

The effectiveness of intervention strategies to reduce motor vehicle crashes involving older drivers. A preliminary report on the systematic review.

A Report Prepared by the
BC Injury Research and Prevention Unit



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Foreword

The British Columbia Injury Research and Prevention Unit (BCIRPU), directed by Dr. Ian Pike, was established by the Ministry of Health and Minister's Injury Prevention Advisory Committee in August 1997. BCIRPU opened its doors in January 1998. It is housed within the Centre for Community Child Health Research (CCCHR) at the Children's & Women's Health Centre of British Columbia and supported by the B.C. Research Institute for Children's & Women's Health. The central tenet of the Unit is: *The reduction of unintentional injuries in B.C., through the support and evaluation of effective prevention measures, and the establishment of ongoing injury surveillance across the province.*

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Executive Summary

Summary Statement: A systematic review of the current literature was undertaken to evaluate the efficacy of various intervention strategies for reducing the risk and rate of motor vehicle crashes (MVC) involving older drivers. Six different types of strategies which included: driver-related, vehicle-related, road infrastructure-related, clinical-related, legal- and policy-related, and screening strategies were assessed for effectiveness. Further, risk factors pertaining to older driver-related MVCs were researched. Based on the collective evidence, a plan has been formulated for a comprehensive final report of all the systematically searched publications for the period 1990 to 2007 related to older driver safety.

Introduction: One of the leading causes of unintentional injury death in Canada is MVC (38%). Older drivers are a growing segment of the population and account for 35 percent of the injury-related hospitalizations in Canada. MVC rates for older drivers tend to be comparable to rates for young, less experienced drivers, and prevention initiatives are needed to reduce associated risk factors and enhance safety for older drivers. This report, commissioned by the BC Ministry of Health, is a preliminary step in a larger process that will provide a systematic review of the evidence to support the effectiveness of intervention strategies to reduce the burden of injury among older drivers.

Search strategy: The following electronic databases were searched for the period 1990 to 2007: Cinahl, EBM Reviews (Cochrane DSR, ACP Journal Club, DARE, CCTR) Embase, ERIC, Medline, Proquest, PsycInfo, Transport (NTIS, TRIS, TRANSDOC, IRRD), and Web of Science.

Selection Criteria: Studies evaluating prevention or intervention strategies, including screening, which aimed to prevent motor vehicle injuries among older drivers, were included in the review. Eligible study designs included: randomized controlled trials (RCT), quasi-experimental, case-control, before/after, and cohort studies. The study population included drivers over 55 years of age and the study outcomes incorporated crash rates, injury rates, frequency of injuries, or change in drivers' knowledge or skills (excluding self-reported data).

Data analysis and results: The search retrieved a total of 200 articles, and 66 articles met the criteria for inclusion. The studies were categorized based on intervention strategies that included: driver-related interventions (12 articles), vehicle-related interventions (10 articles); road-infrastructure-related interventions (4 articles), 2 clinical-related interventions and legal and policy interventions that yielded 10 articles. Twenty-eight articles were categorized as screening interventions. The significant methodological aspects and results of each study are listed (Appendix B). The search demonstrated a lack of statistically significant research related to randomized controlled trials (RCTs). Search results showed that most of the interventions were evaluated using ecological designs¹.

Authors' Comments: The authors realize the level of difficulty in conducting randomized controlled trials and controlled before and after study designs, particularly when the intervention being evaluated is a law. Also, to further enhance the efficiency of evaluating ecological studies, it is important to consider the recruitment or inclusion of participants based upon their exposure, outcome and potential confounding factors. Appropriate statistical methods can be used to control for confounding factors.

Strategy for Final Report: Formulating the final report will involve the following steps:

¹ Ecological designs are defined as, studies where a comparison is made between populations rather than individuals and the intervention is not subject to the influence of the investigators.

- 1) Selected studies that have met the inclusion criteria will undergo a comprehensive quality assessment before they are included for the final systematic review.
- 2) The relevant data will be abstracted for comprehension and statistical purposes.
- 3) Meta-analyses will be performed for RCT studies in which the study populations and intervention strategies are comparable. This will be conducted for each identified intervention category.
- 4) A new literature search for studies published in 2007 will be conducted so as to ensure the systematic review contains the most recent and relevant published literature

The full report will be inclusive of all systematically searched publications for the 1990 to 2007 for interventions related to older drivers' safety.

Abstract

Background: The older driver population is continuing to increase and their increasing age is accompanied by cognitive and physical changes that may negatively affect their driving abilities. Older drivers tend to exhibit higher rates of motor vehicle crashes, similar to rates associated with young inexperienced drivers. Coupled with the increasing number of older drivers, this situation is a growing concern to health, safety and insurance professionals; one which must be addressed.

Objectives: To evaluate the effectiveness of intervention strategies aimed at older drivers. In particular, those intended to reduce motor vehicle crash rates, injury rates, frequency of injuries and rate of change in older drivers' level of knowledge and/or skill (excluding self-report data).

Search strategy: The following electronic databases (1990-2007) were searched: Cinahl, EBM Reviews (Cochrane DSR, ACP Journal Club, DARE, CCTR), Embase, ERIC, Medline, Proquest, PsycInfo, Transport (NTIS, TRIS, TRANSDOC, IRRD) and Web of Science.

Data collection & analysis: Two reviewers independently extracted articles based on the study title and abstract, inclusion/exclusion criteria, type of study and characteristics of intervention strategies. The results of the eligible reviews were compiled and tabulated.

Main results:

Included Intervention Studies

Intervention Type	RCT	Quasi-experimental	Before/After	Case-control	Cohort	Total
Driver-related	6	1	1	3	1	12
Vehicle-related	1	5	0	3	1	10
Road-infrastructure-related	0	0	0	4	0	4
Clinical	0	0	1	0	1	2
Legal/Policy-related	0	1	1	3	5	10
Screening	0	9	0	9	10	28
Totals	7	16	3	22	18	66

Authors' conclusions: Available evidence suggests that extensive research has been conducted in identifying the potential risk factors for motor vehicle crashes involving older drivers. In terms of the intervention strategies, there has been much emphasis on screening interventions, but very little research is related to road-infrastructure and clinical interventions. Many studies have documented that older drivers experience difficulty as the complexity of the driving experience increases; for example, a complex traffic control device such as intricate traffic light patterns. This indicates the importance of adopting safety measures for older drivers such as older driver-friendly vehicle crash avoidance technologies, enhancing crashworthiness of the vehicle design and improving highway design and operations. In addition the literature highlights the relationship between cognitive function and driving performance of older drivers. Evidence suggests that screening procedures must not be focused solely on the older drivers' shortcomings, such as deteriorating vision or reduced dexterity, but also on possibilities for maximizing the driver's mobility. When driving becomes no longer possible for the elderly, potential alternatives focusing on coping strategies and effective transport systems should be provided. Since driving is an important skill required for the well being and independence of the elderly, great care and consideration should be given to the design of future evidence-based traffic safety policies for older drivers.

The search also concluded that there were a limited number of RCTs and controlled before/after study designs, illustrating a need for additional research using improved study designs. Randomized controlled trials, with adequate allocation and blinding are required to improve the bases of evidence. Well conducted non-randomized trials are also recommended, when random allocation is not feasible.

Background

Injuries, both unintentional and intentional, are an important public health problem in Canada (Government of Canada, 1999). Each year, more than 13,000 Canadians die and over 200,000 are admitted to hospitals due to injuries, accounting for an estimated 2-million hospital days. Injuries account for 9% of all acute care hospitalizations, and the average length of stay is 10-days (Canadian Institute for Health Information; CIHI, 1999). The leading causes of unintentional injury death in Canada are motor vehicle crashes (38%), falls (31%), poisonings (9%), drowning and suffocation (5%), and fires (4%) (Government of Canada, 1999). Injury death rates are high among the elderly, largely due to the impact of falls and motor vehicle crashes. Collectively, the social cost of motor vehicle crashes to Canadians is at least \$10 billion per year (about 1% of GDP) (Transport Canada, 2007). Recent estimates suggest that injuries cost Canadians \$14.3 billion each year, with \$3.1 billion spent on health care (Minister of Public Works and Government Services Canada, 1997).

