Interventions for increasing pedestrian and cyclist visibility for the prevention of death and injuries (Review)

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[**Intervention Review**]

Interventions for increasing pedestrian and cyclist visibility for the prevention of death and injuries

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ABSTRACT

Background

Pedestrians and cyclists account for nearly one in three of all road users killed and seriously injured in road traffic crashes. Late detection of other road users is one of the basic driver failures responsible for collisions. Aids to improve pedestrians and cyclist visibility have been used to avert potential collisions. However, the impact of these strategies on drivers' responses, and on pedestrian and cyclist safety is unknown.

Objectives

1. To quantify the effect of visibility aids versus no visibility aids, and of different visibility aids on the occurrence of pedestrian and cyclist-motor vehicle collisions and injuries.

2. To quantify the effect of visibility aids versus no visibility aids, and of different visibility aids on drivers' detection and recognition responses.

Search strategy

Searches were not restricted by date, language or publication status. All electronic databases were searched from date of inception to the most recent date available. We searched CENTRAL (*The Cochrane Library* 2009, Issue 2), MEDLINE (Ovid SP), TRANSPORT (to 2007/06), PsycINFO (Ovid SP), PsycEXTRA (Ovid SP), ISI Web of Science: Social Sciences Citation Index (SSCI) and ISI Web of Science: Conference Proceedings Citation Index- Science (CPCI-S). We searched the reference lists of included trials, contacted authors and searched the websites of relevant transport research organisations. The searches were last updated in May 2009.

Selection criteria

1. Randomised controlled trials and controlled before-and-after studies of the effect of visibility aids on the occurrence of pedestrian and cyclist-motor collisions and injuries.

2. Randomised controlled trials of the effect of visibility aids on drivers' detection and recognition responses. This included trials where the order of presentation of visibility aids was randomised or balanced using a Latin Square design.

Data collection and analysis

Two authors independently screened records, extracted data and assessed trial quality.

Main results

We found no trials assessing the effect of visibility aids on pedestrian and cyclist-motor vehicle collisions and injuries. To date we have identified 42 trials assessing the effect of visibility aids on drivers' responses. Fluorescent materials in yellow, red and orange colours improve detection and recognition in the daytime. For night-time visibility, lamps, flashing lights and retroreflective materials in red and yellow colours increase detection and recognition. Retroreflective materials enhance recognition, in particular when arranged in a 'biomotion' configuration, taking advantage of the motion from a pedestrian's limbs. Substantial heterogeneity between and within the trials limited the possibility for meta-analysis. Summary statistics and descriptive summaries of the outcomes were presented for individual trials when appropriate.

Authors' conclusions

Visibility aids have the potential to increase visibility and enable drivers to detect pedestrians and cyclists earlier. Biomotion markings, which highlight the movement and form of the pedestrian, showed evidence of improving pedestrians' conspicuity at night. Public acceptability of various effective strategies which improve visibility would merit further development. However, the effect of visibility aids on pedestrian and cyclist safety remains unknown. A cluster randomised controlled trial involving large communities may provide an answer to this question. It would, however, be a challenging trial to conduct. Studies that collect data of road traffic injuries relating to the use of visibility aids also warrant consideration.

PLAIN LANGUAGE SUMMARY

Increasing pedestrian and cyclist visibility to prevent deaths and injuries

Pedestrians and cyclists are often killed or seriously injured in traffic crashes, especially in developing countries where walking and bicycling are essential modes of transportation. In the UK, one in three road traffic fatalities is a pedestrian or cyclist. Usually, in these crashes drivers fail to see the pedestrian or cyclist until it is too late. In recent years reflective garments, flashing lights, and other visibility aids have been used to try to prevent crashes.

The authors of this Cochrane review looked for studies which showed how effective visibility aids are for protecting pedestrians and cyclists. They focused their search on a type of study called a randomised controlled trial, which compares two similar groups of people who only differ on the issue being studied, for instance, the rate of crashes in communities with and without introduction of visibility aids. The authors found no studies that compared number of crashes but to date they have found 42 studies which compare driver detection of people with or without visibility aids. These studies showed that fluorescent materials in yellow, red and orange improved driver detection during the day; while lamps, flashing lights and retroreflective materials in red and yellow, particularly those with a 'biomotion' configuration (taking advantage of the motion from a pedestrian's limbs), improved pedestrian recognition at night. Although these visibility measures help drivers see pedestrians and cyclists, more research should be done to determine whether the increased visibility actually does prevent deaths and serious injuries.

BACKGROUND

Road traffic crashes account for over a million deaths and some ten million permanent disabilities a year worldwide (Murray 1996). Nearly three-quarters of road deaths occur in low and middle-income countries (Odero 1997), predominantly as a result of bicycle and pedestrian injuries. In Ethiopia, pedestrian and bicyclist injuries account for 85% of all road traffic fatalities compared with 37% in the UK and 17% in the USA (Barss 1998). In 2008, there were 28,482 pedestrian and 16,297 bicyclist casualties in the UK (Department of Transport 2008).

One of the basic driver errors responsible for collisions is the late detection of other road users (Rumar 1990). Pedestrian casualties are over-represented at night, partly due to reduced visibility (Owens 1993). Over 60% of all pedestrian fatalities occur between the hours of 8pm and 4am, and more than half of all pedestrian deaths and injuries occur when pedestrians cross or enter streets (National Safety 1994). Night-time cycling is two to five times more dangerous than cycling in daylight. Forty per cent of cyclist fatalities occur during the hours of darkness (Jaermark 1991) with a high proportion related to frontal rather than rear conspicuity (Gale 1998).

Walking and cycling are essential modes of travel for many people in low and middle-income countries, and are also promoted for their environmental, economic and health benefit. The Highway Code states that pedestrians and cyclists should wear or carry materials to improve their visibility to drivers in poor daylight conditions and at night (Department of Transport 2009). Visibility aids such as bright coloured clothing, lights and reflectors enhance the conspicuity of the pedestrians and cyclists, thus attracting the driver's attention to their presence. Reflective garments are also widely used by construction workers, firefighters, police and emergency medical workers at accident scenes for high visibility and safety.

Many factors affect conspicuity, including object contrast, size, movement, illumination, background 'clutter' and road condition, also the cognitive process of the drivers' responses in detection and recognition. The efficiency of visibility aids depends on whether they can visually alert the drivers in time to avoid a collision. Longer times and distances before impact indicate earlier detection, which may allow hazard recognition and evasion. To assess the effect of visibility aids on occurrence of pedestrian and cyclist-motor vehicle collisions and injuries, and on drivers' responses in detection and recognition, we conducted a systematic review for randomised controlled trials of visibility aids.

OBJECTIVES

Primary

1. To quantify the effect of visibility aids versus no visibility aids on the occurrence of pedestrian and cyclist-motor vehicle collisions and injuries

2. To quantify the effect of different visibility aids on the occurrence of pedestrian and cyclist-motor vehicle collisions and injuries

Secondary

1. To quantify the effect of visibility aids versus no visibility aids on drivers' responses in detection and recognition

2. To quantify the effect of different visibility aids on drivers' responses in detection and recognition

METHODS

Criteria for considering studies for this review

Types of studies

For primary objectives

- Randomised controlled trials
- Controlled before-and-after trials

For secondary objectives

- Randomised controlled trials

This included studies in which the participants are randomised to the intervention (one or more visibility aids) or control (no visibility aid) group; or when more than one visibility aid is compared, the order of the presentation of visibility aids is randomised, or balanced (that is, each aid is presented only once to each observer using a Latin Square design) or counter-balanced (that is, not all subjects see them in the same order).

Types of participants

For primary objectives

- Pedestrians and cyclists

For secondary objectives

- Drivers and participants in field (on-road) and laboratory (off-road) experiments 'acting' as drivers
- Observers inside a vehicle (for example, front/back seat passengers)
- Observers of slides or video simulation of a car journey or driving scene

We excluded motorcyclists and riders of mopeds and other motorised vehicles.

Types of interventions

Comparisons of all types of day-time and night-time visibility aids as used on bicycles and by pedestrians/cyclists, or by simulated pedestrians/cyclists presented as targets;

- Any visibility aid versus no visibility aid
- Different visibility aids, such as active versus passive visibility aids
- Positioning of visibility aids, such as 'biomotion' versus no 'biomotion' marking.

Visibility aids for pedestrians, cyclists and bicycles include;

- Active conspicuity materials such as lights, flashing or non-flashing lamps, light emitting diode, helmet lights and coloured lights
- Passive conspicuity materials such as bright colours and reflective materials, coloured garments and accessories, coloured bicycles and reflectors such as fluorescent and retroreflective vests, strips, tags, rings, bands, 'biological motion' clothing and shoe reflectors.

We did not consider studies investigating visibility of street lighting, traffic signals, road signage, street furniture, road and pavement markings in this review.

Types of outcome measures

Primary outcomes

- Pedestrian and cyclist-motor vehicle collisions and injuries (fatal and non-fatal)

Secondary outcomes

Drivers' responses in detection and recognition as operationally defined by trialists, for example:

- reaction times - time taken from when object presented to its detection;
- detection times - time taken when object detected to when object reached;
- recognition times - time taken when object recognised as a pedestrian/cycle/cyclist to when object reached;
- detection distances - distance from when object detected to when object reached;
- recognition distances - distance from when object recognised as a pedestrian/cycle/cyclist to when object reached;
- frequency of successful object detection and recognition.

Search methods for identification of studies

The searches were not restricted by date, language or publication status.

Electronic searches

We searched the following electronic databases:

- Cochrane Injuries Group Specialised Register (to May 2009)
- CENTRAL (*The Cochrane Library* 2009, Issue 2)
- MEDLINE (Ovid SP) 1950 to May (week 3) 2009
- PubMed [www.ncbi.nlm.nih.gov/sites/entrez/] (searched 18 May 2009 for records added to PubMed in the last 180 days)
- TRANSPORT (1988 to 2007/06)
- PsycINFO (Ovid SP) 1806 to May (week 3) 2009
- PsycEXTRA (Ovid SP) 1908 to May 18, 2009
- ISI Web of Science: Social Sciences Citation Index (SSCI) 1970 to May 2009
- ISI Web of Science: Conference Proceedings Citation Index- Science (CPCI-S) 1990 to May 2009
- National Research Register (Issue 1, 2005)

Detailed search strategies can be found in Appendix 1.

Searching other resources

We searched known websites of transport and traffic research organisations worldwide including;
http://www.astm.org (American Society for Testing & Materials, USA)
http://www.cpsc.gov (Consumer Product Safety Commission, USA)
http://www.fhwa.dot.gov (Federal Highway Administration, USA)
http://www.nhtsa.dot.gov (National Highway Traffic Safety Administration, USA)
http://www.trb.org (Transport Research Board, USA)
http://www.bsi-global.com (British Standards Institution, UK)
http://www.itai.org (Institute of Traffic Accident Investigators, UK)
http://www.rospa.org (Royal Society for the Prevention of Accidents, UK)
http://www.trl.co.uk (Transport Research Laboratory, UK)
http://www.arrb.org.au (Australian Road Research Board, Australia)
http://www.nrtc.gov.au (National Road Transport Commission, Australia)
http://www.standards.com.au (Standards, Australia)
http://www.crt.umontreal.ca (Centre de Recherche sur le Transports, Canada)
http://www.swov.nl (Institute for Road Safety Research, Netherlands)
http://www.csir.co.za (Council for Scientific & Industrial Research, South Africa)
http://www.sabs.co.za (South African Bureau of Standards, South Africa)
We contacted manufacturers of retroreflective and fluorescent materials (for example, Reflexite, 3M Corp) and the British Standards Institution (BSI) for test trials and standard guide to bicycle lighting and high visibility garment specification. We also searched the reference lists of included trials and contacted authors about unpublished studies.

