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

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TABLE OF CONTENTS

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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 not known.

Objectives

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

Search strategy

We searched the Cochrane Controlled Trials Register, the Injuries Group Specialised Register, MEDLINE, TRANSPORT, TRANSDOC from ECMT (European Conference of Ministers of Transport), IRRD (International Road Research Documentation), TRIS (Transportation Research Information Services), NRR (National Research Register), PsycInfo and PsycLit.

Selection criteria

1. Randomised controlled trials and controlled before/after trials 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 reviewers independently screened records, extracted data and assessed trial quality.

Main results

We found no trials assessing the effect of visibility aids on the occurrence of pedestrian and cyclist-motor vehicle collisions and injuries. We identified 37 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 arranged in a 'biomotion' configuration also enhance recognition. 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. Public acceptability of these strategies would merit further development. However, the effect of visibility aids on pedestrian and cyclist safety remains unknown. Studies which collect data on simple, meaningful outcomes are required.

PLAIN LANGUAGE SUMMARY

Visibility aids have the potential to increase the visibility of pedestrians and cyclists who use these devices, but their effect on safety is unknown

Walking and cycling are promoted for their environmental, economic and health benefits. However, pedestrians and cyclists account for nearly one third of all road traffic deaths. Seeing pedestrians and cyclists too late is one of the most common causes of collisions. Aids, such as reflective garments and flashing lights, in red and yellow colours, aim to enhance visibility and alert drivers in time to avoid collision. The review of trials shows that visibility aids improved drivers' responses in detecting and recognising pedestrians and cyclists. However, no trials were found which studied whether this improves safety for pedestrians and cyclists.

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 2000, there were 42,033 pedestrian and 20,612 bicyclist casualties in the UK (DETR 2001).

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 the cyclists 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 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 condition (DETR 1998). 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

A. Primary
1. To quantify the effect of visibility aids vs 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

B. Secondary
1. To quantify the effect of visibility aids vs 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

CRITERIA FOR CONSIDERING STUDIES FOR THIS REVIEW

Types of studies

A. For primary objectives
. Randomised controlled trials
. Controlled before-and-after trials

B. 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 aids are compared, the order of the presentation of visibility aids is randomised, or balanced (i.e., each aid is presented only once to each observer using a Latin Square design) or counterbalanced (i.e., not all subjects see them in the same order).

Types of participants

A. For primary objectives
Pedestrians and cyclists

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

Motorcyclists and riders of mopeds and other motorised vehicles were excluded.

Types of intervention

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

1. Any visibility aids vs no visibility aids
2. Different visibility aids, such as active vs passive visibility aids
3. Positioning of visibility aids, such as 'biomotion' vs no 'biomotion' marking

Visibility aids for pedestrians, cyclists and bicycles include:

1. Active conspicuity materials such as lights, flashing or non-flashing lamps, light emitting diode, helmet lights and coloured lights

2. 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

Studies investigating visibility of street lighting, traffic signals, road signage, street furniture, road and pavement markings were not considered in this review.

Types of outcome measures

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

B. Secondary
Drivers' responses in detection and recognition as operationally defined by trialists, for example:
1. Reaction times - time taken from when object presented to its detection
2. Detection times - time taken when objects detected to when objects reached
3. Recognition times - time taken when objects recognised as a pedestrian/cycle/cyclist to when objects reached
4. Detection distances - distance from when objects detected to when objects reached
5. Recognition distances - distance from when objects recognised as a pedestrian/cycle/cyclist to when objects reached
6. Frequency of successful object detection and recognition

SEARCH METHODS FOR IDENTIFICATION OF STUDIES

See: methods used in reviews.

The following databases were searched:
The Cochrane Controlled Trials Register (2001)
Specialised register of the Cochrane Injuries Group (2001)
MEDLINE (1966-2001)
TRANSPORT (1963-2001)
TRANSDOC from ECMT (European Conference of Ministers of Transport)(1963-2001)
TRIS (Transportation Research Information Services)(1963-2001)
IRRD (International Road Research Documentation)(1963-2001)
National Research Register (Issue 3, 2001)
PsycInfo/PsycLit (1967-2001)

using the following strategy (with some typographical variations for different electronic databases):

#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

There was no language restriction.