While seniors currently comprise 12% of the Canadian population, they account for 35% of all injury hospitalizations. In addition to the substantial economic costs of seniors' injuries, the impact due to their loss of independence is also considerable. It is estimated that 20% of seniors who enter a hospital for injury treatment are permanently relocated from their private residences to institutionalized care. Unintentional injuries among seniors receive relatively little attention in comparison to injuries in other age groups and to other health problems in Canada (http://www.phac-aspc.gc.ca/seniors-aines/pubs/workshop_healthyaging/pdf/injury_prevention_e.pdf, 2001).

On the basis of kilometres driven, older drivers are involved in approximately the same number of motor vehicle crashes as drivers aged 16 to 24 years. However, the research related to the risk that older drivers pose is not conclusive. It is known that seniors are more likely to die from their injuries or take longer to recover. In 1996, although seniors represented 11% of the population, they accounted for 18% of all fatalities and 6% of injuries occurring on Canadian roadways (http://www.phac-aspc.gc.ca/seniors-aines/pubs/workshop_healthyaging/pdf/injury_prevention_e.pdf, 2001). According to Transport Canada, 61.5% of mature drivers (65 years old or over) were killed in fatal crashes and 23% suffered non-fatal injuries in MVC (in 1998). In addition, mature drivers accounted for 7% of all drivers in casualty-producing collisions. They represented 15.6% of all driver fatalities in 1998 (Transport Canada, 1998).

As older adults continue to make up an increasing proportion of the population, they become a more important consideration when designing future evidence-based traffic safety policies. For example, Statistics Canada projects that the oldest segment of the population, those 85 years and older who are most affected by age-related changes on their driving, will increase by 37.8% between 2001 and 2011 (Transport Canada, 1998). Furthermore, a greater proportion of older individuals, particularly women, will be licensed to drive and will drive more often and more consistently than the current cohort of older drivers. Both, this demographic shift and the increased driving exposure will allow for the number of crashes involving older drivers to increase.

This situation requires that a greater emphasis be placed on fitness-to-drive assessments, as practical approaches to help facilitate a reduction in motor vehicle crashes in the elderly population is essential. However, it seems that there is little evidence-based information to help physicians make informed decisions regarding older drivers' medical fitness to drive (Molnar, Byszewski, Marshall, & Man-Son-Hing, 2005). Research has shown that the current procedures for medical fitness-to-drive testing are imprecise and that the evidence for the tools is rather

weak (Molnar, Byszewski, Marshall, & Man-Son-Hing, 2005). Therefore, there is great concern among physicians and the transportation safety community, as the proportion of British Columbians aged 65 years and over will double by 2028 (Table 1). This will significantly increase the economic and personal burden of unintentional injuries in this population if this current pattern continues. Data from the Canadian National Population Health Survey (NPHS) show that within the baby boom cohort over 90% of men and 90% of women hold a driver's license (Porter, 2004). As these people age, their sensory, perceptual, cognitive and physical functions will decline.

From 2005-2025, the number of licensed drivers 65 years and older is expected to double (Statistics Canada, <http://www.bcstats.gov.bc.ca/data/pop/pop/project/bctab3.htm>), however this projection may underestimate the number of older drivers as the rate of driving in the general population is increasing. Recent data from the U.S., Australia, Germany, New Zealand, Norway, and the United Kingdom suggests that compared to a decade ago, older people are more likely to have a license, to take more trips and are likely to do this more often as the driver of the vehicle (Millar, 1999). This study also highlighted that the elderly are less likely to use public transit.

Table 1: BC population growth projection by age group, 2005-2031

Year	15-24 yrs	Index 2005=100	25-44 yrs	Index 2005=100	45-64 yrs	Index 2005=100	65+ yrs	Index 2005=100
2005	579.6	100.0	1231.4	100.0	1149.7	100.0	751.5	100.0
2006	582.2	100.4	1232.2	100.0	1183.9	102.9	772.1	102.7
2007	582.1	100.4	1237.3	100.4	1217.0	105.8	792.3	105.4
2008	579.6	100.0	1243.0	100.9	1250.2	108.7	813.2	108.2
2009	576.2	99.4	1251.8	101.6	1281.3	111.4	834.8	111.0
2010	573.4	98.9	1264.8	102.7	1309.0	113.8	856.4	113.9
2011	571.9	98.6	1280.3	103.9	1330.4	115.7	880.2	117.1
2012	570.2	98.3	1297.3	105.3	1340.1	116.5	911.9	121.3
2013	567.6	97.9	1313.5	106.6	1351.2	117.5	943.1	125.4
2014	563.7	97.2	1329.3	107.9	1364.7	118.7	972.8	129.4
2015	558.4	96.3	1344.5	109.1	1377.7	119.8	1004.0	133.5
2016	552.5	95.3	1359.0	110.3	1390.1	120.9	1035.1	137.7
2017	546.0	94.2	1376.8	111.8	1397.7	121.5	1066.6	141.9
2018	540.8	93.3	1394.1	113.2	1403.0	122.0	1099.3	146.2
2019	536.0	92.4	1411.2	114.6	1405.6	122.2	1134.1	150.9
2020	530.9	91.5	1427.7	115.9	1406.8	122.3	1171.1	155.8
2021	526.6	90.8	1442.9	117.1	1408.1	122.4	1209.3	160.9
2022	524.8	90.5	1455.2	118.1	1409.4	122.5	1248.0	166.0
2023	525.1	90.5	1465.1	118.9	1410.2	122.6	1289.0	171.5
2024	527.0	90.9	1471.7	119.5	1413.5	122.9	1329.6	176.9
2025	529.9	91.4	1475.0	119.7	1418.0	123.3	1370.2	182.3
2026	534.1	92.1	1475.3	119.8	1424.6	123.9	1411.2	187.7
2027	539.8	93.1	1471.7	119.5	1434.5	124.7	1457.3	193.9
2028	545.0	94.0	1466.6	119.1	1444.3	125.6	1504.6	200.2
2029	551.0	95.0	1460.4	118.5	1456.1	126.6	1548.9	206.1
2030	557.4	96.1	1454.1	118.0	1471.1	127.9	1589.6	211.5
2031	563.7	97.2	1449.8	117.7	1488.0	129.4	1625.1	216.2

Source: Statistics of Canada-British Columbia's Population statistics and projection-Statistics <http://www.bcstats.gov.bc.ca/data/pop/pop/project/bctab3.htm> Canada.

Many injury risk factors can be modified when appropriate interventions are in place. However, many interventions are implemented as time-limited programs with limited resources. To date, no single systematic review on older drivers' safety has been completed to determine the effectiveness of interventions to reduce older drivers' injury and fatality. The older driver population is often ignored politically, even though the highest risk of crash per miles driven is among drivers 65 years and over. More efforts to identify risk factors for crash events, to support randomized, population-based clinical trials and to critically evaluate promising interactions based on these risk factors need to be established and funded (Wister, Carriere, Sauter, & McWhirter, 2000).

The fact that older drivers do not represent a major road safety problem in most motorized societies when compared with other age groups, such as young drivers, may partially account for this negligence. However, older drivers are involved in significantly more serious injury and casualty crashes per capita. Furthermore, as older drivers are likely to become a more significant problem in the years ahead, it is necessary to begin examining evidence-based strategies that enhance the safety of older drivers. Given the rapid increase in the older adult population, it is imperative to invest in motor vehicle injury prevention and to plan for social and environmental change.

Visual attention problems have been shown to predict increased crash involvement in older adults, and these crashes are much more likely to result in injury and long-term disability or death than those involving younger individuals. Interventions that improve cognitive skills such as visual attention can reduce crash involvement and improve mobility. Continued mobility fosters independence, thereby improving quality of life, enhancing productivity, and minimizing the need for specialized care among older people (Rosenbloom, 2001).

