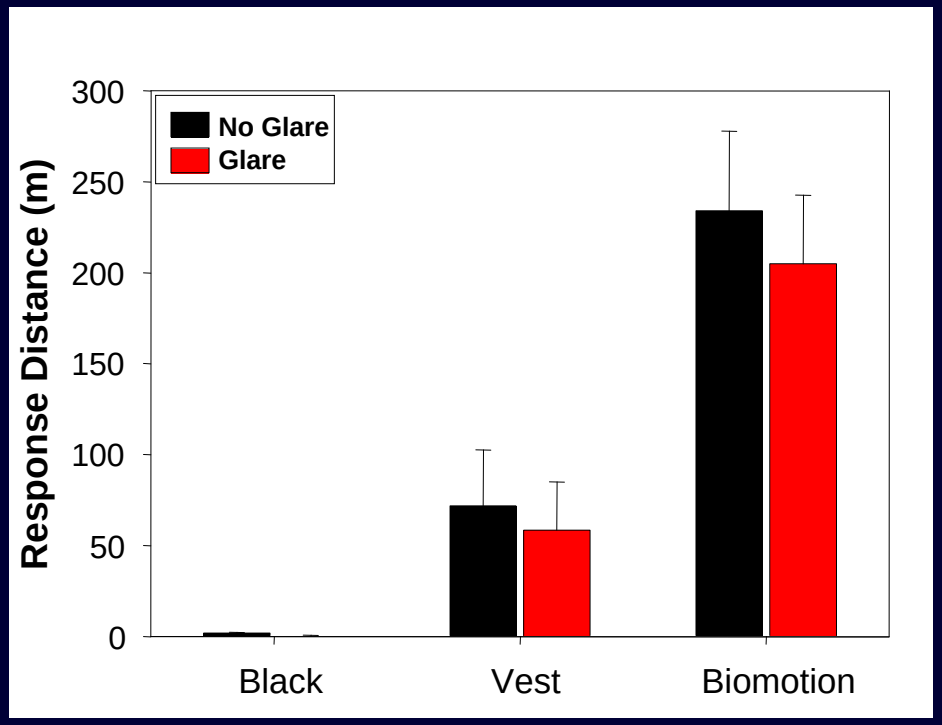
- Biomotion consistently maximizes conspicuity
- Recall that surface area of reflective material was constant

Results: Glare



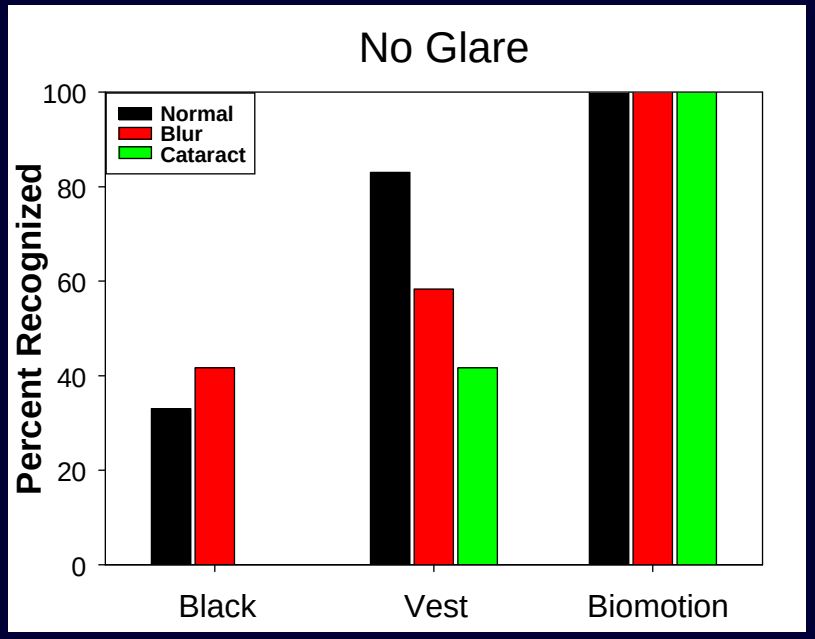
- For drivers with normal vision
  - Glare significantly degrades conspicuity
  - With glare, pedestrians wearing black were never seen; biomotion seen 83% of trials