We searched the reference lists of included trials and contacted authors to ask about unpublished studies. We contacted manufacturers of retroreflective and fluorescent materials (e.g., 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 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)

METHODS OF THE REVIEW

Two reviewers (IK, JM) independently examined the electronic search results for possible eligible trials and these were retrieved in full. Two reviewers (IK, JM) applied the selection criteria independently to the trial reports. To assess trial quality, the two reviewers independently extracted information on the type of trials, method of randomisation and allocation concealment, the number of participants in each group, the nature of the intervention and the outcomes in each group, blinding of outcomes assessment and loss to follow up. Differences in data extraction were resolved by discussion. Reviewers were not blinded to the authors or journal when extracting data. Where there was insufficient information in the published report we contacted the authors for clarification.

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 37 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 were presented.

DESCRIPTION OF STUDIES

Our electronic search strategy yielded 1976 reports. Of these no studies met the inclusion criteria for the primary objectives. However, 29 papers reporting 37 trials (two unpublished, one in press) met the inclusion criteria for the secondary objectives; involving 882 participants aged between 17 to 77 years. There were six laboratory-based and 31 road-based simulation trials, the largest and smallest trial involved 65 and four observers respectively. Nineteen trials were conducted in the USA, five in the UK, three in Australia, three in the Netherlands, two in South Africa, two in Israel, one in Canada, one in Sweden and one in Finland.

A. Daytime visibility aids
There were 12 trials which compared the effectiveness of daytime visibility aids; four on pedestrians, two on cyclists/bicycles and six on materials/targets:

1. Pedestrians:
Turner 1997
This trial involved 23 observers who compared the effect of fluorescent and non-fluorescent coloured vests on detection distances.

Michon 1969
This study reported three trials. Trial one 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.
Trial two 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.
Trial three 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.

2. 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.

3. 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 1986
This study reported two trials. The first 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.
Trial two 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.

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.

B. Night-time visibility aids
There were 26 trials (one trial assessed both pedestrian and bicycle/cyclist visibility aids - Blomberg 1986) which compared the effectiveness of night-time visibility aids, 12 on pedestrians, ten on bicycles/cyclists and four on materials /targets:

1. 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.

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 tee 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 vs no retroreflectors, and also the positioning of retroreflectors on major joints (biomotion) vs 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 vs no retroreflectors, and also the positioning of retroreflectors on major joints (biomotion) vs no biomotion, viewed approaching the motorist and crossing the road. The outcome measured was recognition distance.

Moberley 2001
This trial involved 65 observers who compared the effect of the positioning of retroreflectors on major joints (biomotion) vs 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 vs no retroreflectors, and the effect of different retroreflective colours, viewed in a 'noisy' environment. The outcome measured was recognition time.

Owens 1994
Trial one
This trial involved 32 observers who compared the effect of retroreflectors vs no retroreflectors, also the positioning of retroreflectors on major joints (biomotion) vs no biomotion, viewed from a video film of a car journey in four road environments. The outcome measured was detection time.
Trial two
Same as Trial one but involved 20 observers who were given additional distraction tasks.

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.

Shinar 1984
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.

2. Bicycles/Bicyclists
Blomberg 1986
This trials 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 1978
Trial one
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.
Trial two
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.

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 1978
Trial one
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.
Trial two
Same as Trial one but involved four observers.

Watts 1984b
Trial one
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.
Trial two
This trial involved six observers who compared the effect of reflectorised accessories on cyclist and bicycles. The outcomes measured were detection and recognition distances.

3. 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 1991
Trial one
This trial involved seven observers who compared the effect of targets of different retroreflective colours on recognition distance.
Trial two
This trial involved six observers who compared the effect of targets of different retroreflective colours on recognition distance.

The details of each trial are listed in the Table of Included Studies.