Safe driving relies on key skills involving visual, cognitive, and physical capabilities. Impairments in these functional capabilities can occur at any age but are more prevalent in the older population. A clear understanding of how diminished capabilities contribute to crash risk in older drivers would greatly facilitate society's efforts to develop strategies for reducing crash rates in this population and to enhance driving mobility. Restrictions to mobility from policy or age-related declines in driving capability, limit the lifestyles of older people. Maintaining an independent and meaningful lifestyle that is supported by driving requires an array of policy, service, infrastructure, and technical solutions. The purpose of this systematic review of the literature is to identify best practices and model programs related to safe mobility for older drivers, and to educate policy makers and practitioners in the fields of transportation, health, seniors' services, and law enforcement regarding which policies and initiatives should be undertaken in BC to address this critical issue.

Older driver crash prevention strategies

Three suggested methods for increasing older driver safety are: optimizing the driver; optimizing the driving environment, and optimizing the vehicle (Consdorf, 2004; Dissanayake, Lu, & Yi, 2002; Takayuki, Atsumi, Hitoshi, & Miyayo, 2002). Under these three major themes we have elected to further breakdown intervention strategies as follows: driver-related interventions; vehicle-related interventions; road-infrastructure related interventions; clinical interventions; legal and policy interventions; and screening interventions.

Objectives

The overall objective of this systematic review is to critically evaluate the effectiveness of interventions reducing older driver-involved motor vehicle crash rates, injury rates, frequency of injuries, or change in drivers' knowledge or skill (excluding self-reported data). Subsequent objectives of this systematic review are to identify effective strategies to prevent older driver motor vehicle crashes in BC to:

- (1) Increase political awareness in the province - priorities for changes are only meaningful if they are embraced by policy makers and others with the capability to effect change.
- (2) Provide evidence-based practices and strategies for older driver motor vehicle crash prevention to the policy makers and stakeholders in BC.
- (3) Consider implementation of evidence-based approaches which may be inhibited, if political concerns based on a perceived restriction of the privileges and activities of older adults are raised by this systematic review. As this could lead to deaths from motor vehicle crashes among older adults in BC, and if the trend continues, the death rate could possibly surpass that of falls in the near future².
- (4) Conduct further research into the validity of current older drivers' safety strategies, thereby, enhancing our knowledge of the best available procedures for BC. More evidence-based research is required to help policy makers frame future guidelines and legislation, so as to promote safe mobility among older adults. This systematic review will provide comprehensive information on currently available global best practices as they apply to the situation in BC.

Criteria for considering studies for this review

Types of studies

All randomized controlled trials (RCTs) (where they exist) comparing crash rates among older drivers, before and after an intervention will be included. In the absence of RCTs evaluating an intervention, quasi-experimental, case-control, before/after, or cohort studies will be considered for inclusion. Studies must include one or more of the primary outcomes of interest: crash rates, injury rates, frequency of injuries, or change in driver knowledge or skill.

Types of participants

Participants must be motor vehicle drivers aged 55 years and older, without any known mental deficiencies.

Types of interventions

Driver-related (including education, self-regulation), vehicle-related, road infrastructure-related, clinical, legal and policy, and screening interventions will be considered for inclusion.

Types of outcome measures

Studies were included if any of the following were recorded as outcome measures:

Crash rates, injury rates, frequency of injuries, change in driver knowledge or skill (excluding self-reported data).

Search methods for identification of studies

The search was international, using published research to be considered for inclusion according to the methodology and quality of the study. Keywords and the synonyms used by respective databases were used in an extensive literature search (see Table 2 for the full search strategy). Full

² We have seen the positive effects of falls prevention initiatives in British Columbia, and we believe that with similar attention, there could be a reduction in motor vehicle related injuries in the elderly. If left unchecked, it is our contention that the rate of motor vehicle related injuries and mortality may surpass that of mortality due to falls in the elderly.

copies of articles identified by the search, and considered to meet the inclusion criteria based on title, abstract and subject descriptors, were obtained for data synthesis.

Published studies

In collaboration with a librarian, comprehensive search strategies have been developed, and the following electronic databases were searched (1990 to present):

CINAHL;

EBM Reviews (Cochrane DSR, ACP Journal Club, DARE, CCTR);

EMBASE;

ERIC;

MEDLINE;

Proquest;

PsycINFO;

TRANSPORT (NTIS, TRIS, TRANSDOC, IRRD);

Web of Science

Table 2: Electronic databases and search strategies	
<i>Database</i>	<i>Search Strategy</i>
Cinahl (Ebscohost version): Limit to 1990-2007	<ol style="list-style-type: none"> 1. older OR elderly OR aged 2. senior OR retired 3. 1 OR 2 4. driver OR motorist 5. motor vehicle OR car 6. 4 OR 5 7. 3 AND 6 8. older driver 9. 7 OR 8
EBM Reviews (OVID Version): Limit 1990-2007	<ol style="list-style-type: none"> 1. exp Aging OR exp Age Factors/ OR exp Aged/ OR exp "Aged, 80 and over" / 2. exp Aged/ 3. exp Retirement/ OR exp "Aged 80 and over" / OR exp Aging/ OR exp Aged/ 4. OR/1-3 5. exp Automobile Driving/ OR exp Automobile Driver Examination/ OR exp Accidents, Traffic/ 6. exp Accidents, Traffic/ OR exp Automobile Driving/ OR exp Automobile Driver Examination/ 7. 5 OR 6 8. exp Accidents, Traffic/ OR exp Automobiles/ OR exp Motor Vehicles/ OR exp Protective Devices/ 9. exp Seat Belts/ OR exp Automobiles/ OR exp Accidents, Traffic/ OR exp Automobile Driving/ 10. OR/7-9 11. 4 AND 10 12. older driver\$.mp. 13. 11 OR 12
Embase (OVID Version): Limit 1990-2007	Same as EBM Reviews
ERIC (Ebscohost Version): Limit 1990-2007	Same as Cinahl
Medline (OVID Version):	Same as EBM Reviews, Embase

Limit 1990-2007	
Proquest: Limit 1990-2007	Same as Cinahl, ERIC
PsycInfo (Ebscohost Version): Limit 1990-2007	Same as Cinahl, ERIC, Proquest
Transport: Limit 1990-2007	Same as Cinahl, ERIC, Proquest, PsycInfo
Web of Science: Limit 1990-2007	<ol style="list-style-type: none"> 1. older 2. elderly 3. aged 4. senior* 5. retired 6. OR/1-5 7. driver* 8. motorist* 9. 7 OR 8 10. car* 11. motor vehicle* 12. automobile* 13. OR/10-12 14. 9 OR 13 15. 6 AND 14 16. older driver* 17. 15 OR 16