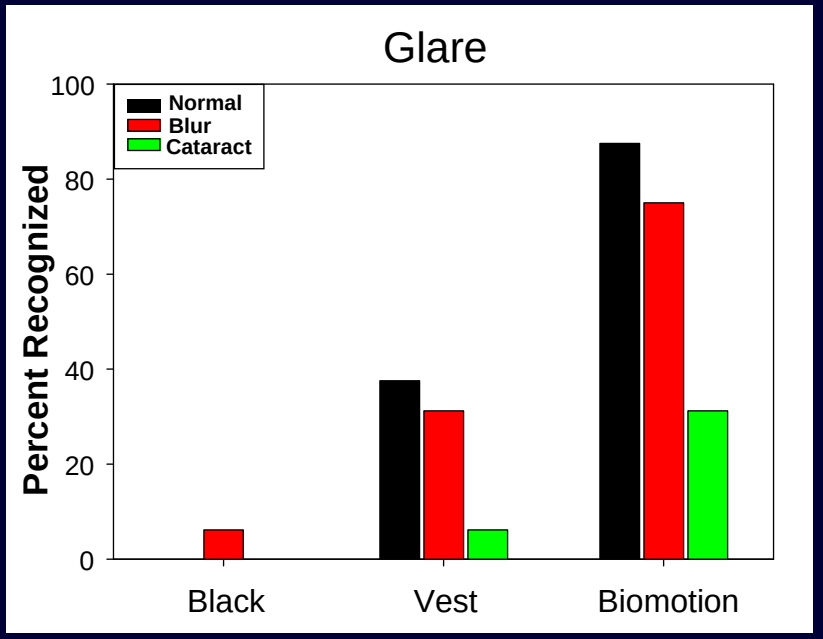
Results: Glare



- For drivers with normal vision
  - Glare significantly degrades conspicuity
  - With glare, pedestrians wearing black were never seen; biomotion seen 83% of trials
  - With glare, response distances range from 0.0 m (black) to 204 m (biomotion)
  - Biomotion maximizes conspicuity even in glare

Interaction Between Glare And Vision





- With glare:
  - Pedestrians wearing black or a vest are usually not seen, particularly if the driver has cataracts
  - Biomotion + blur: seen on 75% of trials (mean response distance of 61 m)
  - Biomotion + cataracts: seen on only 31% of trials (mean of 6 m)
- The combination of cataracts and glare has a devastating impact on pedestrian visibility

Discussion

- Common visual impairments had a significant effect on pedestrian visibility
  - Even when acuity is better than driver licensing standards
  - Cataracts had the greatest detrimental effect on pedestrian conspicuity even though acuity was equal for the blur and cataract conditions
- In the absence of glare, biomotion configuration is relatively robust to the effects of visual impairment
  - Drivers with cataracts failed to recognise pedestrians wearing black, but always recognised a pedestrian wearing biomotion
  - In all conditions, biomotion maximizes conspicuity

Discussion

- Pedestrian visibility is reduced in the presence of oncoming glare
  - With glare present pedestrians wearing black were rarely seen
  - For drivers with unimpaired vision, only biomotion is robust to the effects of glare
- The effects of glare exacerbate the effects of visual impairment of drivers
  - The combination of cataracts and glare has a devastating impact on pedestrian visibility
  - Not even biomotion can ensure pedestrians' safety when a driver with cataracts is facing a glare source

Conclusions

- Even mild visual impairment reduces pedestrian visibility, particularly when it results from cataracts rather than refractive blur
- Licensure standards that require visual acuity of 20/40 do not ensure adequate visual capacity at night
- Biomotion configurations consistently maximize pedestrian conspicuity

Acknowledgments

- All of our participants
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