METHODOLOGICAL QUALITY

Participants were randomised in two trials (Moberley 2001, Muttart 2000). In another three trials (Cole 1984, Hughes 1986 - two trials), 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 14 trials (Allen 1970, Hanson 1963, Luoma 1996, Luoma 1998, Matthews 1980, Michon 1969 - one trial, Sator 1978 -two trials, Sayer 1998, Shinar 1984, Zwahlen 1991 -two trials, 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 18 trials (Blomberg 1986, Burg 1978 -two trials, CPSC 1997, Johansson 1963, Kumagai 1999, Marsh 1998, Michon 1969 - two trials, Owens 1994 - two trials, Sayer 1999, Shinar 1985, Turner 1997, Watts 1980, Watts 1984a, Watts 1984b - two trials) .

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, Moberley 2001, Muttart 2000, Sayer 1998, Sayer 1999, Zwahlen 1991 - two trials, 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 23 trials (Allen 1970, Burg 1978 - two trials , Cole 1984, Hughes 1986 - two trials, CPSC 1997, Hanson 1963, Johansson 1963, Matthews 1980, Michon 1969 - three trials, Owens 1994 - two trials , Sator 1978 - two trials, Shinar 1984, Shinar 1985, Turner 1997, Watts 1980, Watts 1984a, Watts 1984b).

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 (Moberley 2001), from three and four observers respectively in two trials (Owens 1994 - two trials) and from the first night of testing in one trial (Sator 1978).

Participants in one trial (Marsh 1998) received extra psychology course credit for taking part in the study. Participants were paid in six trials (Burg 1978 - two trials, Luoma 1996, Luoma 1998, Sayer 1998, Sayer 1999). 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 1978).

RESULTS

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

A. Day time visibility aids

Fluorescent colours vs non fluorescent colours

There were nine trials which compared fluorescent colours with non-fluorescent colours. The use of fluorescent colours increased visibility in eight trials but one (Watts 1980). Detection distances improved in two trials (Turner 1997, Hanson 1963), recognition distances in one trial (Hanson 1963) and reaction times in three trials (Michon 1969 - three trials). Detection and recognition frequency were higher with fluorescent colours in two trials (Zwahlen 1994, Zwahlen 1997). In all but three trialsl (Michon 1969, 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 (Turner 1997, Hanson 1963, Watts 1980, Michon 1969 - three trials) 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 1986 - two trials).

Watts 1980
Viewed against a dark and light background, fluorescent colours did not yield a greater detection distance than non-fluorescent colours (62m vs 64m). But fluorescent orange colours yielded a greater detection distance when compared with other fluorescent colours (63m vs 62m). Non-fluorescent yellow yielded a greater detection distance when compared with dark blue (66m vs 63m).

Turner 1997
Fluorescent red-orange coloured vests yielded a greater detection distance when compared with other fluorescent colours (300m vs 242m). For non-fluorescent colours, yellow yielded a greater detection distance when compared with other colours (214m vs 203m).

Hanson 1963
Fluorescent yellow-orange targets yielded a greater detection and recognition distance when compared with other fluorescent colours (184m vs 170m and 134m vs 120m respectively). For non-fluorescent colours, yellow yielded a greater detection and recognition distance when compared with other colours (174m vs 160m and 96m vs 81m respectively).

Michon 1969
Trial one - 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 vs 2.8 sec). For non-fluorescent colours, white and yellow yielded a shorter reaction time when compared with grey (3.3 sec vs 5.8 sec).
Trial two and three - In these two trials, fluorescent orange colour jackets yielded a shorter reaction time when compared with other fluorescent colours (0.9 sec vs 1.1 sec and 0.6 sec vs 0.9 sec respectively). For non-fluorescent colours, yellow yielded a shorten reaction time when compared with a white jacket (0.9 sec vs 1.5 sec and 0.8 sec vs 1.1 sec respectively).

Zwahlen 1994
Fluorescent colours yielded a greater detection and recognition frequency when compared with non-fluorescent colours (85% vs 65% and 49% vs 48% respectively). Fluorescent yellow yielded a higher detection but not recognition frequency when compared with other fluorescent colours (88% vs 81% and 51% vs 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% vs 60% and 45% vs 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% vs 76% and 49% vs 48% respectively). Fluorescent yellow and orange did not yield a higher detection and recognition frequency when compared with other fluorescent colours (83% vs 84% and 40% vs 59% respectively). For non-fluorescent colours, yellow and orange yielded a higher detection but not recognition frequency when compared with other colours (82% vs 76% and 32% vs 56% respectively).