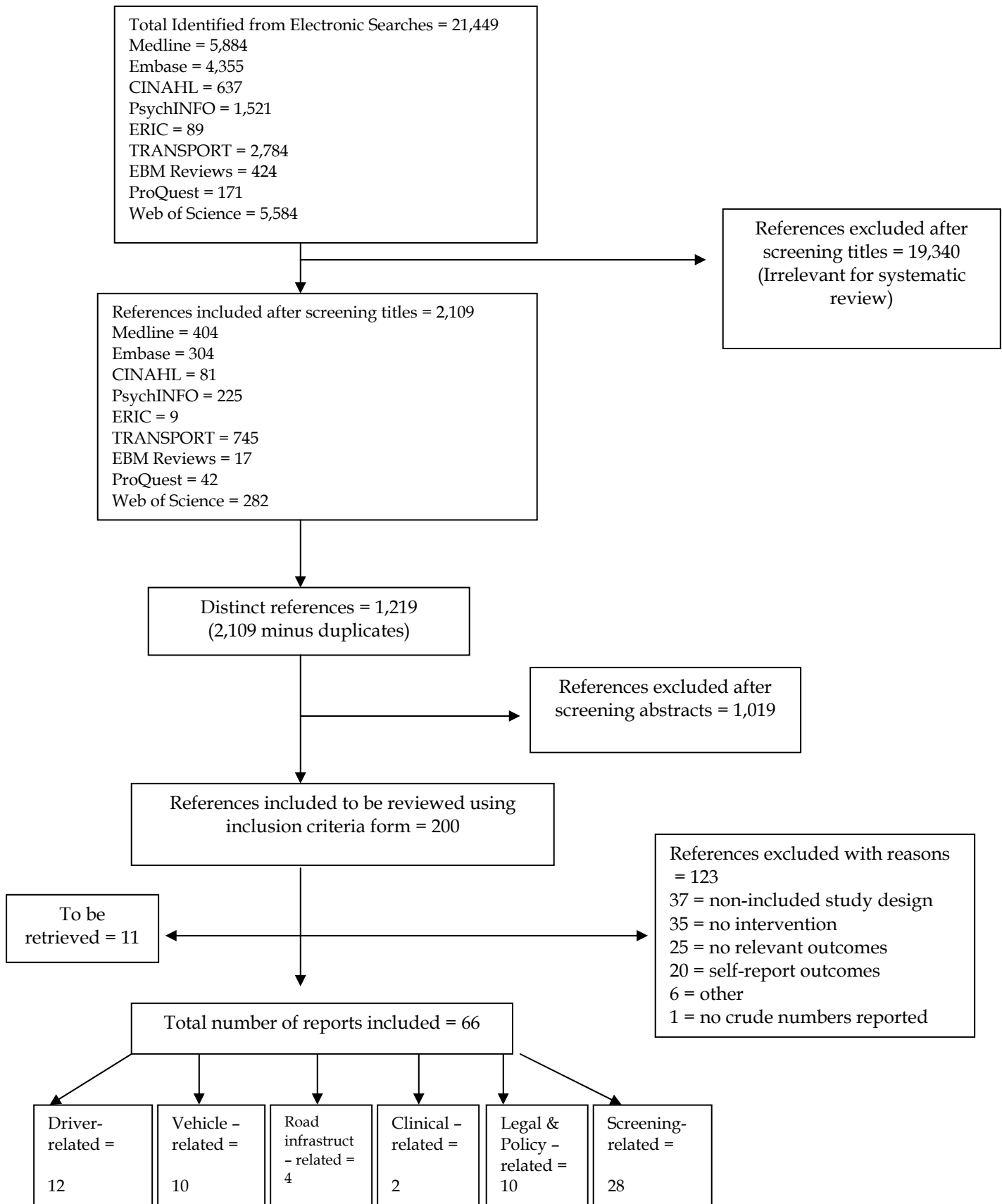


Figure 1: Search strategy and selection of articles for final review

Methods of the review

Study identification and selection

Eligible reviews were selected from the search outputs. Two reviewers (GS & ED) assessed all search results independently for applicable articles based on the titles and abstracts (where available).

Inclusion data extraction

Two reviewers (GS & ED) independently extracted inclusion data from each eligible study using a standardized inclusion criteria form. Data was extracted based on the type of intervention, type of study and the type of outcome. Discrepancies found in data extraction were resolved through discussions, among the two reviewers (GS & ED). A third reviewer (SB) was involved if necessary. A list of excluded studies and the reasons for exclusion, along with a comprehensive methodological quality appraisal will be provided in the final report.

Assessment of methodological quality

There are established approaches to quantify or rank the studies for methodological quality. Several tools are available for validating the primary studies and many are still being developed. At present, there exists no gold standard instrument for assessing the methodological quality of studies. The Cochrane guidelines for systematic reviews (Alderson, Green, & Higgins, 2004) will be used to assess methodological quality for the RCTs, and the guidelines for the additional study designs are listed below.

Assessment of quality of RCTs

The quality of individual study components such as randomization, adequate allocation concealment methods, blinding and patient follow-up will be assessed. Key definitions from Cochrane guidelines for systematic reviews (Alderson, Green, & Higgins, 2004), will be used to determine the quality of selected studies. The elements inherent in a carefully designed and well conducted RCT will minimize sources of bias, balance for confounders, and hence produce reliable estimates of treatment effect. Each included trial will be assessed using a comprehensive checklist found in the Cochrane handbook to ensure methodological quality. Quality assessment will be performed independently by two reviewers (ED & GS). Disagreements will be resolved by discussion between the reviewers.

In the absence of RCTs, quasi-experimental, case-control, before/after, and cohort studies will be considered for inclusion. The following methodological criteria will be used to assess the relevant studies:

- (1) Study design
- (2) Data collection methods
- (3) Assessment of comparability of groups on potential confounders
- (4) Sound method of ascertaining exposure (Should be valid, reproducible and blinded)
- (5) Sound case definition (Should be valid, reproducible and blinded)
- (6) Sound outcome assessment (Should be valid, reproducible and blinded)
- (7) Completeness of follow up

Data extraction and synthesis

Where possible, odds ratios (for categorical outcome data) or standardized mean differences (for continuous data) and their 95% confidence intervals (CI) will be calculated from the data generated by each included RCT. If appropriate, and with available data, results from comparable groups of studies will be pooled into a statistical meta-analysis using the RevMan 4.2.8 software provided by the Cochrane Collaboration. Heterogeneity between combined studies will be tested using the standard chi-square test. Findings will be summarized by

narrative, in cases where statistical pooling is not appropriate or possible. Two reviewers (ED & GS) will independently extract data using a standardized form.

The following information will be extracted:

- "Type of study: RCT, Controlled Before/After, Case-Control, Cohort studies
- "Study setting: Road, time of year and/or day when outcomes were measured
- "Type of intervention: useful field of view (UFOV), screening, education-retraining, Advanced Transport Telematics (ATT), simplified intersections, surgical and clinical.
- "Follow up: Duration of follow-up from implementation of intervention
- "Outcomes: Number and type of older drivers involved in motor vehicle crashes, and/or sustaining injury rates, frequency of injuries, or change in drivers' knowledge or skill (excluding self-report)

Data analysis

Two reviewers (ED & GS) will perform the applicable data analyses on the extracted data. The data will be analyzed as follows:

(1) Meta-analysis: A random-effect meta-analysis will be performed (given that the studies report similar interventions, data is available and results are statistically and clinically homogeneous).

(2) Continuous data will be analyzed if means and standard deviations are available and there is no evidence of data being skewed. (Data is skewed when the mean > standard deviation). If scales measure the same outcome in different ways, standardized mean differences will be combined across studies.

(3) Binary data: For studies with binary outcome data, the association between intervention and outcome will be quantified using the odds ratio along with 95 % CI.

(4) Heterogeneity: Investigation of heterogeneity of the odds ratios across studies will be assessed using a standard chi-square test.

(5) Funnel plots: Plotting the odds ratios on a funnel plot will examine the relationship between effect size and study precision. The reasons for any identified relationship (sample size, publication bias, diversity of interventions, populations) will be examined.

(6) Sensitivity analysis: The primary analysis will involve all studies. The robustness of the findings will be assessed by subgroup analysis based on sample size, study quality and type of intervention. Where possible, subgroup analyses according to study context will also be conducted.

Presentation

Evidence will be presented using graphs and tables. Attention will be focused on the identification and summary of important gaps in research and data for interventions to improve older drivers' safety.

Interpretation

Findings for the final report will be interpreted after careful evaluation of existing research based on the quality of research methods and study designs (ED, SB, GH, GS, AB).

The following external reviewers who are experts in older drivers' safety research will be contacted to reach consensus on the interpretation of final results derived from our systematic review.

Dr. David Hogan; email: dhogan@ucalgary.ca

Prof. Dellinger; email: amd1@cdc.gov

Prof. Shawn Marshall; email: smarshall@Ottawahospital.on.ca

Prof. Karlene Ball; email: kball@uab.edu

Dissemination

A manuscript will be written for publication in a peer-reviewed international journal, related to injury prevention or geriatric health. Local dissemination of results will be performed through fact sheets, brochures and reports (ED, GS, GH, AB).

Description of studies

A complete description of all included studies is tabulated in (Appendix B). The table summarizes the study characteristics and main findings including, source of research, total number of participants, as well as numbers for both the control and experimental groups (where applicable/available). The study design, intervention, and summary of results are presented for each included article. The research studies are categorized based on intervention type and study design, with the intent to enhance accessibility and understanding of evidence based research studies.