Data collection and analysis

Selection of studies

The search identified 1172 potentially relevant records. We independently examined titles, abstracts, and keywords of citations from electronic databases for eligibility. We obtained the full text of all relevant records and independently assessed whether each met the pre-defined inclusion criteria. No trials met the inclusion criteria for the primary objectives but 35 papers reporting 42 trials (two were unpublished) met the inclusion criteria for the secondary objectives.

Data extraction and management

We independently extracted data from each included study on the following:

- study design;
- number of participants in each group;
- characteristics of the participants;
- characteristics of the intervention;
- outcomes.

Differences in data extraction were resolved by discussion. The review authors were not blinded to the study authors or journal when extracting data.

Assessment of risk of bias in included studies

To assess trial quality, we independently extracted information, according to Higgins 2008, on:

- method of randomisation;
- allocation concealment;
- blinding of outcomes assessment;
- loss to follow up.

Where there was insufficient information in the published report we contacted the authors for clarification.

Data synthesis

Interventions were classified and analysed under broad categories/strategies to increase visibility. For example, all fluorescent coloured materials were combined for comparison with all non-fluorescent coloured materials. The visibility treatments examined in these 42 trials were so diverse that it was not possible for the results to be combined. When data details were insufficient, a descriptive summary of the outcomes of each trial was presented. In the few trials in which data details were available, summary statistics are presented.

R E S U L T S

Description of studies

See: Characteristics of included studies; Characteristics of excluded studies.

Our search strategy did not identify any papers which met the inclusion criteria for the primary objectives. However, we identified 35 papers reporting 42 trials (two unpublished) which met the inclusion criteria for the secondary objectives; involving 1171 participants aged from 17 to 77 years. There were six laboratory-based and 36 road-based simulation trials, the largest and smallest trial involved 120 and four observers respectively. Twenty-three trials were conducted in the USA, five in the UK, four in Australia, three in the Netherlands, two in South Africa, two in Israel, one in Canada, one in Sweden and one in Finland.

Daytime visibility aids

There were 13 trials which compared the effectiveness of daytime visibility aids; five on pedestrians, two on cyclists/bicycles and six on materials/targets:

Pedestrians

Owens 2007

This trial involved 24 observers who compared the effect of retroreflective markings on torso and 'biomotion' markings (on pedestrians) on recognition frequency.

Turner 1997

This trial involved 23 observers who compared the effect of fluorescent and non-fluorescent coloured vests on detection distances.

Michon 1969a

This trial involved six colour normal and four colour-deficient observers in a laboratory setting who compared the effect of fluorescent and non-fluorescent coloured jacket models, viewed while carrying out an additional distraction task. This trial was reported in the same article as Michon 1969b and Michon 1969c.

Michon 1969b

This trial involved 16 observers in an on-road situation who compared the effect of fluorescent and non-fluorescent coloured jacket models of four style designs viewed under 16 various backgrounds of trees, heather, sky and road. This trial was reported in the same article as Michon 1969a and Michon 1969c.

Michon 1969c

This trial involved 12 observers in an on-road situation who compared the effect of fluorescent and non-fluorescent coloured jacket models of three style designs viewed under 16 various backgrounds of trees, heather, sky and road. The outcomes measured in these three trials were reaction times. This trial was reported in the same article as Michon 1969a and Michon 1969b.

Bicycles/bicyclists

Watts 1980

This trial involved 16 observers who compared the effect of fluorescent and non-fluorescent coloured treatments to bicycles and cyclists on detection distances. These treatments were viewed under a dark and a light background.

Watts 1984a

This trial involved 18 observers who compared the effect of fluorescent and non-fluorescent coloured treatments to cyclists on detection distances.

Targets and materials

Cole 1984

This trial involved 50 observers randomised into two groups. One group was instructed to report all objects attracting their attention, the other group to report all target discs seen. Comparison was made on frequency of detection of discs of different sizes in white and black colours.

Hughes 1986a

The trial involved 50 observers randomised into two groups. One group was instructed to report all objects attracting their attention, the other group to report all target discs seen, from slide photos projected for 1500 milliseconds. Comparison was made on frequency of detection of discs of different sizes in white and black colours. This trial was report in the same article as Hughes 1986b.

Hughes 1986b

This trial involved 50 observers randomised into two groups. One group was instructed to report all objects attracting their attention, the other group to report all target discs seen, from slide photos projected for 250 milliseconds. Comparison was made on frequency of detection of discs of different sizes in white and black colours. This trial was report in the same article as Hughes 1986a.

Hanson 1963

This trial involved 19 observers who compared the effect of fluorescent and non-fluorescent coloured targets viewed against four backgrounds, facing four directions and under two sky conditions. The outcomes measured were detection and recognition distances.

Zwahlen 1994

This trial involved 12 observers who compared the effect of fluorescent and non-fluorescent coloured targets presented at three peripheral angles against three non-uniform background colours. The outcomes measured were detection and recognition frequency.

Zwahlen 1997

This trial involved 18 observers who compared the effect of fluorescent and non-fluorescent coloured targets of different sizes, viewed in different peripheral angles. The outcomes measured were detection and recognition frequency.

Night-time visibility aids

There were 29 trials (one trial assessed both pedestrian and bicycle/cyclist visibility aids - Blomberg 1986) which compared the effectiveness of night-time visibility aids, 15 on pedestrians, ten on bicycles/cyclists and four on materials/targets:

Pedestrians

Allen 1970

This trial involved six observers who compared the effect of retroreflective and black or white jackets viewed with headlight glare and no glare against a light and a dark background. The outcome measured was visibility (detection) distance.

Balk 2008

This trial reported data from 120 participants who made 1 and 2 observations each.

This trial involved 120 observers who compared the effect of the positioning of retroreflectors on major joints (biomotion) versus no biomotion in pedestrians standing still or walking, on an unilluminated sidewalk, viewed by passengers in a car journey. The outcome measured was response (recognition) distance.

Blomberg 1986

This trial involved 36 observers (this study investigated visibility aids for both bicycle/cyclists and pedestrians, see below) and compared the effect of retroreflective accessories, flash light and a white T-shirt. The same observers also compared cyclist/bicycle visibility aids as described in the next section. The outcomes measured were detection distance and frequency of recognition.

Luoma 1996

This trial involved 32 observers who compared the effect of retroreflectors versus no retroreflectors, and also the positioning of retroreflectors on major joints (biomotion) versus no biomotion, viewed approaching the motorist and crossing the road. The outcome measured was recognition distance.

Luoma 1998

This trial involved 16 observers, who compared the effect of retroreflectors versus no retroreflectors, and also the positioning of retroreflectors on major joints (biomotion) versus no biomotion, viewed approaching the motorist and crossing the road. The outcome measured was recognition distance.

Moberly 2001

This trial involved 65 observers who compared the effect of the positioning of retroreflectors on major joints (biomotion) versus no biomotion on stationary or moving pedestrians, viewed from a video film of a car journey. The outcome measured was detection distance.

Muttart 2000

This trial involved 34 observers who compared the effect of retroreflectors versus no retroreflectors, and the effect of different retroreflective colours, viewed in a 'noisy' environment. The outcome measured was recognition time.

Owens 1994a

This trial involved 32 observers who compared the effect of retroreflectors versus no retroreflectors, also the positioning of retroreflectors on major joints (biomotion) versus no biomotion, viewed from a video film of a car journey in four road environments. The outcome measured was detection time. This trial was reported in the same article as Owens 1994b.

Owens 1994b

This trial was the same as Owens 1994a but involved 20 observers who were given additional distraction tasks. This trial was reported in the same article as Owens 1994a.

Owens 2007

This trial involved 24 observers who compared the effect of retroreflective markings on torso versus retroreflectors on major joints (biomotion) in pedestrians walking towards the vehicle, viewed with bright to dim headlights. The outcome measured was recognition frequency.

Sayer 1998

This trial involved 16 observers who compared the effect of different retroreflective coloured stripes, viewed walking towards and away from the vehicle. The outcome measured was detection distance.

Sayer 1999

Same as Sayer 1998 but involving 20 observers, 10 of whom were colour normal and 10 colour-deficient.

Sayer 2004

This trial involved 10 observers who compared the effect of the different positioning of retroreflectors in garments versus dark apparel, and different retroreflective colours versus dark apparel in pedestrians walking, viewed by the motorists through simulated work zones. The outcome measured was detection distance.

Schnell 2001

This trial involved 15 observers and compared the effect of dark cloth and light cloth on 'mock' pedestrians under lowbeam illumination and headlamp cover illumination, respectively.

Shinar 1985

This trial involved 19 observers and compared the effect of dark clothing with a retroreflective tag and no retroreflective tag viewed in high beam, low beam and in glare conditions. The outcome measured was detection distance.

Shinar 1985

This trial involved 40 observers and compared the effect of dark and light clothing, the latter with a retroreflective tag under four levels of expectancy. The outcome measured was detection distance.

Wood 2005

This trial involved 20 driver observers and compared the effect of four clothing conditions of different reflectance viewed under high and low headlight beam conditions.

Bicycles/Bicyclists

Blomberg 1986

This trial involved 36 observers (same trial as Blomberg 1986, see above) and compared the effect of reflectors, lamp and retroreflective accessories. The outcomes measured were detection and recognition distances.

Burg 1978a

This trial involved eight observers who compared the effect of reflective bicycle tyres and pedal reflectors, viewed approaching from different directions. The outcome measured was detection distance. This trial was reported in the same article as Burg 1978b.

Burg 1978b

This trial involved 32 observers who compared the effect of reflective bicycle tyres and pedal reflectors, viewed approaching from different directions. The outcome measured was recognition frequency. This trial was reported in the same article as Burg 1978a.

CPSC 1997

This trial involved 48 observers who compared the effect of reflective and non-reflective bicyclist helmets, on detection and recognition distances.

Kumagai 1999

This trial involved 48 observers who compared the effect of rear lights, spoke and pedal reflectors, reflective tyres and fluorescent sheeting on detection and recognition distances.

Matthews 1980

This trial involved 32 observers who compared the effect of rear reflectors and no reflectors, viewed in basic and noisy backgrounds, at two distances and from two lane positions. The outcome measured was reaction time.

Sator 1978a

This trial involved 31 observers who compared the effect of red and red-yellow rear retroreflectors of different luminance. The outcomes measured were detection and recognition distances. This trial was reported in the same article as Sator 1978b.

Sator 1978b

This trial was the same as Sator 1978a but involved four observers. This trial was reported in the same article as Sator 1978a.

Watts 1984b

This trial involved 10 observers who compared the effect of rear lamp and light reflectors, viewed under glare and no-glare conditions. The outcome measured was detection distance. This trial was reported in the same article as Watts 1984c.

Watts 1984c

This trial involved six observers who compared the effect of reflectorised accessories on the cyclist and bicycles. The outcomes measured were detection and recognition distances. This trial was reported in the same article as Watts 1984b.

Targets/materials

Johansson 1963

This trial involved four observers who compared the effect of reflector tapes and grey cloths on visibility (detection) distance, viewed under full and dipped headlights at four meeting distances, with and without an approach light.

Marsh 1998

This trial involved 16 observers who compared the effect of retroreflectorised materials in different colours. The outcome measured was detection distance.

Zwahlen 1991a

This trial involved seven observers who compared the effect of targets of different retroreflective colours on recognition distance. This trial was reported in the same article as Zwahlen 1991b.

Zwahlen 1991b

This trial involved six observers who compared the effect of targets of different retroreflective colours on recognition distance. This trial was reported in the same article as Zwahlen 1991a.