Cole 1984
White coloured discs yielded a higher detection frequency when compared with black or grey colours (46% vs 35%).

Hughes 1986
Trials one and two - white coloured discs yielded a higher detection frequency when compared with black or grey colours (29% vs 15% and 31% vs 21%) respectively.

B. Night-time visibility aids

1. Visibility aids vs no visibility aids

There were thirteen trials which compared the effect of visibility aids vs no visibility aids on driver responses. When compared with no visibility aids the use of visibility aids at night enhanced drivers' detection distances in six trials (Allen 1970, Blomberg

1986, Johansson 1963, Shinar 1984, Shinar 1985, Watts 1984b), recognition distances in two trials (Luoma 1996, Luoma 1998), recognition times in three trials (Muttart 2000, Owens 1994 - two trials) 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 vs 118m). A white jacket yielded a greater visibility distance when compared with a black jacket (138m vs 97m).

Blomberg 1986
A flashlight held by a pedestrian yielded a greater detection and recognition distance when compared with no light (420m vs 68m and 96m vs 32m respectively). The weighted mean differences (WMD) for detection and recognition distance were 352 (95% 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 vs 257m and 147m vs 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 vs 38m). A light grey cloth yielded a greater visibility (detection) distance when compared with grey black cloths (80m vs 38m).

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 vs 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 vs 144m). Light clothing yielded a greater detection distance when compared with dark clothing (156m vs 144m).

Watts 1984b
Trial one
Under both glare and no-glare conditions, a rear lamp and reflectors yielded a greater detection distance when compared with no lamp/reflectors (245m vs 41m).

Luoma 1996
Retroreflectors yielded a greater recognition distance when compared with no retroreflectors (175m vs 38m).

Luoma 1998
Retroreflectors yielded a greater recognition distance when compared with no retroreflectors (193m vs 21m).

Muttart 2000
Retroreflective coloured vests yielded a longer recognition time when compared with no retroreflective coloured vest (4.8 sec vs 2.3 sec). The WMD for recognition time was 2.50 (95% CI 0.50 to 4.50) seconds.

Owens 1994
Trial one and two - retroreflective markings on garments yielded a longer recognition time when compared with no retroreflective markings (3.9 sec vs 0.65 sec and 1.72 sec vs 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 vs 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 vs 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 vs 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 vs 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 vs 237m and 206m vs 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.

2. Active vs passive visibility aids

There were four trials which 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 vs 207m and 96m vs 92m respectively).

Watts 1984b
Trial one
A rear bicycle lamp yielded a greater detection distance when compared with reflectors (306m vs 184m).

Trial two
A flashing beacon on a bicycle yielded a greater detection but not recognition distance when compared with reflectors (588m vs 444m and 59m vs 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 vs 1.09 sec).

3. Retroreflective red, orange and yellow colours vs other retroreflective colours

There were eight trials comparing different retroreflective colours on visibility. Retroreflective red and yellow colours improved detection distances in five trials (Marsh 1998, Sator 1978 - two trials, Sayer 1998, Sayer 1999), recognition distances in three trials (Sator 1978 - trial two, Zwahlen 1991- two trials), 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 vs 170m).

Sator 1978
These two trials only compared red and red-yellow coloured rear reflectors of different levels of luminance.
Trial one
Red-yellow rear retroreflectors yielded a greater detection but not recognition distance when compared with red retroreflectors (189m vs 177m and 92m vs 122m respectively).
Trial two
Red-yellow pedal retroreflectors yielded a greater detection and recognition distance when compared with red pedal retroreflectors (186m vs 92m and 109m vs 66m respectively).

Sayer 1998
Retroreflective markings in red-yellow colours yielded a greater detection distance when compared with retroreflective markings in other colours (108m vs 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 vs 101m).

Zwahlen 1991
Trial one
Retroreflective red-yellow colours yielded a greater recognition distance when compared with other retroreflective colours (226m vs 216m).
Trial two
Retroreflective red-yellow colours yielded a greater recognition distance when compared with other retroreflective colours (232m vs 189m).