Summary of intervention types*Driver-related interventions*

Driver-related interventions are those in which the driver must change his/her behaviour or implement a task. Driver-related interventions found in the current literature included, utilization of the Driving Decisions Workbook; use of educational programs or home-study courses and use of driver re-training programs designed to help older drivers.

Vehicle-related interventions

Vehicle-related interventions are those in which a modification or enhancement is added to the driver's vehicle. Some of the current vehicle-related interventions include, Advanced Traveler Information Systems (ATIS); head-up displays (HUD); pedestrian detection devices; Advanced Transport Telematics (ATT); warning systems; and Surrogate In-vehicle Information Systems (S-IVIS).

Road-infrastructure-related interventions

Road-infrastructure-related interventions are those in which modifications and enhancements occur on roads, with the help of traffic engineers or urban planners, through improvements such as lane additions and improved signage, or lighting. The road-infrastructure-related interventions found in the current review include, prompts or signage promoting seat belt use; symbol signing design for older drivers; left turn signalization; and traffic signal improvements that facilitate driving for the elderly.

Clinical interventions

Clinical interventions are those that require medical personnel and are generally improvements to the human body or senses to augment drivers' safety. In the current review, the only clinical intervention retrieved was the use of cataract surgery for vision enhancement.

Legal & Policy Interventions

Legal and policy interventions are those in which changes or enhancements are made to legislation to promote drivers' safety and reduce motor vehicle crashes. These interventions are mandatory for older drivers' license renewal. The types of interventions in the current review included, California's Mature Driver Improvement (MDI) Program; the National License Assessment Program in Australia; the use of practical on-road driving tests; mandatory vision or knowledge tests; shorter license renewal cycles; in-person license renewal to identify higher-risk drivers; and restricted licensing for medically impaired older drivers.

Screening Interventions

The number and percentage of older drivers will increase significantly in the years ahead. As these people age, their cognitive, perceptual and physical functions will degrade, which in-turn will have an inevitable impact on their safety. This indicates a need to identify individuals most at-risk through screening procedures that are fair, accurate, and can be administered cost-effectively by provincial licensing agencies.

Screening interventions are those in which drivers are tested on certain functioning tasks to ensure that they are 'fit-to-drive'. In most cases, screening includes vision and cognitive function-related tests. The current search retrieved screening interventions for, visual impairment; visual acuity; useful field of view (UFOV)³; brief field of view (BFOV); automated visual field defect testing; perception-reaction time; cognitive functioning and Mini-Mental State Examination (MMSE). Cognitive impairment detected by office-based screening tests may indicate that the patient is at risk of a motor vehicle crash. A growing consensus exists among physicians and experts that several conditions and decrements in physiologic variables can affect driving skills.

Based on the various types of interventions, the findings of this systematic review can be used to improve our understanding of the needs of older drivers to create a safer environment for all. Potential counter-measures and strategies aiming to reduce motor vehicle crash rates involving elderly drivers will be discussed by intervention category in the final report.

Discussion

In general, the systematic review demonstrated that there are several initiatives in place to facilitate reduction in motor vehicle crashes or injuries in the elderly. The preliminary results found interventions that included, driver-related, vehicle-related, and legal/policy interventions. Based on our inclusion criteria, the results also demonstrated a lack of interventions in both the road-infrastructure and clinical (medical screening was a separate category) categories. The majority of resulting interventions were categorized as screening interventions. A preliminary discussion of each intervention category is outlined below.

Driver-related interventions

The results were found to be inconsistent for driver-related interventions. Literature showed certain interventions such as driving simulation to be effective, whereas other strategies such as several educational interventions did not reveal significant results in improving road safety for older drivers. A similar review evaluating educational interventions for older drivers also reached similar conclusions, indicating sparse evidence supporting the utility of educational interventions for this population (Kua, Korner-Bitensky, Desrosiers, Man-Son-Hing, & Marshall, in press). Research suggests that older drivers may not respond to these types of interventions as they require further learning which the elderly are hesitant to acquire as they feel they have already completed their learning cycles. Alternatively, the decline of driver-related skills impairment due to increasing age, are issues which may not simply be addressed by education and re-training interventions alone. In addition, the use of medications by older drivers also contributes towards the impairment of their learning capabilities.

Vehicle-related interventions

Overall results for vehicle-related interventions were positive for older drivers. Advanced traveler information systems, head-up displays, and warning systems all seemed to improve the

³ UFOV is used to assess three aptitudes for processing – divided attention, selective attention, and speed of processing, which are studied using spatial localization tasks. Several researchers have noted that the risk of accident while driving is significantly higher in older people when the UFOV is reduced by 40% or more.

driving experience for the elderly, both physically, as in their driving ability through road tests or simulated driving tests, and mentally, as in their ability to remember and mental well-being, as they feel more confident having these assistive devices. These types of vehicle enhancements will facilitate improved driving performance and help reduce the rate of motor vehicle crashes in the elderly. However, improved technology to enhance older driver driving abilities should be simple and user-friendly.

Road-infrastructure-related interventions

Results related to road-infrastructure interventions were positive for enhanced visibility of road signs and indicated that improved or highlighted signage is beneficial for the elderly. However, results were discouraging with respect to comprehension. The older population did not seem to have a complete grasp of driving maneuvers such as left-turn signaling and several road symbols, demonstrating a need for greater emphasis on older adult road-infrastructure-related comprehension, as this may be a contributing factor towards the high crash rates.

Clinical interventions

Although there were a limited number of clinical interventions found, results showed that an intervention such as cataract surgery has had a significantly positive impact on drivers' performance, as well as on the crash rate among older drivers. It is apparent that vision must be enhanced to allow for improved driving; however, surgery is a major intervention not a simple procedure, and requires synchronization of several factors including a risk taken by the patient, an experienced surgeon, someone to accompany the patient after surgery etc., and the combination of these factors may not be easily achieved by an older person.

Legal and policy related interventions

There were a number of legal and policy interventions retrieved from our search results. These included mandatory road, vision, or knowledge tests for older drivers who had reached a certain age (based on the location), as well as restricted licensing, or in-person license renewal. Overall results for this intervention category were positive, emphasizing the vital role of policy makers in formulating policies which would help reduce crash risk among older drivers.

Screening interventions

As previously stated, several interventions for elderly drivers involve screening tests. The limitation of this finding is that screening merely results in the older driver being informed that they have vision, cognitive, or neural deficiencies, rather than implementing a strategy that would help resolve the issue. Screening tends to restrict rather than enable elderly drivers, and it is unknown whether this will result in a safer environment for drivers, passengers, or pedestrians. However, it should be noted that the results of screening tests tend to correlate with rates of motor vehicle crashes in the elderly, demonstrating their utility in identifying those drivers who require a stronger intervention to improve their driving performance.

Interestingly, several of the screening interventions were conducted in driving simulators, rather than on-road testing. Studies that incorporated realistic views of the driving environment yielded predictive assessments of the cognitive and visual motor components required in driving. A simulation of the driving motion, through a three-dimensional environment (even if simulated on a two-dimensional screen) which contains the visual scene complexity associated with the actual driving environment is important for simulator measures for predicting actual driving performance. Simulators are recommended for pre-testing of drivers, especially those with progressive cognitive disorders, to determine their progress and decide whether it is safe to assess them on the road. They may also be beneficial in highlighting risks for older drivers, who may not acknowledge diminished capabilities, and can be utilized as an educational tool in a driver-retraining rehabilitation environment.

However, the most comprehensive solution to improve drivers' screening and evaluation is likely to incorporate a community-based approach where driving assessments and case management practices are performed by entities outside of the driver licensing agencies (Australasia approach; Fildes, Pronk, Charlton, Langford, & Frith, 2001). Community-based programs offer an opportunity to provide early detection of driving problems and a range of solutions through interventions such as referrals to remediation, retraining, and counseling about changes in driving practices and alternative transportation options, in convenient and non-threatening settings. With the availability of affordable and effective tools, applied consistently across settings, interventions in the community can address a range of older drivers' needs that fall outside of conventional procedures for license renewal. The Australasia approach relies heavily on coordination, cooperation, and communication between various agencies within a community, and while the procedures used will most likely be similar across communities, the specific entities will likely vary with each program implementation. Community-based programs, including voluntary programs to assist aging drivers assess their skills and remain safe on the road include the following components: (1) assessment of competency to drive; (2) driver education and training; and (3) case management/agency referral. This approach is warranted and would be beneficial for older drivers.