Further details of each included trial are presented in the ' Characteristics of included studies' table.

Risk of bias in included studies

Participants were randomised in five trials (Balk 2008; Moberly 2001; Muttart 2000; Owens 2007; Sayer 2004). In another three trials (Cole 1984; Hughes 1986a; Hughes 1986b), participants were randomised into two groups prior to being presented with different orders of visibility aids to view. Orders of visibility aids were randomised in 17 trials (Allen 1970; Balk 2008; Hanson 1963; Luoma 1996; Luoma 1998; Matthews 1980; Michon 1969a; Sator 1978a; Sator 1978b; Sayer 1998; Sayer 2004; Shinar 1984; Wood 2005; Zwahlen 1991a; Zwahlen 1991b; Zwahlen 1994; Zwahlen 1997). The method of Latin Square design was used to produce a balanced or counterbalanced order in the presentation of visibility aids in 19 trials (Blomberg 1986; Burg 1978a; Burg 1978b; CPSC 1997; Johansson 1963; Kumagai 1999; Marsh 1998; Michon 1969a; Michon 1969b; Owens 1994a; Owens 1994b; Owens 2007; Sayer 1999; Shinar 1985; Turner 1997; Watts 1980; Watts 1984a; Watts 1984b; Watts 1984c).
Unpublished methodological details were obtained from authors to establish that the trialists had foreknowledge of the treatment allocation in 13 trials (Blomberg 1986; Kumagai 1999; Luoma 1996; Luoma 1998; Marsh 1998; Moberly 2001; Muttart 2000; Sayer 1998; Sayer 1999; Zwahlen 1991a; Zwahlen 1991b; Zwahlen 1994; Zwahlen 1997) in which only the participants were blinded to the intervention. Three trials had blinded outcome assessment (Kumagai 1999, Luoma 1996, Luoma 1998). Allocation concealment and blinding in outcome assessment were unclear in 28 trials (Allen 1970; Balk 2008; Burg 1978a; Burg 1978b; Cole 1984; CPSC 1997; Hanson 1963; Hughes 1986a; Hughes 1986b;Johansson 1963; Matthews 1980; Michon 1969a; Michon 1969b; Michon 1969c; Owens 1994a; Owens 1994b; Owens 2007; Sator 1978a; Sator 1978b; Sayer 2004; Schnell 2001; Shinar 1984; Shinar 1985; Turner 1997; Watts 1980; Watts 1984a; Watts 1984b; Wood 2005). The review authors' judgement on allocation concealment across trials can also be found in Figure 1 and Figure 2.

Figure 1. Methodological quality graph: review authors' judgements about each methodological quality item presented as percentages across all included studies.

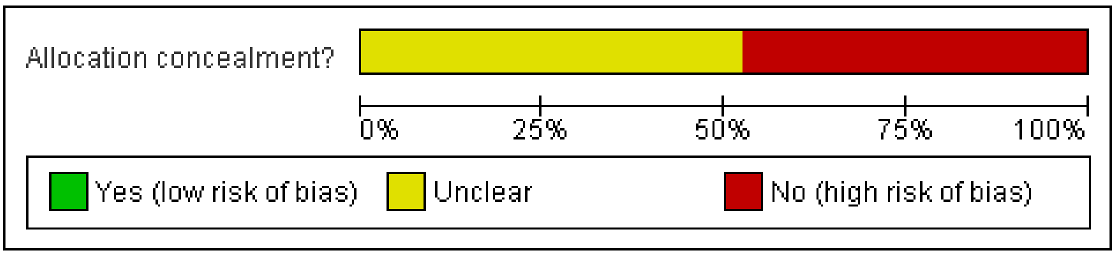
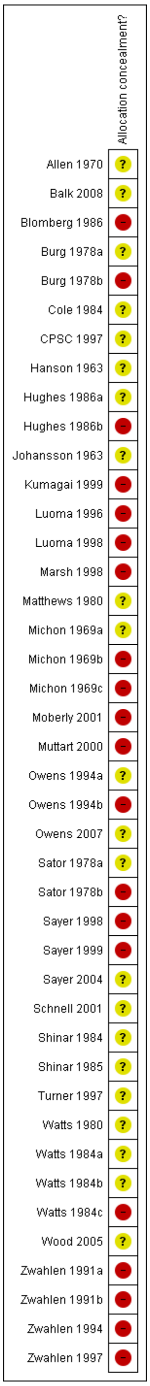


Figure 2. Methodological quality summary: review authors' judgements about each methodological quality item for each included study.



Analyses were not carried out on an intention-to-treat basis in four trials. Data from three observers were excluded from the final analysis in one trial (Moberly 2001), from three and four observers respectively in two trials (Owens 1994a; Owens 1994b) and from the first night of testing in one trial (Sator 1978a).

Participants in one trial (Marsh 1998) received extra psychology course credit for taking part in the study. Participants were paid in seven trials (Burg 1978a; Burg 1978b; Luoma 1996; Luoma 1998; Sayer 1998; Sayer 1999; Sayer 2004). In two trials (Muttart 2000; Sayer 1999), some of the participants were recruited from members of the named research centre, and all participants were staff and members of the named research centre in another trial (Sator 1978a).

Effects of interventions

Due to the diversity of interventions and types of outcomes reported, no attempt was made to combine the results quantitatively.

Day time visibility aids

Fluorescent colours versus non-fluorescent colours

Nine trials compared fluorescent colours with non-fluorescent colours. The use of fluorescent colours increased visibility in all but one (Watts 1980). Detection distances improved in two trials (Hanson 1963; Turner 1997), recognition distances in one trial (Hanson 1963) and reaction times in three trials (Michon 1969a; Michon 1969b; Michon 1969c). Detection and recognition frequency were higher with fluorescent colours in two trials (Zwahlen 1994; Zwahlen 1997). In all but three trials (Michon 1969a; Zwahlen 1994; Zwahlen 1997) among fluorescent colours, fluorescent red, orange and yellow yielded the best responses. For non-fluorescent colours, yellow yielded the best responses in six trials (Hanson 1963; Michon 1969a; Michon 1969b; Michon 1969c; Turner 1997; Watts 1980) but not in recognition frequency in two trials (Zwahlen 1994; Zwahlen 1997). White yielded higher detection frequency when compared with grey and black in three trials (Cole 1984; Hughes 1986a; Hughes 1986b).

Watts 1980

Viewed against a dark and light background, fluorescent colours did not yield a greater detection distance than non-fluorescent colours (62m versus 64m). But fluorescent orange colours yielded a greater detection distance when compared with other fluorescent colours (63m versus 62m). Non-fluorescent yellow yielded a greater detection distance when compared with dark blue (66m versus 63m).

Turner 1997

Fluorescent red-orange coloured vests yielded a greater detection distance when compared with other fluorescent colours (300m versus 242m). For non-fluorescent colours, yellow yielded a greater detection distance when compared with other colours (214m versus 203m).

Hanson 1963

Fluorescent yellow-orange targets yielded a greater detection and recognition distance when compared with other fluorescent colours (184m versus 170m and 134m versus 120m respectively). For non-fluorescent colours, yellow yielded a greater detection and recognition distance when compared with other colours (174m versus 160m and 96m versus 81m respectively).

Michon 1969a

For both colour normal and colour-deficient observers, fluorescent orange colours yielded a similar reaction time when compared with other fluorescent colours (2.8 sec versus 2.8 sec). For non-fluorescent colours, white and yellow yielded a shorter reaction time when compared with grey (3.3 sec versus 5.8 sec).

Michon 1969b and Michon 1969c

In these two trials, fluorescent orange colour jackets yielded a shorter reaction time when compared with other fluorescent colours (0.9 sec versus 1.1 sec and 0.6 sec versus 0.9 sec respectively). For non-fluorescent colours, yellow yielded a shorter reaction time when compared with a white jacket (0.9 sec versus 1.5 sec and 0.8 sec versus 1.1 sec respectively).

Zwahlen 1994

Fluorescent colours yielded a greater detection and recognition frequency when compared with non-fluorescent colours (85% versus 65% and 49% versus 48% respectively). Fluorescent yellow yielded a higher detection but not recognition frequency when compared with other fluorescent colours (88% versus 81% and 51% versus 56% respectively). For non-fluorescent colours, yellow-orange yielded a higher frequency of detection but not recognition when compared with other non-fluorescent colours (75% versus 60% and 45% versus 46% respectively).

Zwahlen 1997

Below a peripheral angle of 30 degrees, fluorescent colours yielded a higher detection and recognition frequency than non-fluorescent colours (84% versus 76% and 49% versus 48% respectively). Fluorescent yellow and orange did not yield a higher detection and recognition frequency when compared with other fluorescent colours (83% versus 84% and 40% versus 59% respectively). For non-fluorescent colours, yellow and orange yielded a higher detection but not recognition frequency when compared with other colours (82% versus 76% and 32% versus 56% respectively).

Cole 1984

White coloured discs yielded a higher detection frequency when compared with black or grey colours (46% versus 35%).

Hughes 1986a and Hughes 1986b

White coloured discs yielded a higher detection frequency when compared with black or grey colours (29% versus 15% and 31% versus 21%) respectively.

'Biomotion' versus 'no-biomotion' retroreflectors

One trial assessed the effects of retroreflective markings on torso and biomotion (Owens 2007).

Owens 2007

Retroreflective slash across torso and biomotion yielded similar recognition frequency (97% versus 97%).

Night-time visibility aids

Visibility aids versus no visibility aids

Fifteen trials compared the effect of visibility aids versus no visibility aids on driver responses. When compared with no visibility aids the use of visibility aids at night enhanced drivers' detection distances in seven trials (Allen 1970; Blomberg 1986; Johansson 1963; Schnell 2001; Shinar 1984; Shinar 1985; Watts 1984b), recognition distances in three trials (Luoma 1996; Luoma 1998; Wood 2005), recognition frequency in one trial (Wood 2005) and recognition times in three trials (Muttart 2000; Owens 1994a; Owens 1994b) and reaction times in one trial (Matthews 1980). One trial (CPSC 1997) did not show any improvement.

Allen 1970

With or without glare, a reflectorised jacket yielded a greater visibility distance when compared with non-reflectorised jackets (234m versus 118m). A white jacket yielded a greater visibility distance when compared with a black jacket (138m versus 97m).

Blomberg 1986

A flashlight held by a pedestrian yielded a greater detection and recognition distance when compared with no light (420m versus 68m and 96m versus 32m respectively). The weighted mean differences (WMD) for detection and recognition distance were 352 (95% confidence interval (CI) 301.68 to 402.32) and 64 (95% CI 39.76 to 88.24) metres respectively.

A leg lamp on a bicyclist yielded a greater detection and recognition distance when compared with no lamp (397m versus 257m and 147m versus 134m respectively). The WMD for detection and recognition distance was 140 (95% CI 95.05 to 184.95) and 13 (95% CI -13.43 to 39.43) metres respectively.

Johansson 1963

Under both full and dipped headlights, reflector tapes yielded a greater visibility (detection) distance when compared with grey black cloths (223m versus 38m). A light grey cloth yielded a greater visibility (detection) distance when compared with grey black cloths (80m versus 38m).

Schnell 2001

Under no headlamp covers, dark clothing (Reflectance = 0.11) yielded a greater detection distance when compared with light clothing (Reflectance = 0.81) (92m in child 'mock-up' and 109m in adult 'mock-up' versus 136m in child 'mock-up' and 186m in adult 'mock-up' respectively). When the headlights were covered, the corresponding data were 51m and 61m versus 93m versus 137m respectively.