Muttart 2000
Retroreflective red vest yielded a longer recognition time than other retroreflective colours (6.2 sec vs 4.1 sec). The WMD for recognition time was 2.10 (95% CI -0.60 to 4.80) seconds.

4. Lights and reflectors vs 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 situation, a red blinking light and reflector combination yielded a greater detection but not recognition distance when compared with reflectors only (147m vs 135m and 125m vs 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 vs 1.1 sec).

5. Reflective tyres vs reflectors

There were two trials (Burg 1978 - two trials) comparing reflective tyres with reflectors on bicycles.

Burg 1978
Trial one and two
Reflectors yielded a greater detection distance when compared with retroreflective tyres (296m vs 232m), but reflective tyres yielded a higher recognition frequency (84% vs 62%). The RR for being recognised when using reflective tyres was 1.32 (95% CI 1.13 to 1.54).

6. 'Biomotion' vs 'no-biomotion' retroreflectors

There were four trials comparing 'biomotion' with no 'biomotion' markings.

Visibility aids in a 'biomotion' configuration enhanced recognition distances in two trials (Luoma 1996, Luoma 1998), recognition times in two trials (Owens 1994 - two trials), but not detection in one trial (Moberley 2001).

Luoma 1996, Luoma 1998
In these two trials, biomotion retroreflectors yielded a greater recognition distance when compared with no biomotion retroreflectors (209m vs 157m and 209m vs 185m respectively).

Owens 1994
In both trials, biomotion retroreflectors yielded a longer recognition time when compared with no biomotion retroreflectors (4.3 sec vs 3.7 sec and 2.4 sec vs 1.4 sec respectively).

Moberley 2001
Biomotion retroreflectors did not yield a greater detection distance when compared with no-biomotion retroreflectors (41m vs 52m).

The WMD for detection distance was -11.00 (95% CI -74.33 to 52.33) metres.

DISCUSSION

We did not find any randomised controlled trials or controlled before-and-after trials which compared the effect of visibility aids vs 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 reviewed do 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.

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 recently 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.

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.

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 37 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. 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' (Hills 1980, Gale 1996). 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). It has also been argued that laboratory trials which use films, video or slides presentation of visibility aids do not adequately reproduce the quality of lights and reflective or fluorescent materials in a real life setting (Cairney 2001).

Based on these 37 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. However, 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 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 effort to quantify their effect on pedestrian and cyclist safety.

The potential impact of visibility aids in reducing pedestrian and cyclist death and injuries needs to be determined. A cluster randomised controlled trial involving large communities may provide the answer to this question.

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. 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 simple, meaningful outcomes 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.

POTENTIAL CONFLICT OF INTEREST

None known.

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* *Indicates the major publication for the study*

TABLES

Characteristics of included studies

Study	**Allen 1970**
Methods	Randomised order of aids presentation Allocation concealment unclear
Participants	Six observers as front seat passengers Age range 21-23 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
Allocation concealment	B – Unclear

Study	**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: 20-33 years Normal vision
Interventions	A. Pedestrian Five treatments: 1. Baseline - white tee shirt 2. Dangle tags - reflective disks

Characteristics of included studies (*Continued*)

	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 tee 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
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
Allocation concealment	C – Inadequate

Study	**Burg 1978**
Methods	A. Trial one Counterbalanced order of aids presentation Allocation concealment unclear B. Trial two Same as Trial one
Participants	A. Trial one Eight paid observers in driver's seat Age range: 19-62 years Normal vision Licensed drivers B. Trial two Thirty-two paid observers in driver's seat Age range: 19-62 years Normal vision Licensed drivers
Interventions	A. Trial one 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 B. Trial two Four retroreflective treatments: 1. 20-inch tyre (High reflectance)

Characteristics of included studies (*Continued*)

	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 in both trials
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 B. Trial two Same as Trial one
Allocation concealment	B – Unclear

Study	**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: 25-44 years
Interventions	Bicyclist helmet treatments: 1. Non-reflective helmet 2. Reflective helmet viewed in a 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
Allocation concealment	B – Unclear