Through combined efforts of elderly drivers, vehicle manufacturers, urban planners, health care professionals, and policy-makers, the rates of motor vehicle crashes in the older population can be reduced, and safety of the population can be enhanced.

Potential conflict of interest

None declared

Task Summary Report

The tasks that have been completed up to this point include:

- 1) Systematic literature search
- 2) Inclusion/exclusion of studies based on created inclusion form
- 3) Literature for major intervention strategies has been identified and selected according to the selection criteria from the study protocol
- 4) Summary report of the preliminary findings (we are waiting to retrieve 11 more articles that must undergo the inclusion/exclusion criteria protocol)

Tasks for the upcoming year include:

- 1) Selected studies will undergo a comprehensive quality assessment and the studies will then be included in the final systematic review
- 2) Relevant data will be abstracted
- 3) Meta-analyses, defined as using statistical methods to combine the results of different studies, which are suitable for summarizing randomized controlled trials (RCT) in which the study populations and interventions are similar enough to warrant combining studies. Meta-analysis is a valuable method of synthesizing the existing evidence from evaluation studies. A meta-analysis will be conducted for each identified intervention stream, with RCTs.
- 4) Much of the useful information in public health is considered grey literature, literature that is not available through traditional scientific data bases or other commercial pathways. Therefore, a comprehensive literature search will be performed to find grey-area literature related to older driver crash prevention strategies.
- 5) A new literature search for studies published in 2007 will be performed to update the systematic review to include the most recent and relevant studies.
- 6) A final report will be compiled

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Adelaide University Centre for Automotive Safety Research <http://casr.adelaide.edu.au/>

ARRB Australian Road Research Board - www.arrb.org.au

Australian Transport Safety Bureau - www.atsb.org.au

Austroroads <http://www.austroroads.com.au/>

CROW Information and Technology Centres for Transport and Infrastructure (Netherlands) - www.crow.nl

Danish Council for Road Safety Research - www.trm.dk/eng/veje/rft

Danish Transport Research Institute - www.dtf.dk

DETR - www.detr.gov.uk/

DVR Deutscher Verkehrssicherheitsrat Road Safety Institute (Germany) - www.dvr.de/

FINNRA Finnish National Road Administration - www.tieh.fi

Injury Prevention Research Centre, School of Population Health <http://www.auckland.ac.nz/ipc>

INRETS Institut National de Recherche sur les Transports et leur Securite (France) - www.inrets.fr

ITE Institute of Transportation Engineers (USA) - www.ite.org

LET Laboratoire d'economie des transports (France) - www.lsh-lyons.cnrs.fr

Monash University Accident Research Centre <http://www.monash.edu.au/muarc/>

NHTSA National Highway Traffic Safety Administration (USA) - www.nhtsa.dot.gov

Swedish National Roads Administration - www.vv.se/for_lang/english/

SWOV Institute for Road Safety Research (Netherlands) - www.swov.nl

TOI - Institute of Transport Economics (Norway) - www.toi.no

TC Transport Canada - www.tc.gov

TRB Transportation Research Board - www.nas.edu/trb/

TRL Transport Research Laboratory - www.trl.co.uk

US Department of Transport - Federal Highway Administration (USA) - www.fhwa.dot.gov

VTI Swedish National Road and Transport Research Institute - www.vti.se

VTT Finland - www.vtt.fi/indexe.htm

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Appendix A: Abbreviations

AGIS	Advanced Glaucoma Intervention Study
ARGOS	Automobile for Research in Ergonomics and Safety
ATIS	Advanced Traveler Information Systems
ATT	Advanced Transport Telematics
BC	British Columbia
BFOV	Brief Field of View
CALTEST	California Driver Screening Test
CDT	Clock Drawing Test
CI	Confidence Interval
DEQ	Driving Experiences Questionnaire
GRIMPS	Gross Impairments Screening
HUD	Head-Up Display
IOR	Inhibition of Return
KEYS	Knowledge Enhances Your Safety
LCD	Liquid Crystal Display
MDI	Mature Driver Improvement
MMSE	Mini-Mental State Examination
MVC	Motor Vehicle Crash
MVPT	Motor-free Visual Perception Test
OR	Odds Ratio
PASAT	Paced Auditory Serial Addition Test
PC	Personal Computer
PDQ	Post-Diary Questionnaire
PRT	Perception Response Time
RCT	Randomized Controlled Trial
RR	Relative Risk
S-IVIS	Surrogate In-Vehicle Information System
TSRT	Traffic Sign Recognition Test
UFOV	Useful Field of View
VES	Vision Enhancement Systems

Appendix B: Study Characteristics and Main Findings

Source	Subjects	Control Group	Intervention Group	Study Design	Intervention
Driver-Related Interventions					
RCTs					
Bedard et al., 2004 (id157)	65 (52% women)			Randomized Controlled Trial	Re-training program for older drivers (adaptation of 55Alive)
Main Results: No statistically significant difference between the control and experimental groups was found. The mean improvement for the control group was 3.46 (SD=6.72) compared to 4.02 (SD=7.11) for the experimental group (p = 0.747). Drivers' age was related to overall driving scores (r = -0.55, p = 0.001) but not to changes between the first and second evaluations (r = 0.01, p = 0.955).					
Jacobs et al., 1997 (id904)	21	7	14 (2 treatment groups of 7)	Randomized Controlled Trial	Participation - oriented education for rehabilitation of driving skills in older adults
Main Results: Significant difference was found between treatment type and subjects' accuracy scores for on-road evaluation, thus suggesting that driving simulation may result in a significant improvement in older adults' driving performance as compared to other intervention strategies.					
McCoy et al., 1993 (id1160)	94	17	18 + 10 + 15 + 15 + 19 (6 separate interventions groups)	Randomized Controlled Trial	Physical therapy; Perceptual therapy; Driver education; Traffic engineering improvements
Main Results: All of the countermeasures significantly improved the driving performance of the older drivers by an average of 7.9%. The cost-effectiveness analysis indicated that traffic engineering improvements would be most cost-effective on high volume roadways and the remaining countermeasures would be most cost-effective on low-volume roadways.					
Owsley et al., 2004 (id170)	403	176	227	Randomized controlled single-masked intervention evaluation	Individually tailored and administered educational intervention promoting safe driving strategies.
Main Results: Intervention group did not differ significantly from the control group in crash rate per 100 person-years of driving (RR, 1.08; 95% CI, 0.71-1.64) and per 1 million person miles of travel (RR, 1.40; 95% CI, 0.92-2.12). The intervention group reported more avoidance of challenging driving maneuvers and self-regulatory behaviors during follow-up than did the control group (p<0.0001).					
Stalvey & Owsley, 2003 (id872)	365 (69% male/	171	194	Randomized Controlled Trial	Knowledge Enhances Your