Shinar 1984

Under high beam, low beam and glare situation, retroreflective tags worn by pedestrians yielded a greater detection distance when compared with no retroreflective tags (220m versus 104m). The WMD for detection distance was 116 (95% CI 95.99 to 136.01) metres.

Shinar 1985

Across the four levels of expectancy, retroreflective tags worn by pedestrians yielded a greater detection distance when compared with no retroreflective tags (327m versus 144m). Light clothing yielded a greater detection distance when compared with dark clothing (156m versus 144m).

Watts 1984b

Under both glare and no-glare conditions, a rear lamp and reflectors yielded a greater detection distance when compared with no lamp/reflectors (245m versus 41m).

Luoma 1996

Retroreflectors yielded a greater recognition distance when compared with no retroreflectors (175m versus 38m).

Luoma 1998

Retroreflectors yielded a greater recognition distance when compared with no retroreflectors (193m versus 21m).

Muttart 2000

Retroreflective coloured vests yielded a longer recognition time when compared with no retroreflective coloured vest (4.8 sec versus 2.3 sec). The WMD for recognition time was 2.50 (95% CI 0.50 to 4.50) seconds.

Owens 1994a and Owens 1994b

Retroreflective markings on garments yielded a longer recognition time when compared with no retroreflective markings (3.9 sec versus 0.65 sec and 1.72 sec versus 0.15 sec respectively).

Matthews 1980

Viewed at a distance of 60m in a quiet environment, lights yielded a shorter reaction time when compared with no lights (0.9 sec versus 1.18 sec). The WMD for reaction time was -0.27 (95% CI -0.358 to -0.172) seconds. Pedal reflectors and lights together yielded a shorter reaction time when compared with no light nor reflectors (0.89 sec versus 1.18 sec). The WMD for reaction time was -0.29 (95% CI -0.38 to -0.2) seconds.

Viewed at a distance of 60m in a noisy environment, lights yielded a shorter reaction time when compared with no lights (1.12 sec versus 1.25 sec). The WMD for reaction time was -0.13 (95% CI -0.32 to 68.6) seconds. Pedal reflectors and lights together yielded a shorter reaction time when compared with no light nor reflectors (1.06 sec versus 1.25 sec). The WMD for reaction time was -0.19 (95%CI -0.38 to -4.54) seconds.

CPSC 1997

A reflective helmet did not yield a longer detection nor recognition distance when compared with a non-reflective helmet (228m versus 237m and 206m versus 216m respectively). The WMD for detection and recognition distance were -9.00 (95% CI -11.56 to -6.44) and -10.00 (95% CI -12.44 to -7.56) metres respectively.

Active versus passive visibility aids

Four trials compared active with passive visibility aids. Active visibility aids improved driver detection distances when compared with passive visibility aids in three trials (Blomberg 1986, Watts 1984b - two trials), recognition distance in one trial (Blomberg

1986), and reaction times in one trial (Matthews 1980). Recognition distance was not improved in one trial (Watts 1984b).

Blomberg 1986

A flashing light held by a pedestrian yielded a greater detection and recognition distance when compared with reflectorised accessories (420m versus 207m and 96m versus 92m respectively).

Watts 1984b

A rear bicycle lamp yielded a greater detection distance when compared with reflectors (306m versus 184m).

Watts 1984c

A flashing beacon on a bicycle yielded a greater detection but not recognition distance when compared with reflectors (588m versus 444m and 59m versus 71m respectively).

Matthews 1980

Viewed at a distance of 60m, a bicycle light yielded a shorter reaction time when compared with reflectors (1.02 sec versus 1.09 sec).

Retroreflective red, orange and yellow colours versus other retroreflective colours

Ten trials compared different retroreflective colours on visibility. Retroreflective red and yellow, orange and white colours improved detection distances in six trials (Marsh 1998; Sator 1978a; Sator 1978b; Sayer 1998; Sayer 1999; Sayer 2004), recognition distances in three trials (Sator 1978b; Zwahlen 1991a; Zwahlen 1991b), and recognition time in one trial (Muttart 2000).

Marsh 1998

Yellow retroreflectorised materials yielded a greater detection distance when compared with other retroreflectorised colours (198m versus 170m).

Sator 1978a

This trial compared red and red-yellow coloured rear reflectors of different levels of luminance. Red-yellow rear retroreflectors yielded a greater detection but not recognition distance when compared with red retroreflectors (189m versus 177m and 92m versus 122m respectively).

Sator 1978b

This trial compared red and red-yellow coloured rear reflectors of different levels of luminance. Red-yellow pedal retroreflectors yielded a greater detection and recognition distance when compared with red pedal retroreflectors (186m versus 92m and 109m versus 66m respectively).

Sayer 1998

Retroreflective markings in red-yellow colours yielded a greater detection distance when compared with retroreflective markings in other colours (108m versus 103m).

Sayer 1999

For both colour normal and colour-deficient observers, retroreflective markings in red-yellow colours yielded a greater detection distance when compared with retroreflective markings in other colours (103m versus 101m).

Sayer 2004

Retroreflective trims in blaze orange colour was the most conspicuous, yielding a detection distance of 344m, compared to silver white colour (329m). Both blaze orange trims and silver white trims were more conspicuous than fluorescent red trim, yielding a significantly greater detection distance (344m versus 288m and 329m versus 288m respectively, $P < 0.04$).

Zwahlen 1991a

Retroreflective red-yellow colours yielded a greater recognition distance when compared with other retroreflective colours (226m versus 216m).

Zwahlen 1991b

Retroreflective red-yellow colours yielded a greater recognition distance when compared with other retroreflective colours (232m versus 189m).

Muttart 2000

Retroreflective red vest yielded a longer recognition time than other retroreflective colours (6.2 sec versus 4.1 sec). The WMD for recognition time was 2.10 (95% CI -0.60 to 4.80) seconds.

Lights and reflectors versus reflectors

There were two trials comparing lights and reflectors with only reflectors on bicycles. A combination of lights with reflectors for bicycles improved detection distances in one trial (Kumagai 1999), and reaction times in another trial (Matthews 1980).

Kumagai 1999

For both parallel path and crossing path situations, a red blinking light and reflector combination yielded a greater detection but not recognition distance when compared with reflectors only (147m versus 135m and 125m versus 126m respectively).

Matthews 1980

Viewed at a distance of 60m, a light with reflector combination yielded a shorter reaction time when compared with reflectors only (1 sec versus 1.1 sec).

Reflective tyres versus reflectors

Two trials (Burg 1978a; Burg 1978b) compared reflective tyres with reflectors on bicycles.

Burg 1978a and Burg 1978b

Reflectors yielded a greater detection distance when compared with retroreflective tyres (296m versus 232m), but reflective tyres yielded a higher recognition frequency (84% versus 62%). The relative risk for being recognised when using reflective tyres was 1.32 (95% CI 1.13 to 1.54).

'Biomotion' versus 'no-biomotion' retroreflectors

Seven trials compared 'biomotion' with no 'biomotion' markings. Visibility aids in a 'biomotion' configuration enhanced recognition distances in three trials (Balk 2008; Luoma 1996; Luoma 1998), recognition times in two trials (Owens 1994a; Owens 1994b), recognition frequency in one trial (Owens 2007), detection distance in one trial (Sayer 2004) but not in another trial (Moberly 2001).

Balk 2008

For participants making two observations

With pedestrians standing still, biomotion retroreflectors yielded a significantly greater recognition distance than no biomotion or black (no retroreflectors) (88.4m versus 69.8m (retroreflectors on ankles and wrists), versus 58.1m (retroreflectors on ankles only), versus 23.8m (one rectangular retroreflective patch on torso) and versus 30.6m (black), respectively, P < 0.01).

With pedestrians walking, biomotion retroreflectors yielded a significantly greater recognition distance than no biomotion or black (no retroreflectors) (113.5m versus 94.2m (retroreflecors on ankles and wrists), versus 88.9m (retroreflectors on ankles only), versus 25.0m (one rectangular retroreflective patch on torso) and versus 29.5m (black), respectively, P < 0.01).

For participants making one observation only

With pedestrians standing still, biomotion retroreflectors yielded a significantly greater recognition distance than no biomotion or black (no retroreflectors) (44m versus 18m [retroreflecors on ankles and wrists], versus 18m [retroreflecors on ankles only], versus 15m [one rectangular retroreflective patch on torso] and versus 15m [black], respectively, P < 0.01).

With pedestrians walking, biomotion retroreflectors yielded a significantly greater recognition distance than no biomotion or black (no retroreflectors) (117m versus 84m [retroreflectors on ankles and wrists], versus 70m [retroreflectors on ankles only], versus 17m [one rectangular retroreflective patch on torso] and versus 20m [black], respectively, P < 0.01).

Luoma 1996 and Luoma 1998

In these two trials, biomotion retroreflectors yielded a greater recognition distance when compared with no biomotion retroreflectors (209m versus 157m and 209m versus 185m respectively).

Owens 1994a and Owens 1994b

In both trials, biomotion retroreflectors yielded a longer recognition time when compared with no biomotion retroreflectors (4.3 sec versus 3.7 sec and 2.4 sec versus 1.4 sec respectively).

Owens 2007

Biomotion retroreflectors yielded a significantly higher recognition frequency than a retroreflective slash placed across the torso (90% versus 47%, P < 0.01).

Moberly 2001

Biomotion retroreflectors did not yield a greater detection distance when compared with no biomotion retroreflectors (41m versus 52m). The WMD for detection distance was -11.00 (95% CI -74.33 to 52.33) metres.

Sayer 2004

Retroreflective trims located in torso and arms (Class 3 Jacket), producing a biomotion effect in a moving pedestrian, yielded a significantly greater detection distance than configurations with four or three trims on torso (Class 3 or 2 vest) or dark clad comparison (335m versus 311m, versus 295m, and versus 94m, respectively, P < 0.02).

Wood 2005

Biomotion clothing yielded the highest recognition frequency when compared with black, white and vest clothing conditions in the absence of glare (100% versus 47.5% versus 90% versus 67.5%) and in the presence of glare (87.5% versus 20% versus 77.5% versus 60%). Biomotion clothing also yielded the highest response distance (165m versus 13m versus 73m versus 56m).

DISCUSSION

Summary of main results

We found no randomised controlled trials or controlled before-and-after trials which compared the effect of visibility aids versus no visibility aids, or of different visibility aids on the occurrence of pedestrian and cyclist-motor vehicle collision. The effect of visibility aids on pedestrian and cyclist safety therefore remains unknown.

Results of the trials suggest that visibility aids influence drivers' reaction, detection and recognition. For daytime visibility, fluorescent materials in yellow, red and orange colours improved detection and recognition. Yellow was the most effective non-fluorescent colour. For night-time visibility, lamps, flashing lights and retroreflective materials in red and yellow colours enhanced drivers' detection and recognition. 'Biomotion' markings also improved recognition.

Any potential effect of visibility aids needs to be considered in the context of the dynamic complexities of any road environment and the users. These 42 trials highlighted the many factors which could influence visibility, such as road condition, contrast, weather, street lighting, background 'clutter' and the roadworthiness of the vehicles. However, detection of an object does not equate to its recognition as a hazard and subsequent evasion. Driving is a highly skilled activity, situated in a complex and unpredictable environment. The cognitive process of understanding and correct interpretation of visual information in recognition is complex, influenced by driver expectancy, level of vigilance, attention, judgement, experience, etc. which can lead to perception errors in drivers who 'looked but did not see' (Gale 1996; Hills 1980). The behaviours of the drivers and pedestrians/bicyclists, such as intoxication and speeding are important considerations. Past studies have shown that pedestrians tend to over-estimate their own visibility (Allen 1970; Shinar 1984; Tyrrell 2004). It has also been argued that laboratory trials which use films, video or slides as presentation of visibility aids do not adequately reproduce the quality of lights and reflective or fluorescent materials in a real life setting (Cairney 2001). The plethora of different experimental settings and visibility measures demonstrated in the studies reviewed may influence the generalisability of the findings. A more unified framework for future research to improve ecological validity in conspicuity research needs to be considered (Langham 2003).