Study	**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: 18-26 years Normal vision
Interventions	Five disc target treatments: 1. White - diameter 70cm 2. White - diameter 50cm

Characteristics of included studies (*Continued*)

	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
Allocation concealment	B – Unclear

Study	**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
Allocation concealment	B – Unclear

Study	**Hughes 1986**
Methods	A. Trial one Randomisation of participants into two groups - the randomised order of aids presentation in each group Allocation concealment unclear B. Trial two Same as Trial one
Participants	A. Trial one Fifty observers (18F; 32M) Age range: 18-29 years

	Normal vision B Trial two Fifty observers (18F; 32M) Age range: 18-29 years Normal vision
Interventions	A. Trial one 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	A. Trial one 1. Setting - laboratory (Daytime) 2. Disc targets shown in slides 3. Blinding of outcome assessment not stated B. Trial two Same as Trial one
Allocation concealment	B – Unclear

Study	**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
Allocation concealment	B – Unclear

Study	**Kumagai 1999**
Methods	Cross-over design of a multiple number of Latin squares

Characteristics of included studies (*Continued*)

	Order of presentation known to trialist
Participants	Forty-eight observers as drivers (24 F; 24M) Age range: 25-44 years Two colour blind, rest normal vision 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 32-40km/h 4. Outcome assessment by statistician not involved in the trial 5. Unpublished methodological details provided by author
Allocation concealment	C – Inadequate

Study	**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: 20-77 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)

Characteristics of included studies (*Continued*)

	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
Allocation concealment	C – Inadequate

Study	**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: 20-68 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
Allocation concealment	C – Inadequate

Study	**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: 18-27 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

Characteristics of included studies (*Continued*)

	3. Vehicle speed not stated 4. No blinding in outcome assessment 5. Unpublished methodological details and outcomes data provided by author
Allocation concealment	C – Inadequate

Study	**Matthews 1980**
Methods	Randomised order of aids presentation Allocation concealment unclear
Participants	Thirty-two observers (18F; 14M) Mean age: 21 Normal vision Licensed drivers
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
Allocation concealment	B – Unclear

Study	**Michon 1969**
Methods	A. Trial one - Randomised order of aids presentation B. Trial two - Latin square design C. Trial three - Latin square design Allocation concealment unclear
Participants	A. Trial one Ten observers in driver's cabin (six normal vision, four colour deficient) B. Trial two: Sixteen observers as drivers Licensed drivers B. Trial Three Twelve observers as drivers Licensed drivers
Interventions	A. Trial one 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 B. Trial two 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. C. Trial three 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	A. Trial one 1. Setting: off-road (Daytime) 2. Subject in 'mock-up' cabin 3. 'Jackets' mounted on levers 4. Blinding of outcome assessment not stated B. Trial two 1. setting: on-road (Daytime) 2. Jacket model on 'cardboard' 3. vehicle speed 50 km/h 4. Blinding of outcome assessment not stated C. Trial three Same as Trial two
Allocation concealment	B – Unclear

Study	**Moberley 2001**
Methods	Randomisation of participants Allocation by order of arrival of the observers
Participants	Sixty-five observers (37 F; 28M) Age range: 17-52 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
Allocation concealment	C – Inadequate

Study	**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: 17-70 years Normal vision Licensed drivers Subjects recruited by advertisement , also members of research center
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
Allocation concealment	C – Inadequate

Study	**Owens 1994**
Methods	A. Trial one Counterbalanced order of aids presentation (Latin square design) Allocation concealment unclear B. Trial two Same as Trial one
Participants	A. Trial one Thirty-two undergraduates (17 F; 15 M) B. Trial two Twenty paid undergraduates (8 F; 12 M)
Interventions	A. Trial one Pedestrians

Characteristics of included studies (*Continued*)

	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. 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)
Allocation concealment	B – Unclear