	31% female)				Safety (KEYS) Curriculum
<p>Main Results: KEYS participants improved self-perceptions of vision impairment, perceived a greater number of benefits in the performance of self-regulatory behaviors, and moved closer to the preparation and action/maintenance stages of change. Results indicate that high-risk older drivers benefit from educational interventions that promote self-awareness and self-regulation of driving.</p>					
Yee & Melichar, 1992 (id1148)	250 older drivers	50	200	Randomized Controlled Trial	Computer-based multi-phasic modules approach to identifying "at-risk" older drivers
<p>Main Results: The multiphasic approach incorporating all 3 components resulted in improvement in driver's skills as well as in their attitudes and knowledge. The multiphasic programmatic approach showed increased cost-effectiveness over any single approach and the computer based version showed decreased cost of delivery without loss of information delivery.</p>					
<p>Quasi-experimental</p>					
Tarawneh, 1991 (id2313)	107 (52 males; 55 females)	19	86	Quasi-experimental study	Conceptual model of the driving task: Physical therapy; perceptual therapy; driver education
<p>Main Results: The conceptual model was found to be valid in terms of its ability to predict the impact of safety measures to help elderly drivers. Trunk rotation was improved by physical therapy, visual perception was improved by perceptual therapy, and driving knowledge was improved by the driver education course.</p>					
<p>Before/After</p>					
Simoes, 1998 (id325)	14	7	7	Before/After study	Training programme to improve driving performance of elderly drivers
<p>Main Results: The observed improvements resulting from the training or the learning factor in performing the tests showed learning potential of the sample. As the effects of the training have been more evident in the performance of the specific psychological tests than in the tests on the simulator, the model of these tests was not adapted to the programme.</p>					
<p>Case-control</p>					
Berube, 1995 (id1723)	105,309	68,598	1335 (home-study); 35,376 (in-person)	Case-control study	Mature Driver Improvement (MDI) Program Home-Study Courses
<p>Main Results: The results provide little evidence that home-study courses are less effective than in-person courses in reducing fatal/injury crashes and total citations, and no evidence that MDI course graduates are at a</p>					

lower fatal/injury crash risk than non-participants. The MDI program may have reduced the rate of traffic violation citations, but not the rate of fatal/injury crashes, among course graduates.					
Eby et al., 2003 (id193)	99 (56% women; 44% male) (92 - driving data)		99	Case-control study	Driving Decisions Workbook
Main Results: After completing the workbook, 75% reported being more aware of changes that could affect driving. 14% reported a change in themselves, and workbook responses were positively correlated with overall road test scores.					
Karagiannidou, 2003 (id1306)	221 (DEQ); 154 (PDQ)	93 (non-diary group; 52 men; 41 women)	154 (diary group) 61 diary	Case-control study	Driving Diary
Main Results: Drivers in the diary group avoided driving at rush hours, when tired/sleepy/ill, parking in busy roads and narrow spaces, and driving at night less frequently in the post-diary questionnaire, than in the driving experiences questionnaire (pre-diary), and these were all significant differences. The diary group also reported more stress under various situations, and after the diary, drivers' confidence in relation to how it was when they were younger, decreased. It should be noted that their beliefs of being more skillful than their peers became stronger. The point of the study was to raise older drivers' self-awareness through self-monitoring, and encourage the adoption of self-protective behaviours and the avoidance of risky situations.					
Cohort					
Lee et al., 2003 (id186)	129 older drivers		129 (22% female)	Retrospective Cohort study	Interactive PC-based Driving Simulator
Main Results: Driving skill of older drivers was found to decline with age. The cognitive abilities associated with the crash occurrence were working memory, decision making under pressure of time, and confidence in driving at high speed. The findings indicated those individuals at inflated risk of vehicle crashes could be identified using the PC-based interactive driving simulator.					
Vehicle-Related Interventions					
RCT					
Liu, 2000 (id1020)	32 (gender balanced)	16 (young)	16 (old)	Randomized Controlled Trial	Advanced Traveler Information System (ATIS)
Main Results: All drivers made significantly fewer errors in responding to hazard warnings when using multi-modality and auditory displays compared to visual-only displays. When complex information was presented, the multi-modality display led to significantly faster and more accurate recognition of hazards and better control of car direction and speed. The multi-modality display is optimal, particularly for older drivers.					
Quasi-experimental					
Kiefer, 1998 (id1581)	24		24 (13 men; 11 women)	Quasi-experimental study	Head-Up Display pedestrian detection benefits
Main Results: During the pedestrian trials, results indicated a HUD detection time advantage and a trend toward fewer missed pedestrians with the HUD. Results clearly suggest that HUDs improve the driver's ability to see forward scene events surrounding display glances.					

Marin-Lamellet et al., 1994 (id1785)	26	9 young	17 elderly	Quasi-experimental study	Man-machine interfaces/ Training programme on simulator tests
<p>Main Results: Elderly subjects scored lower for visual acuity and showed some reduction in short term visual memory. Driving time increases with age, the maximum difference being observed when using the LCD screen alone.</p>					
Nwagboso et al., 1997 (id1707)	100		80	Quasi-experimental study	Advanced Transport Telematics (ATT)
<p>Main Results: Results show that ATTs are proven to enhance the safe driving abilities of older adults. It was also found that volunteers generally liked the devices that were evaluated and found them both easy to use and useful. Many subjects could see benefits in the technology in terms of encouraging them to drive to places to which they would not otherwise drive. Some ATT systems were seen to increase the visual and mental workload in the driving task. No major safety concerns arose from the trials.</p>					
Pauzie, 1996 (id1558)	26	13 young	13 elderly	Quasi-experimental study	Advanced Transport Telematics (ATT) (Complex Guidance Systems)
<p>Main Results: Qualitative and quantitative analysis indicated that the efficiency of the presentation modality is closely linked to two main parameters: the complexity of crossing road layout and the design of the route to follow by the vehicle during the maneuver inside the intersection. With respect to the glance duration, it is significantly longer for the older drivers in comparison with the younger ones.</p>					
Van der Hulst et al., 1994 (id1667)	27 (both males and females)	18 (mean age 37)	9 (mean age 66)	Quasi-experimental study	Tutoring & warning system/ Advanced Driving Simulator
<p>Main Results: Warnings were effective; fewer violations were made in the tutoring conditions. No difference in mental effort costs was found between tutoring modalities or between the 2 age groups. There was a difference in acceptance. Elderly were more positive about the system. With the elderly, the favourable effects persisted when the system was switched off. There was no evidence of any overload in the older drivers.</p>					
Case-control					
Caird et al., 2000 (id1487)	48	24 younger	24 older	Case-control study	Vision enhancement systems (VES) and head-up display (HUD)
<p>Main Results: In all driving scenarios, conformal displays had a performance advantage over non-conformal displays. Cluttered environments such as heavy traffic may not be conducive to enhancement.</p>					
Granda et al., 1997 (id1678)	109		109	Case control study	Advanced Traveler Information Systems (ATIS)
<p>Main Results:</p>					

Older drivers were worse than younger drivers, in terms of safety. In regard to the number of crashes per hour and the deviation from lane/center line, age, by itself, was a significant factor.					
Merat et al., 2005 (id944)	48	24 (average drivers)	24 (older drivers)	Case- Control Study	Surrogate in-vehicle information systems (S-IVIS)
<p>Main Results: Compared to the older drivers, average drivers were more successful at performing the two S-IVIS tasks, both in isolation and with driving. In the field, the effect of the 2 S-IVIS tasks was found to be more profound on older drivers, resulting in closer car following, more speed variation, less lane keeping compared to average drivers. Older drivers kept longer distance headways and reduced their speed in the presence of the S-IVIS tasks.</p>					
Cohort					
Morris et al., 2003 (id2111)	1541	889 + 515	137	Cohort study	Vehicle crash-worthiness
<p>Main Results: In crashes of approximately equal severity, older drivers were significantly more likely than middle-aged and younger drivers to be fatally injured in both frontal ($p < 0.001$) and side ($p < 0.05$) impact crashes. Older drivers sustained more injuries to the chest ($p < 0.0001$) and this body region is particularly problematic. The main sources of the chest injuries were found to be the seat belt in frontal crashes and the door in side impact crashes. Vehicle re-designs are required, including in-vehicle crash worthiness systems.</p>					
Road-Infrastructure-Related Interventions					
Case-control					
Cox et al., 2005 (id110)	12 senior communities 300 drivers/ 251 passengers	6 senior communities without signs	6 senior communities with signs	Matched Case-Control study (matched subjects group design)	Prompts (signs) to use safety belts exiting senior communities
<p>Main Results: Safety belt usage was stable across 4 years, at approximately 80% for both male and female drivers and front seat passengers for the experimental group, and 55% for control sites. The simple and low-cost intervention of erecting signs to prompt safety belt use has persistent benefits that affect driver and passenger behavior alike. Safety belt usage was greater at each experimental site than at the matched control site (paired $t = 3.84$, $p = .006$).</p>					
Dewar et al., 1997 (id1649)	930	537 (young or middle-aged)	393 (elderly)	Case- control Study	Symbol Signing Design for Older Drivers
<p>Main Results: Of the 85 symbols, many were well understood, but 10 were understood by fewer than 40% of drivers. Increased driver age was associated with lower comprehension levels and legibility distances (under all test conditions), as well as higher glance legibility thresholds, reaction times and conspicuity search times. Glare reduced legibility of the signs only for the elderly drivers.</p>					
FHWA 1990 (id1518)	247	121 (young)	126 (elderly)	Case-control study	Left turn signalization comprehension & Traffic signal responses & stopping behavior
Main Results:					