Based on these 42 trials, visibility aids have the potential to increase conspicuity and enable drivers to detect and recognise pedestrians and cyclists earlier. This does not imply that evasive actions will be taken and collisions avoided. Public acceptability of these strategies would depend on their ease of application, maintenance and cost. High visibility garments can be cumbersome and unsuitable to wear in hot and humid climates. Lights and lamps need to be kept in working order. Visibility aids which can yield simultaneous detection and recognition, and made with a combination of fluorescent and retroreflective materials would be useful as they cover both day and night conditions. Detachable accessories such as tags, strips and vests may encourage user acceptability.

The focus of recent research has been on the effects of biomotion markings which make pedestrians conspicuous by highlighting the movement and form of the pedestrian, whether moving or not. Biomotion configuration showed evidence, over other visibility aids, in improving pedestrian conspicuity, in particular taking advantage of the motion from a pedestrian's limbs (arms or legs), can be of great benefit to pedestrians' safety at night (Balk 2008; Owens 2007; Sayer 2004).

The problem of pedestrian and cyclist death and injuries will not be fully resolved in terms of increased conspicuity. Visibility aids may be relatively low cost to produce and purchase but it will require the individual road user to buy, wear and maintain them. Efforts to implement complementary measures such as improved street environment, traffic calming schemes, better vehicle design, speed limit, and continuous driver and pedestrian/bicyclist education may also contribute towards improving the safety of all vulnerable road users. Whether visibility aids will make a worthwhile difference needs careful economic evaluation alongside research efforts to quantify their effect on pedestrian and cyclist safety.

Overall completeness and applicability of evidence

The objective of this review was to make explicit the totality of the evidence available from randomised trials on the effects of visibility aids. The TRANSPORT database provided the main source of records for the identification of potential trials in this review. This database has a limited range of indexing terms describing study methodology, and the problem of devising reliable electronic search strategies in the TRANSPORT database has been highlighted (Wentz 2001). It is possible that a small number of relevant trials may have been missed. To avoid the effect of publication bias, we contacted trialists and experts in the field of visibility and illumination research, manufacturers of high-visibility materials and Standards authorities for further information, and from this two additional trials were identified. Websites of transport and related organisations worldwide were also searched, which identified two more trials. Some trials were unavailable due to proprietary reasons. Details of some trials carried out before 1970 were unavailable as the authors had retired or the records were inaccessible.

Potential biases in the review process

The primary outcome of death and injury rates are of universal relevance to all concerned with traffic safety. None of the trials studied these outcomes. However, the surrogate outcomes of reaction, detection, and recognition are considered valid field measures of visibility. We chose to compare red, orange and yellow colours with other colours, as the former are the colours most commonly used by firefighters and emergency workers and vehicles for high visibility and safety. This decision was made post-hoc.

The Latin Square design of some of the trials permit systematic presentation of the interventions to be viewed by the observers under different conditions. This is considered to be appropriate in visibility investigations to simulate a dynamic road environment. However, foreknowledge of the order of presentation of the interventions by the trialists and the non-blinding of outcome assessment can introduce an important source of potential bias. The recruitment of participants from research centres where the trials took place can also introduce selection bias and ascertainment bias.

In combining data to create dichotomies for comparisons in each of the trials, we obtained an overall effect of visibility aids on detection and recognition. This effect would have masked some of the important differences of the individual interventions. Reflectors viewed at low beam and high beam would yield different detection and recognition measurements. Substantial heterogeneity between the trials limit the potential for meta-analysis. Summary statistics for individual trials were presented when data details were available.

Agreements and disagreements with other studies or reviews

A recent randomised controlled trial conducted in Nottingham reported that school children provided with free visibility aids and educational booklets on road safety are more likely to use these aids, thus increasing their conspicuity and potential detection by car drivers (Mulvaney 2006). However, the potential impact of visibility aids in reducing pedestrian and cyclist death and injuries needs to be determined. While challenging, a cluster randomised controlled trial involving large communities may provide the answer to this question. Research including large observation studies and data collection of road traffic injuries in relation to the use of visibility aids, in particular biomotion apparels, would warrant consideration.

AUTHORS' CONCLUSIONS

Implications for practice

The effect of visibility aids on pedestrian and cyclist safety is unknown. Fluorescent, retroreflective materials and flashing lights have the potential to improve detection and recognition. Biomotion markings, which highlight the movement and form of the pedestrian, showed evidence of improving pedestrians' conspicuity at night. Public acceptability of these strategies would merit further consideration and development.

Implications for research

The safety benefit of visibility aids on pedestrians and cyclists has not yet been determined. Studies which collect data on road traffic injuries relating to the use of visibility aids are required. A cluster randomised controlled trial involving large communities may provide an answer to this question. It would, however, be a challenging trial to conduct.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Allen 1970

Methods	Randomisation of participants into two groups - the randomised order of aids presentation in each group. Allocation concealment unclear.
Participants	Six observers as front seat passengers. Age range 21 to 23 years. Normal vision.
Interventions	Pedestrian Three treatments: 1. Black clothing 2. Black trousers with white jacket 3. Black trousers with reflectorised jacket viewed with headlight glare and no glare against dark and light backgrounds
Outcomes	Visibility distance.
Notes	1. Setting: on-road (Night-time) 2. 'Acted' pedestrians 3. Vehicle speed 48km/h 4. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Balk 2008

Methods	Randomisation of participants and order of presentation Allocation concealment unclear
Participants	One hundred and twenty undergraduates as passengers (65 F; 55M) Licensed drivers Mean age 18.8 years Binocular acuity 20/40
Interventions	Pedestrians Five treatments: 1. Black (no retroreflective material) 2. Vest (a rectangular retroreflective patch on torso) 3. Ankles (retroreflective straps on both ankles) 4. Ankles + wrists (retroreflective straps on both ankles and both wrists) 5. Biological motion (retroreflective straps on the ankles, wrists, knees, elbows and waist)

Balk 2008 (*Continued*)

Outcomes	Response (recognition of pedestrian) distance.
Notes	1. Setting: A 8.2 km route which included university and residential areas (Night-time) 2. Car headlamps on low-beam setting 3. Vehicle driven at speed limit (between 56.3 and 40.3 km/hr) 4. Pedestrians stood or walked in place facing the approaching vehicles 5. Two sets of data collected. One set with two observations for each participant on pedestrians (wearing five levels of clothing configurations) standing still and walking; the other set with one observation for each participant on pedestrians (wearing five levels of clothing configurations) standing still or walking. Blinding of outcome assessment not stated.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Blomberg 1986

Methods	Counterbalanced order of aids presentation. Order of presentation known to trialist. Allocation blinded to observers only.
Participants	Thirty six observers as drivers (11 F; 25 M). Age range: 20 to 33 years. Normal vision.
Interventions	A. Pedestrian Five treatments: 1. Baseline - white T-shirt 2. Dangle tags - reflective disks 3. Flashlight - carried in hand 4. Jogger's vest - combination retroreflective and fluorescent vest 5. Rings - retroreflective bands on hand, wrists, waist and ankles B. Bicyclist/bicycle Four treatments: 1. Baseline - bicyclist wearing T-shirt on bike with reflectors 2. Spokes and crank - baseline cyclist on bike with reflective strips on bicycle cranks and rear wheel spoke 3. Leg lamp - baseline bicyclist wearing a small light on left ankle 4. Fanny bumper and anklebands - baseline bicyclist wearing a 12-in fluorescent triangle over his posterior, also retroreflective anklebands. Additional distractor targets present.
Outcomes	Detection distance. Recognition distance.

Blomberg 1986 (*Continued)*

Notes	1. Setting: on-road (Night-time) 2. 'Acted' pedestrians 3. Vehicle speed not stated 4. No blinding of outcome assessment 5. Unpublished methodological details provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

Burg 1978a

Methods	Counterbalanced order of aids presentation. Allocation concealment unclear.
Participants	Eight paid observers in driver's seat. Age range: 19 to 62 years. Normal vision. Licensed drivers.
Interventions	Bicycles Seven retroreflective treatments: 1. 20-inch tyre (High reflectance) 2. 20-inch tyre (Medium reflectance) 3. 20-inch tyre (Low reflectance) 4. 26-inch tyre (High reflectance) 5. 26-inch tyre (Low reflectance) 6. Amber reflector 7. Red reflector viewed approaching from different directions Moderately 'cluttered' visual background.
Outcomes	Detection distance. Frequency of successful recognition.
Notes	A. Trial one 1. Setting: on-road (Night-time) 2. 'Bicycle wheels' mounted on wooden carts 3. Vehicle stationary 4. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description

Burg 1978a (*Continued)*

Allocation concealment?	Unclear	Unclear

Burg 1978b

Methods	Counterbalanced order of aids presentation. Allocation concealment unclear.
Participants	Thirty-two paid observers in driver's seat. Age range: 19 to 62 years. Normal vision. Licensed drivers.
Interventions	Four retroreflective treatments: 1. 20-inch tyre (High reflectance) 2. 20-inch tyre (Low reflectance) 3. Crystal Spoke reflector 4. Amber and red spoke reflector Viewed approaching from different directions. Moderately 'cluttered' visual background.
Outcomes	Detection distance. Frequency of successful recognition.
Notes	1. Setting: on-road (Night-time) 2. 'Bicycle wheels' mounted on wooden carts 3. Vehicle stationary 4. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Not used

Cole 1984

Methods	Randomisation of participants into two groups - then randomised order of aids presentation in each group. Allocation concealment unclear.
Participants	Fifty observers as drivers. Age range: 18 to 26 years. Normal vision.
Interventions	Five disc target treatments: 1. White - diameter 70cm 2. White - diameter 50cm 3. White - diameter 30cm

	4. Black - diameter 50cm 5. Grey - diameter 50cm viewed in 35 target locations within residential, arterial and shopping road condition for 2 groups of observers who were instructed to report: 1. All objects attracting their attention (Attention conspicuity) 2. All disc targets seen (Search conspicuity)
Outcomes	Frequency of disc detection.
Notes	1. Setting: on-road (Daytime) 2. Discs supported on poles 3. Vehicle speed not stated 4. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

CPSC 1997

Methods	Cross-over design of a multiple number of Latin Squares. Allocation concealment unclear.
Participants	Forty-eight observers as drivers (24 F; 24M). Age range: 25 to 44 years.
Interventions	Bicyclist helmet treatments: 1. Non-reflective helmet 2. Reflective helmet viewed in combinations of six bicycles with six levels of reflectivity in six physical locations, for two age groups
Outcomes	Detection distance. Recognition distance.
Notes	1. Setting: on-road (Night-time) 2. 'Acted' bicycle riders 3. Vehicle speed not stated 4. Trial designed based on the assumption that there would be no interaction of various factors except for possibly age group and helmet reflectivity 5. Unpublished data from the Internet 5. Three subjects not tested on designated night 6. Blinding of outcome assessment not stated

Risk of bias

CPSC 1997 (*Continued)*

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Hanson 1963

Methods	Randomised order of aids presentation. Allocation concealment unclear.
Participants	Nineteen observers in car (all male). Normal vision.
Interventions	Six colour targets treatments: 1. Yellow 2. Fluorescent red-orange 3. International orange 4. Red 5. White 6. Fluorescent yellow-orange viewed under four combinations: a) Three backgrounds: white, tan, olive drab b) Three time periods: noon, 3pm, 6pm c) Four directions: south facing at noon and 6pm, east facing at 3pm, west facing at 6pm d) Two sky conditions: clear and sunny, overcast
Outcomes	Detection distance. Recognition distance.
Notes	1. Setting: on-road (Daytime) 2. Targets mounted on panels of background colours 3. Vehicle speed 8km/h 4. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Hughes 1986a

Methods	Randomisation of participants into two groups - the randomised order of aids presentation in each group. Allocation concealment unclear.
Participants	Fifty observers (18F; 32M). Age range: 18 to 29 years. Normal vision.