Study	**Sator 1978**
Methods	A. Trial one Randomised order of aids presentation Allocation concealment unclear B. Trial two Same as Trial one
Participants	A. Trial one Thirty-one observers as drivers (1 F; 30 M) Age range: 26-59 years Licensed drivers Subjects were all staff or members of the research centre Trial two Four observers as drivers No demographic details
Interventions	A. Trial one 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) B. Trial two 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	A. Trial one 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 B. Trial two 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
Allocation concealment	B – Unclear

Study	**Sayer 1998**
Methods	Randomised order of aids presentations Order of presentation known to trialist
Participants	Sixteen paid observers in driver seat: Age range: 20-73 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
Allocation concealment	C – Inadequate

Study	**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

Characteristics of included studies (*Continued*)

	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
Allocation concealment	C – Inadequate

Study	**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:18-55 years Normal vision
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
Allocation concealment	B – Unclear

Study	**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: 20-58 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

Characteristics of included studies (*Continued*)

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 5. Unpublished methodological details provided by author
Allocation concealment	B – Unclear

Study	**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: 19-54 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
Allocation concealment	B – Unclear

Study	**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: 19-66 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

Characteristics of included studies (*Continued*)

	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 4. Blinding of outcome assessment not stated
Allocation concealment	B – Unclear

Study	**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: 18-67 years Normal vision in all but one observer
Interventions	Bicyclists Six fluorescent green yellow treatments: 1. Jacket 2. Waistcoat 3. Hat 4. Armbands 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 3. Vehicle stationary 4. Blinding of outcome assessment not stated
Allocation concealment	B – Unclear

Study	**Watts 1984b**
Methods	A. Trial one Balanced order of aids presentations (Latin Square design) Allocation concealment unclear B. Trial two same as Trial one
Participants	A. Trial one Ten observers as drivers Age range: 22-70 years B. Trial Two: Six observers as driver

Characteristics of included studies (*Continued*)

	Age range: 22-66 years
Interventions	A. Trial one Bicycles Three treatments: 1. Rear lamp 2. Red reflectors 3. Lamp and reflectors covered - rider in dark jacket (control) viewed under two glare conditions B. Trial two 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	A. Trial one 1. Setting: on-road (Night-time) 2. Stationary bicycle 3. Vehicle speed 35km/h B. Trial two 1. Setting: on-road (Night-time) 2. Test cyclist rode bicycle on rollers 3. Vehicle speed 35km/h Blinding of outcome assessment not stated in both trials
Allocation concealment	B – Unclear

Study	**Zwahlen 1991**
Methods	A. Trial one Randomised order of aids presentation (Randomised block design) Order of presentation known to trialist B. Trial two Same as Trial one
Participants	A. Trial one Seven observers in car Mean age: 21 years B. Trial two Six observers in car Mean age 23.3 years Normal vision
Interventions	A. Trial one Six reflectorised colour target treatments: 1. Red 2. Blue 3. Orange 4. Green

	5. white 6. yellow B. Trial two Six reflectorised colour target treatments: 1. Red 2. Blue 3. Orange 4. Green 5. white 6. yellow
Outcomes	Recognition distance
Notes	A. Trial one 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 B. Trial two Same as Trial one
Allocation concealment	C – Inadequate

Study	**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: 20-22 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
Allocation concealment	C – Inadequate

Study	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
Allocation concealment	C – 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

Study	Reason for exclusion
Austin 1974	Subjective outcome measurements of perceived visibility
Beith 1982	Conspicuity aids used by coal-miners in mines
Cairney 1992	No randomisation process
Connors 1975	Cockpit simulation
Hazlett 1968	Participants were exposed to alcohol prior to conspicuity aids
Hills 1975	Unclear methodology
Isler 1997	Conspicuity garments used by forestry workers in forest environment
Ryan 1998	Subjective outcome measurements of perceived brightness
Sator 1976	Subjective outcome measurements of visibility scale
Schmidt-Clausen 1982	Unclear methodology

Characteristics of excluded studies (*Continued*)

Schmidt-Clausen 1987	Unclear methodology
Summala 1980	Driving speed as outcome measures

GRAPHS AND OTHER TABLES

This review has no analyses.

INDEX TERMS

Medical Subject Headings (MeSH)

Accidents, Traffic [mortality; *prevention & control]; *Bicycling

MeSH check words

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COVER SHEET

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