Interventions	Five disc target treatments: 1. White - diameter 70cm 2. White - diameter 50cm 3. White - diameter 30cm 4. Black - diameter 50cm 5. Grey - diameter 50cm presented in slides photos projected at 1500 msecs to 2 groups of observers who were instructed to report: 1. All objects attracting their attention (Attention conspicuity) 2. All disc targets seen (Search conspicuity) B. Trial two Same as Trial one but the slides photos were projected at 250 msecs to the two groups of observers.
Outcomes	Detection frequency.
Notes	1. Setting - laboratory (Daytime) 2. Disc targets shown in slides 3. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Hughes 1986b

Methods	Randomisation of participants into two groups - the randomised order of aids presentation in each group. Allocation concealment unclear.
Participants	Fifty observers (18F; 32M). Age range: 18-29 years. Normal vision.
Interventions	Five disc target treatments: 1. White - diameter 70cm 2. White - diameter 50cm 3. White - diameter 30cm 4. Black - diameter 50cm 5. Grey - diameter 50cm presented in slides photos projected at 250 msecs to two groups of observers who were instructed to report: 1. All objects attracting their attention (Attention conspicuity) 2. All disc targets seen (Search conspicuity)
Outcomes	Detection frequency.

Hughes 1986b (*Continued)*

Notes	1. Setting - laboratory (Daytime) 2. Disc targets shown in slides 3. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Not used

Johansson 1963

Methods	Balanced order of target presentations. Allocation concealment unclear.
Participants	Four observers inside car. No demographic details.
Interventions	Four clothing target treatments: 1. Grey black - Reflectance 1 2. Dark grey - Reflectance 2 3. Light grey - Reflectance 3 4. Reflector tapes - Reflectance 4 viewed under full and dipped headlights, at 4 distances from a glare source, and at a distance when there was no approach lights
Outcomes	Visibility (Detection) distance.
Notes	1. Setting: on-road (Night-time) 2. Cloth targets shown 3. Vehicle speed at 50km/h 4. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Kumagai 1999

Methods	Cross-over design of a multiple number of Latin squares. Order of presentation known to trialist.
Participants	Forty-eight observers as drivers (24 F; 24M). Age range: 25 to 44 years. Two colour blind, rest normal vision.

Kumagai 1999 (*Continued*)

	Licensed drivers.
Interventions	Bicycle reflectors Six rear treatments: 1. Red blinking tail light/reflector 2. Yellow/Green fluorescent sheeting on rear and pedals 3. Amber rear reflectors 4. White pedal reflectors 5. CPSC regulation reflectors 6 Large red rear reflectors viewed in a parallel path situation. Six wheel/tyre reflectors: 1. Wheel circles reflectors 2. CPSC spoke reflectors 3. Two CPSC spoke reflector per wheel 4. Head light and blinking red tail light/reflector, with CPSC spoke reflectors 5. Blinking white front head light and blinking red tail light/reflector, with CPSC spoke reflectors 6. Yellow/Green fluorescent sheeting on front, rear and pedals, reflective tyres viewed in a crossing path situation
Outcomes	Detection distance. Recognition distance.
Notes	1. Setting: on-road (Night-time) 2. Mannequin riders on bicycles held on metal frame 3. Vehicle speed at 32 to 40km/h 4. Outcome assessment by statistician not involved in the trial 5. Unpublished methodological details provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

Luoma 1996

Methods	Randomised order of aids presentation. Order of presentation known to trialist. Allocation blinded to observers only.
Participants	Thirty-two paid observers as front and back seat passengers (16 F; 16 M). Age range: 20 to 77 years. Licensed drivers.
Interventions	Pedestrians Four treatments: 1. No retroflectors

	2. Retroflectors on torso 3. Retroflectors on wrists and ankles 4. Retroflectors on major joints (Biomotion) viewed in two walking directions: approaching and crossing Additional distracter targets present
Outcomes	Recognition distance.
Notes	1. Setting: on road (Night-time) 2. "Acted" pedestrians 3. Vehicle speed 50km/h 4. Blinding of outcome assessment - analysis done by someone not involved with data collection 5. Unpublished methodological details and outcomes data provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

Luoma 1998

Methods	Randomised order of aids presentation. Order of presentation known to trialist. Allocation blinded to observers only.
Participants	Sixteen paid observers as front and back seat passengers (all male). Age range: 20 to 68 years.
Interventions	Pedestrians Four treatments: 1. No retroreflectors 2. Retroreflectors on torso 3. Retroreflectors on wrists and ankles 4. Retroreflectors on major joints (Biomotion) viewed in two walking directions: towards and away from vehicle Additional distracter targets present
Outcomes	Recognition distance.
Notes	1. Setting: on road (Night-time) 2. "Acted" pedestrians 3. Vehicle speed 50km/h 4. Blinding of outcome assessment -analysis done by someone not involved with data collection 5. Unpublished methodological details and outcomes data provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

Marsh 1998

Methods	Balanced order of aids presentations (Latin square design). Order of presentation known to trialist. Allocation blinded to observers only.
Participants	Sixteen psychology students as front seat passengers (11 F; 5 M). Age range: 18 to 27 years. Normal vision. Observers received extra course credit for taking part.
Interventions	Six retroreflective material treatments: 1. Blue 2. Green 3. Orange 4. Red 5. Yellow 6. White
Outcomes	Detection distance.
Notes	1. Setting: on-road (Night-time) 2. Retroreflective samples mounted on a rotating disc 3. Vehicle speed not stated 4. No blinding in outcome assessment 5. Unpublished methodological details and outcomes data provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

Matthews 1980

Methods	Randomised order of aids presentation. Allocation concealment unclear.
Participants	Thirty-two observers (18F; 14M). Mean age: 21. Normal vision. Licensed drivers.

Matthews 1980 (*Continued*)

Interventions	Bicycles Rear treatments: 1. Red reflectors 2. Pedal reflectors 3. Red light 4. All reflectors and light 5. No reflectors or light viewed under basic and noisy background, two distances and in two lane positions
Outcomes	Reaction time.
Notes	1. Setting: laboratory (Night-time) 2. Colour slides of bicycle in traffic scenes 3. Dark clothing worn by bicycle riders 4. Blinding of outcome assessment not stated 5. Unpublished outcomes data provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Michon 1969a

Methods	Randomised order of aids presentation. Allocation concealment unclear.
Participants	Ten observers in driver's cabin (six normal vision, four colour deficient).
Interventions	Six colour 'jacket' treatments: 1. Grey 2. White 3. Yellow 4. Orange 5. Orange with chevron 6. Red under seven background contrasts for colour normal subjects, and two background contrasts for colour blind subjects while carrying out additional distracter tasks
Outcomes	Reaction time. Frequency of successful detection.
Notes	1. Setting: off-road (Daytime) 2. Subject in 'mock-up' cabin 3. 'Jackets' mounted on levers 4. Blinding of outcome assessment not stated

Michon 1969a (*Continued*)

Risk of bias		
Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	Unclear

Michon 1969b

Methods	Latin square design. Allocation concealment unclear.
Participants	Sixteen observers as drivers. Licensed drivers.
Interventions	Four 'jacket' treatments: 1. White 2. Yellow 3. Fluorescent yellow 4. Fluorescent orange of four designs under sixteen various settings: trees, heather, sky or road.
Outcomes	Reaction time. Frequency of successful detection.
Notes	1. Setting: on-road (Daytime) 2. Jacket model on 'cardboard' 3. vehicle speed 50 km/h 4. Blinding of outcome assessment not stated

Risk of bias		
Item	**Authors' judgement**	**Description**
Allocation concealment?	No	Not used

Michon 1969c

Methods	Latin square design. Allocation concealment unclear.
Participants	Twelve observers as drivers. Licensed drivers.
Interventions	Four 'jacket' treatments: 1. White 2. Yellow

	3. Fluorescent yellow 4. Fluorescent orange of three designs under sixteen various settings: trees, heather, sky or road.
Outcomes	Reaction time. Frequency of successful detection.
Notes	1. Setting: on-road (Daytime) 2. Jacket model on 'cardboard' 3. Vehicle speed 50 km/h 4. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Not used

Moberly 2001

Methods	Randomisation of participants. Allocation by order of arrival of the observers.
Participants	Sixty-five observers (37 F; 28M). Age range: 17 to 52 years. Observers recruited from university campus.
Interventions	Pedestrians Four retroreflective treatments: 1. Stationary vest 2. Moving vest 3. Stationary biomotion 4. Moving biomotion
Outcomes	Detection distance.
Notes	1. Setting: laboratory (Night-time) 2. Subjects watched a video of a road journey 3. Vehicle speed 80km/h in video 4. Data from 3 observers were excluded (non-intention-to-treat) 5. No blinding in outcome assessment 6. Unpublished outcomes data and methodological details provided by author

Risk of bias

Item	Authors' judgement	Description

Moberly 2001 (*Continued)*

Allocation concealment?	No	Inadequate

Muttart 2000

Methods	Randomisation of participants. Order of presentation known to trialist.
Participants	Thirty-four observers as front seat passenger (20 F; 14 M). Age range: 17 to 70 years. Normal vision. Licensed drivers. Subjects recruited by advertisement, also members of research centre.
Interventions	Pedestrians Three retroreflective vest treatments: 1. Fluorescent lime 2. Fluorescent red orange 3. Silver -white worn over bright yellow T-shirt 4. Yellow T-shirt only viewed under 'noisy' street environment
Outcomes	Recognition time.
Notes	1. Setting: on-road (Night-time) 2. Stationary pedestrians made out of cardboard 3. Vehicle speed 48.3km/h 4. No blinding of outcome assessment 5. Unpublished outcomes data and methodological details provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

Owens 1994a

Methods	Counterbalanced order of aids presentation (Latin Square design). Allocation concealment unclear.
Participants	Thirty-two undergraduates (17 F; 15 M).
Interventions	Pedestrians Four treatments 1. Dark control: dark navy blue suit 2. Vest: dark control with yellow fluorescent vest and diagonal retroreflective strip on front and back

Owens 1994a (*Continued*)

	3. Strips: dark control with five silver retroreflective strips at mid-torso, upper arms and lower legs 4. Biomotion: dark control suit with eleven silver retroreflective strips around the hips, both knees and ankles, wrists, elbows and shoulders viewed in four road environments: dark, residential, busy and lighted. B. Trial two Same interventions as trial one but with additional secondary task
Outcomes	Detection time.
Notes	A. Trial one 1. Setting: laboratory (Night-time) 2. Subjects watched a video of night-time driving scene 3. Vehicle speed 40km/hr in video 4. Data from four subjects excluded (non-intention to treat) 5. Blinding of outcome assessment not stated B. Trial two Same as trial one but data from four subjects excluded (non-intention-to-treat)

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Owens 1994b

Methods	Counterbalanced order of aids presentation (Latin Square design). Allocation concealment unclear.
Participants	Twenty paid undergraduates (8 F; 12 M).
Interventions	Pedestrians Four treatments 1. Dark control: dark navy blue suit 2. Vest: dark control with yellow fluorescent vest and diagonal retroreflective strip on front and back 3. Strips: dark control with five silver retroreflective strips at mid-torso, upper arms and lower legs 4. Biomotion: dark control suit with eleven silver retroreflective strips around the hips, both knees and ankles, wrists, elbows and shoulders viewed in four road environments: dark, residential, busy and lighted. 5. Additional secondary task
Outcomes	Detection time.
Notes	1. Setting: laboratory (Night-time) 2. Subjects watched a video of night-time driving scene 3. Vehicle speed 40km/hr in video 4. Data from four subjects excluded (non-intention to treat) 5. Blinding of outcome assessment not stated Four subjects excluded (not intention-to-treat).

Owens 1994b (*Continued)*

Risk of bias		
Item	**Authors' judgement**	**Description**
Allocation concealment?	No	Not used

Owens 2007

Methods	Randomisation of participants and order of aids presentation counterbalanced. Allocation concealment unclear.
Participants	24 observers as drivers (12 F; 12 M). Age range: 22 to 72 years. Licensed drivers. Visual acuity 20/40.
Interventions	Pedestrians Two retroreflective treatments 1. Retroreflective slash across torso 2. Biomotion: retroreflective strips at the waist, shoulders, elbows, wrists, knees and ankles viewed in day time and night-time. For night-time test, bright headlights followed by successively dimmer intensities.
Outcomes	Recognition frequency
Notes	1. Setting: A 1.8 km closed road situated in a rural 'bush' setting 2. Drivers instructed to travel at a 'comfortable speed' without speedometer information. 3. Blinding of outcome assessment not stated

Risk of bias		
Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	Unclear

Sator 1978a

Methods	Randomised order of aids presentation. Allocation concealment unclear.
Participants	Thirty-one observers as drivers (1 F; 30 M). Age range: 26 to 59 years. Licensed drivers. Subjects were all staff or members of the research centre. Four observers as drivers. No demographic details.

Sator 1978a (*Continued)*

Interventions	Bicycles Six rear retroreflector treatments: 1. Red and yellow (High luminance) 2. Red and yellow (Medium luminance) 3. Red and yellow (Low luminance) 4. Red (High luminance) 5. Red (Medium luminance) 6. Red (Low luminance)
Outcomes	Detection distance. Recognition distance.
Notes	1. Setting: on-road (Night-time) 2. Vehicle speed 70km/h 3. Only eight observers used on night of trial 4. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Sator 1978b

Methods	Randomised order of aids presentation. Allocation concealment unclear.
Participants	Four observers as drivers. No demographic details.
Interventions	Bicycles Four rear reflector treatments: 1. Red & yellow (High luminance) 2. Red & yellow (Medium luminance) 3. Red & yellow (Low luminance) 4. Red
Outcomes	Detection distance. Recognition distance.
Notes	1. Setting: on-road (Night-time) 2. Vehicle speed 70 km/h 3. Data from first night's tests excluded (non-intention-to-treat) 4. Blinding of outcome assessment not stated

Risk of bias

Sator 1978b *(Continued)*

Item	Authors' judgement	Description
Allocation concealment?	No	Not used

Sayer 1998

Methods	Randomised order of aids presentations. Order of presentation known to trialist.
Participants	Sixteen paid observers in driver seat: Age range: 20 to 73 years. Normal vision.
Interventions	Pedestrians Four colour treatments: 1. Green 2. Yellow 3. Red 4. White in high and low retroreflective power worn on front and back lower legs of pedestrian under two conditions: walking towards and away from vehicle
Outcomes	Detection distance.
Notes	1. Setting: on-road (Night-time) 2. 'Acted' pedestrians 3. Vehicle stationary 4. Blinding of outcome assessment not stated 5. Unpublished outcomes data and methodological details provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

Sayer 1999

Methods	Balanced order of aids presentations. Order of presentation known to trialist.
Participants	Twenty paid subjects in driver seat (ten colour normal; ten colour deficient, all male) recruited by advertisement, also members of research centre.
Interventions	Pedestrians Four colour treatments 1. Green

	2. Yellow 3. Red 4. White in high and low retroreflective power worn on front and back lower legs of pedestrian
Outcomes	Detection distance.
Notes	1. Setting: on-road (Night-time) 2. 'Acted' pedestrians 3. Vehicle stationary 4. Blinding of outcome assessment not stated 5. Unpublished outcomes data and methodological details provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

Sayer 2004

Methods	Randomisation of participants and order of presentation. Allocation concealment unclear.
Participants	Ten paid licensed drivers (1F; 9 M) Six older participants, mean age 69.2 years (range 64 to 75 years), mean visual acuity score 20/26.2 Four younger participants, mean age 25 years (range 21 to 30 years), mean visual acuity score 20/23.5 Colour normal vision, but instructed to wear any corrective lenses they would normally wear when driving at night Visual acuity score of 20/40
Interventions	Pedestrians Four treatments: location of retroreflective trim on garments 1. Dark clad comparison 2. Class 2 vest (two vertical and one horizontal strips on torso) 3. Class 3 vest (two vertical and two horizontal strips on torso) 4. Class 3 jacket (two vertical and two horizontal strips on torso, and two straps on each arm/sleeve of jacket) Four treatments: retroreflective trim colour on garments 1. Dark clad comparison 2. Silver/white 3. Blaze orange 4. Fluorescent red Two treatments: placement of pedestrians 1. Illuminated zone 2. Dark area
Outcomes	Detection distance

Sayer 2004 (*Continued*)

Notes	1. Setting: Simulated work zones in a 4.4 km oval test track, close to all traffic during experiment (Night-time) 2. Car headlamps on low-beam setting 3. Vehicle driven at speed limit of between 40 and 56 km/hr 4. Pedestrians located in or opposite the work zone, walked in place, with arms and legs in motion, while rotating, in order to provide a 360 degree view of each garment Blinding of outcome assessment not stated.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Schnell 2001

Methods	Randomised block design (3 factors: size, reflectivity and illumination).
Participants	Fifteen healthy licensed drivers.
Interventions	Child and adult 'mock-up' in 1. Dark clothing (R = 0.11) 2. Light clothing (R = 0.81) Observed with and without headlamp cover
Outcomes	Detection distance.
Notes	1. Setting: on-road (Night-time) 2. Pedestrian 'mock-up's 3. Vehicle driven at speed of 10 to 15km/hr

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Shinar 1984

Methods	Partial factorial randomised block design. Allocation concealment unclear.
Participants	Nineteen unpaid volunteer observers as front seat passenger and pedestrian (5 F; 14 M). Age range:18 to 55 years. Normal vision.

Shinar 1984 (*Continued)*

Interventions	Pedestrians Six treatments: 1. High beam + retroreflective tag 2. Low beam + retroreflective tag 3. Low beam + retroreflective tag + glare 4. High beam + no retroreflective tag 5. Low beam + no retroreflective tag 6. Low beam + no retroreflective tag + glare
Outcomes	Detection distance.
Notes	1. Setting: on-road (Night-time) 2. Subjects as pedestrians 3. Pedestrians in dark khaki clothing, retroreflective tags were pinned to shirt pockets 4. Vehicle speed 36 km/h 5. Outcome assessment by two people independently, one was the author 6. Unpublished methodological details provided by author

Risk of bias

Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	Unclear

Shinar 1985

Methods	Counterbalanced order of aids presentations. Allocation concealment unclear.
Participants	Forty volunteer observers as front seat passengers (21 F; 19 M). Age range: 20 to 58 years. Normal vision. Licensed drivers.
Interventions	Pedestrians Four treatments: 1. Dark khaki clothing 2. Light khaki clothing 3. Dark khaki clothing + retroreflective tag 4. Dark khaki clothing + retroreflective tag + cue under four levels of expectancy
Outcomes	Detection distance.
Notes	1. Setting: on-road (Night-time) 2. 'Acted' pedestrians 3. Vehicle speed 40km/h 4. Outcome assessment by two people independently, one was the author

Shinar 1985 *(Continued)*

	5. Unpublished methodological details provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Turner 1997

Methods	Counterbalanced order of aids presentations (partial Latin Square design). Allocation concealment unclear.
Participants	Twenty-three observers as front seat passengers (11 F; 12 M). Age range: 19 to 54 years. Normal vision. Licensed drivers. Recruited from research centre's list.
Interventions	Highway construction workers Eleven fluorescent coloured vest treatments: 1. Green 2. Yellow-green 3. Yellow 4. Semi-Fl Yellow 5. ordinary yellow 6. Yellow-orange 7. Red-orange 8. Red-orange with yellow-green 9. Red mesh on white 10. Ordinary orange 11. Pink in 4 work-zone configurations
Outcomes	Detection distance.
Notes	1. Setting: on-road (Daytime) 2. 'Dummy' highway workers 3. Vehicle speed 32km/h 4. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Watts 1980

Methods	Balanced order of aids presentation (Latin Square design). Allocation concealment unclear.
Participants	Sixteen observers in driver's seat (8F; 8 M). Age range: 19 to 66 years. Normal vision.
Interventions	Bicycles/bicyclists Eight treatments: 1. Orange spacer pennant 2. Yellow panel below handlebars 3. Fl orange cycle helmet 4. Fl orange waistcoat 5. Fl yellow waistcoat 6. Fl orange jacket 7. Non-fl yellow jacket 8. Dark blue jacket (control) viewed against four different backgrounds Additional subsidiary tracking task
Outcomes	Detection distance.
Notes	1. Setting: on-road (Daytime) 2. 'Acted' bicycle riders 3. Bicycle speed 16km/h 4. Vehicle stationary 5. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Watts 1984a

Methods	Balanced order of aids presentations (Latin Square design). Allocation concealment unclear.
Participants	Eighteen observers in driver's seat (4 F; 14 M). Age range: 18 to 67 years. Normal vision in all but one observer.
Interventions	Bicyclists Six fluorescent green yellow treatments: 1. Jacket 2. Waistcoat 3. Hat 4. Armbands

Watts 1984a (*Continued)*

	5. Sam Browne belt 6. Black jacket (control) with additional subsidiary tracking task
Outcomes	Detection distance.
Notes	1. Setting: on-road (Daytime) 2. 'Acted' bicycle riders 3. Bicycle speed 16km/h 4. Vehicle stationary 5. Blinding of outcome assessment not stated

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Watts 1984b

Methods	Balanced order of aids presentations (Latin Square design). Allocation concealment unclear.
Participants	Ten observers as drivers. Age range: 22 to 70 years.
Interventions	Bicycles Three treatments: 1. Rear lamp 2. Red reflectors 3. Lamp and reflectors covered - rider in dark jacket (control) viewed under two glare conditions
Outcomes	Detection distance. Recognition distance.
Notes	1. Setting: on-road (Night-time) 2. Stationary bicycle 3. Vehicle speed 35km/h Blinding of outcome assessment not stated.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Watts 1984c

Methods	Balanced order of aids presentations (Latin Square design). Allocation concealment unclear.
Participants	Six observers as driver. Age range: 22-66 years.
Interventions	Six treatments: 1. Flashing amber light attached to cyclist belt 2. Jacket with reflective silver and yellow bands 3. White reflective Sam Brown belt 4. Red reflective 'spacer' flag 5. Pedal reflector 6. Rear light and mudguard reflector, rider in dark jacket (control)
Outcomes	Detection distance. Recognition distance.
Notes	1. Setting: on-road (Night-time) 2. Test cyclist rode bicycle on rollers 3. Vehicle speed 35km/h Blinding of outcome assessment not stated.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Not used

Wood 2005

Methods	Randomised order of four clothing configurations within each randomised beam (high or low beam) conditions. Methods of randomisation and allocation concealment not reported.
Participants	Twenty local licensed driver volunteers with no knowledge of the hypothesis under investigation (10 older drivers: 67.9 ± 5.3 years; range 60 to 75; 10 younger drivers: 27.8 ± 4.7 years; range 21 to 34).
Interventions	Four pedestrians' clothing conditions: 1. Black (2% reflectance) 2. White (68% reflectance) 3. Vest (black condition + white retroreflective panel) 4. Biomotion
Outcomes	Recognition frequency. Recognition distance.
Notes	1. Setting: driving circuit 2. Acted pedestrians

Wood 2005 (*Continued*)

	3. Trial conducted under high and low headlight beam conditions 4. Car drive at 'comfortable ' speed Blinding of outcome assessment not stated.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	Unclear

Zwahlen 1991a

Methods	Randomised order of aids presentation (Randomised block design). Order of presentation known to trialist.
Participants	Seven observers in car. Mean age: 21 years.
Interventions	Six reflectorised colour target treatments: 1. Red 2. Blue 3. Orange 4. Green 5. White 6. Yellow
Outcomes	Recognition distance.
Notes	1. Setting: on-road (Night-time) 2. Colour targets attached to front of bicycles 3. Bicycle rider in dark clothing 4. Vehicle stationary 5. Bicycle speed 16km/h 6. No blinding of outcome assessment 7. Unpublished methodological details provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

Zwahlen 1991b

Methods	Randomised order of aids presentation (Randomised block design). Order of presentation known to trialist.
Participants	Six observers in car. Mean age 23.3 years. Normal vision.
Interventions	Six reflectorised colour target treatments: 1. Red 2. Blue 3. Orange 4. Green 5. White 6. Yellow
Outcomes	Recognition distance.
Notes	1. Setting: on-road (Night-time) 2. Colour targets attached to front of bicycles 3. Bicycle rider in dark clothing 4. Vehicle stationary 5. Bicycle speed 16km/h 6. No blinding of outcome assessment 7. Unpublished methodological details provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Not used

Zwahlen 1994

Methods	Randomised order of aids presentation (Randomised block design). Order of presentation known to trialist.
Participants	Twelve observers in driver's seat (6 F; 6 M). Age range: 20 to 22 years. Colour normal.
Interventions	Ten colour target treatments: 1. Non-Fl red 2. Non-Fl blue 3. Non-Fl regular orange 4. Non-Fl green 5. Non-Fl yellow 6. Non-Fl white 7. Fl orange 8. Fl regular pink

	9. Fl regular orange 10. Fl regular yellow viewed presented at 3 different peripheral angles and against 3 non-uniform background colours
Outcomes	Frequency of successful detection and recognition.
Notes	1. Setting: on-road (Daytime) 2. Colour targets mounted on portable stand 3. No blinding of outcome assessment 4. Unpublished methodological details provided by author

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

Zwahlen 1997

Methods	Randomised order of aids presentation (Randomised block design). Order of presentation known to trialist.
Participants	Eighteen observers as drivers (7 F; 11 M). Mean age 21.4 years. Normal vision.
Interventions	Ten colour target treatments: 1. Orange 2. Green 3. Blue 4. Red 5. White 6. Yellow 7. Fl orange 8. Fl yellow 9. Fl red 10. Fl yellow-green of four different sizes viewed from five peripheral angles
Outcomes	Frequency of successful detection and recognition.
Notes	1. Setting: on-road (Daytime) 2. Colour targets presented on tripod 3. No blinding of outcome assessment 4. Unpublished methodological details provided by author

Risk of bias

Zwahlen 1997 (*Continued)*

Item	Authors' judgement	Description
Allocation concealment?	No	Inadequate

M = Male
F = Female
Fl = Fluorescent
Definitions:
Fluorescence - Fluorescent colours absorb short wavelength light to which the eye is not sensitive, and then re-emit the energy as visible light.
Retroreflectance - Retroreflection occurs when light rays are returned in the direction from which they came, achieved with microprismatic technology.
Biomotion - When light points are attached to major joints of the body (shoulders, hips, elbows, wrists, knees and ankles), relative motions among the joints provide virtually immediate perception of the person in action.

Characteristics of excluded studies *[ordered by study ID]*

Austin 1974	Subjective outcome measurements of perceived visibility.
Bartmann 1991	Unclear methodology - author did not respond to request for information.
Beith 1982	Conspicuity aids used by coal-miners in mines.
Blomberg 1981	Unclear methodology - data cannot be used due to proprietary (ownership) reasons.
Cairney 1992	No randomisation process.
Connors 1975	Cockpit simulation.
Hazlett 1968	Participants were exposed to alcohol prior to conspicuity aids.
Helmers 1993	Study not of randomised design.
Hills 1975	Unclear methodology.
Isler 1996	Paper unavailable - author did not respond to request for further information.
Isler 1997	Conspicuity garments used by forestry workers in forest environment.
Markowitz 1971	Study not related to road users.
Rumar 1976	Unclear methodology and interventions not eligible for inclusion.
Ryan 1998	Subjective outcome measurements of perceived brightness.

(*Continued*)

Sator 1976	Subjective outcome measurements of visibility scale.
Sayer 2004a	Unclear methodology.
Sayer 2004b	Unclear methodology.
Schmidt-Clausen 1982	Unclear methodology.
Schmidt-Clausen 1987	Unclear methodology.
Summala 1980	Driving speed as outcome measures.
Tyrrell 2004	Pedestrians' estimate of their own conspicuity as outcomes.
Zwahlen 1981	Inappropriate randomisation.
Zwahlen 1989	Inappropriate outcomes.

DATA AND ANALYSES

This review has no analyses.

APPENDICES

Appendix 1. Search strategy

Cochrane Injuries Group Specialised Register (to May 2009)

(pedestr* or cycli* or bike* or bicycl* or walk or walking or walker*) and (night* or twilight* or dusk* or sign* or safety or lamp* or contrast* or reflect* or retro-reflect* or retroreflect* or fluoresc* or warning or daytime-running or flashing* or blink* or color* or colour* or yellow or light*)

CENTRAL (The Cochrane Library 2009, Issue 2)

#1 MeSH descriptor Accident Prevention explode all trees
#2 MeSH descriptor Walking explode all trees
#3 MeSH descriptor Bicycling explode all trees
#4 pedestr* or cycli* or bike* or bicycl* or walk or walking or walker*
#5 (#2 OR #3 OR #4)
#6 (#1 AND #5)
#7 night or twilight* or dusk* or sign* or safety or lamp*
#8 contrast* or reflect* or retro-reflect* or retroreflect* or fluoresc*
#9 (warning or daytime-running or flashing* or blink* or color* or colour* or yellow) near3 (light*)
#10 (#7 OR #8 OR #9)
#11 (#6 AND #10)

MEDLINE (Ovid SP) 1950 to May (week 3) 2009

PubMed [www.ncbi.nlm.nih.gov/sites/entrez/] (added to PubMed in the last 180 days): 19 records
1.exp Accident Prevention/
2.exp Walking/
3.exp Bicycling/
4.(pedestr* or cycli* or bike* or bicycl* or walk or walking or walker*).mp.
5.4 or 3 or 2
6.1 and 5
7.(night* or twilight* or dusk* or sign* or safety or lamp*).mp.
8.(contrast* or reflect* or retro-reflect* or retroreflect* or fluoresc*).mp.
9.((warning or daytime-running or flashing* or blink* or color* or colour* or yellow) adj3 light*).mp.
10.8 or 7 or 9
11.6 and 10

TRANSPORT 1988 to 2007/06

#1 conspic*
#2 visib*
#3 visual
#4 perception
#5 #1 or #2 or #3 or #4
#6 warning light* or daytime running or ((day or night) near3 light*) or twilight* or dusk* or sign* or safety or lamp* or flashing* or blink* or contrast* or reflect* or retro-reflect* or retroreflect* or fluoresc* or color* or colour* or yellow
#7 pedestr* or walk* or cycle* or cycli* or cross-walk* or crosswalk* or crossing* or bike* or bicycl*
#8 #5 and #6 and #7

PsycINFO (Ovid SP) 1806 to May (week 3) 2009
PsycEXTRA (Ovid SP) 1908 to May 18, 2009

1.exp Accident Prevention/
2.exp Highway Safety/
3.exp Transportation Safety/
4.1 or 2 or 3
5.(pedestr* or cycli* or bike* or bicycl* or walk or walking or walker*).ab,ti.
6.exp Walking/
7.5 or 6
8.4 and 7
9.(night* or twilight* or dusk* or sign* or safety or lamp*).mp.
10.(contrast* or reflect* or retro-reflect* or retroreflect* or fluoresc*).mp.
11.((warning or daytime-running or flashing* or blink* or color* or colour* or yellow) adj3 light*).mp.
12.9 or 10 or 11
13.8 and 12
14.(2005* or 2006* or 2007* or 2008* or 2009*).up.
15.13 and 14

ISI Web of Science: Social Sciences Citation Index (SSCI) 1970 to May 2009
ISI Web of Science: Conference Proceedings Citation Index- Science (CPCI-S) 1990 to May 2009

1.Topic=((head or crani* or cerebr* or brain* or skull* or intra-cran* or inter-cran*) same (injur* or trauma* or lesion* or damag* or wound* or destruction* or oedema* or edema* or fractur* or contusion* or concus* or commotion* or pressur*)) AND Topic=(pedestr* or cycli* or bike* or bicycl* or walk or walking or walker*)
2.Topic=((head or crani* or cerebr* or brain* or skull* or intra-cran* or inter-cran*) same (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressure)) AND Topic=(pedestr* or cycli* or bike* or bicycl* or walk or walking or walker*)
3.Topic=(injur* or accident* or trauma* or wound* or fatal*) AND Topic=(pedestr* or cycli* or bike* or bicycl* or walk or walking or walker*)
4.1 or 2 or 3
5.Topic=(night* or twilight* or dusk* or sign* or safety or lamp*) OR Topic=(contrast* or reflect* or retro-reflect* or retroreflect* or fluoresc*) OR Topic=((warning or daytime-running or flashing* or blink* or color* or colour* or yellow) same light*)
6.Topic=(accident same prevent*) OR Topic=(road same safe*) OR Topic=(transport* same safe*) OR Topic=(highway same safe*)
7.5 and 6
8.4 and 7

WHAT'S NEW

Last assessed as up-to-date: 17 May 2009.

28 July 2009	New search has been performed	The search has been updated to May 2009. Data from three trials has been included. The Results and Conclusions sections have been amended.

HISTORY

Protocol first published: Issue 1, 2002

Review first published: Issue 2, 2002

20 August 2008	Amended	Converted to new review format.
14 July 2006	New search has been performed	This review was updated in June 2006 and two additional RCTs were identified, which provide further support that visibility aids used by pedestrians and cyclists have the potential to improve detection and recognition by car drivers. However, the safety benefit of visibility aids on pedestrians and cyclists has yet to be determined.

CONTRIBUTIONS OF AUTHORS

IK and JM screened the citations, applied inclusion criteria and extracted data. IK developed the protocol, contacted authors, entered data into RevMan and wrote the review. JM commented on the review and helped to write the review.

DECLARATIONS OF INTEREST

None known.

SOURCES OF SUPPORT

Internal sources

- No sources of support supplied

External sources

- The NHS Research & Development Programme, UK.

INDEX TERMS

Medical Subject Headings (MeSH)

*Bicycling [injuries]; *Safety; Accidents, Traffic [mortality; *prevention & control]; Clothing; Color; Fluorescence; Lighting; Protective Devices; Time Factors

MeSH check words

Humans