Older drivers do not understand the protected/permitted left-turn signalizations as well as younger drivers do. Neither group had a full understanding of left-turn signalization. The decision reaction times of both younger and older were comparable.					
MacGregor et al., 2001 (id266)	120	60 (non-crash subjects)	60 (crash subjects)	Retrospective matched case-control study	Traffic sign recognition test (TSRT)
Main Results: The TSRT significantly distinguished between groups ($p = .01$). The MMSE did not ($p = .61$). A TSRT predicted MVC (OR =0.88, 95% CI: 0.77-1.00). A TSRT successfully identifies older drivers with a recent MVC, but the test lacks sensitivity and specificity.					
Clinical Interventions					
Before/After					
Wood & Carberry, 2004 (id2070)	46 older adults	18	28	Before/After (age-matched controls)	Cataract Surgery
Main Results: Participants with cataracts had significantly poorer ($p < .05$) driving performance at the first visit compared with control participants, which significantly improved to matched levels following cataract surgery.					
Cohort					
Owsley et al., 2002 (id232)	277	103	174	Prospective Cohort study	Cataract surgery
Main Results: Comparing the experimental group with the control group, the rate ratio for crash involvement was 0.47 (95% CI, 0.23-0.94), adjusting for race and baseline visual acuity and contrast sensitivity. The absolute rate reduction associated with cataract surgery was 4.74 crashes for million miles of travel. Patients who underwent cataract surgery and intraocular lens implantation had half the rate of crash involvement during the follow-up period compared with the control group.					
Legal & Policy Interventions					
Quasi-experimental					
Levy et al., 1995 (id385)	All persons 70+ in all states who had resulted in fatal crashes		All persons 70+ in all states who had resulted in fatal crashes	Retrospective observational study (Quasi-experimental)	Driver's License Renewal Policies (vision tests/ knowledge tests/ road tests)
Main Results: In the 50 states, there were 16840 fatal crashes involving a total of 17294 drivers aged 70+ during the 5 year study. State-mandated tests of visual acuity were associated with lower fatal crash risk for senior drivers (RR, 0.93; 95% CI, 0.89-0.97). Knowledge tests, when added to vision tests and applied only to seniors, provided a non-significant reduction in the senior fatal crash risk (RR, 0.91; 95% CI, 0.79-1.05). Tests of vision and knowledge for senior drivers at license renewal merit further attention.					
Before/After					
Lindstrom, 2003 (id2290)	65 (31 female; 34 male)	33 (waitlist control group; 15 female; 18 male)	32 (16 female; 16 male)	Before/After Study	Neuropsychological tests to identify responders to a driving refresher course
Main Results: Age was negatively associated with baseline driving ability but was not associated with overall change in driving scores. Neuropsychological tests were associated with specific baseline driving abilities and change scores. A multiple regression model for overall change in driving ability included baseline					

ability, age, education, the Motor-free Visual Perception Test, and the Stroop test and accounted for 35% of the variability in overall change scores.					
Case-control					
Langford et al., 2004 (id154)	~ 243723 (Aged 80+)	99,422 (Aged 80+ in Melbourne)	144, 301 (Aged 80+ in Sydney)	Case-control study	Mandatory license testing
Main Results: Poisson regression analysis incorporating an offset to control for inter-jurisdictional road safety differences indicated that there was no difference in crash risk for older drivers based on population. Drivers aged 80+ in the Sydney region has statistically higher rates of casualty crash involvement than their Melbourne counterparts on a per license issued basis (RR: 1.15, 1.02-1.29, p=0.02) and time spent driving basis (RR: 1.19, 1.06-1.34, p=0.03). Mandatory license re-testing schemes have no demonstrable road safety benefits overall.					
Rock, 1998 (id350)	All drivers over 69 years old in Illinois	75 to 80 year old age group (no changes to policy)	69-74 year old age group; 81+ age group (policy changes)	Case-control study	Changes in Illinois Drivers Licence Renewal Requirements for older drivers
Main Results: It does not appear that eliminating the road test for those ages 69-74 had any negative impact. It does not appear that the more frequent renewal period for those ages 81+ produced any benefit compared to the control group.					
Shipp, 1998 (id2306)	48 States & the District of Columbia	10 states not requiring vision testing	39 states & the District of Columbia which require vision testing	Case-control study	Vision testing policy for licensure
Main Results: This study found that relicensing policies requiring vision testing were associated with lower vehicle-occupant fatality rates and lower economic costs. According to study estimations, if vision testing for driver license renewal policies had been in effect in jurisdictions without such policies, approximately 341 fewer traffic fatalities involving older drivers, a 15.6% reduction would be projected from 1989-1991. Those avoidable deaths represent an estimated \$47.8 million in non-workplace and non-household productivity related economic costs. State-level mandatory vision testing for relicensure may enhance traffic safety and reduce the economic burden of fatal crashes. Vision testing requirements should be maintained by jurisdictions with such requirements, and jurisdictions without such requirements should consider the potential traffic safety benefits of vision testing for driver license renewal.					
Cohort					
Fildes et al., 2001 (id1327)	56		56 older drivers (37 male/ 19 female)	Cohort Study	National License Assessment Program for older drivers in Australasia
Main Results: Results of the process evaluation showed that the majority of participants were able to complete the screening test within 40 minutes. The average time to complete the driving test was 30 minutes. In total 98% (51 participants) indicated that they had found the on-road driving test to be acceptable. Older drivers indicated that they found the case officer to be very helpful and several used this position as a resource leading up to and after their assessment.					
Grabowski et al., 2004 (id165)	305,926	231, 488 fatalities for drivers aged 25-64	74,428 driver fatalities among those aged 65+	Retrospective Longitudinal Cohort Study	Elderly Licensure Laws
Main Results:					

<p>Those 85+ = a total of 4605 driver fatalities and 4179 daytime driver fatalities during the study period. States with in-person license renewal were associated with a lower driver fatality rate (incident RR, 0.83; 95% CI, 0.72-0.96). This was the only policy related to older drivers that was significantly associated with a lower fatality risk. State-mandated vision tests, road tests, more frequent license renewal, and in-person renewal (for ages 65-74 & 75-84) were not found to be independently associated with the fatality rate among older drivers.</p>					
Janke, 1994 (id1766)	All drivers 55+ in California	Ransom sample of drivers aged 55+ who had not taken the course	All drivers aged 55+ who completed the MDI course between July 1, 1987-June 30 th , 1988	Cohort (matched controls) study	California's Mature Driver Improvement (MDI) Program
<p>Main Results: Unadjusted fatal & injury crash rates showed significant differences in favor of the MDI group in the first 2 cohorts. All between group differences on unadjusted citation rates were significant favoring the MDI group. On citations all adjusted differences were significant, favouring the MDI group. Analyses of 2 cohorts' 6-month data using generalized two-stage least-squares regression indicated that program completion was associated with more total and fatal injury crashes and fewer citations.</p>					
Keall & Frith, 2004 (id163)	39,318		39,318	Cohort Study	New system for licensing older drivers in New Zealand (practical on-road driving test)
<p>Main Results: Each driving test failure was associated with a 33% increase in the odds of crash involvement (95% CI 14-55%). Minor traffic violations in the 2 years following the driving test were associated with twice the odds of crash involvement. This suggests that the new on-road driving test does identify older driver behaviors or limitations that are related to crash liability.</p>					
Stutts et al., 2000 (id1492)	771, 269		771, 269 (All licensed North Carolina drivers age 65+ as of Dec. 31 st , 1999.	Cohort Study	Restricted Licensing for Older Drivers
<p>Main Results: Overall, 89.6% of the drivers were not involved in any crashes during the 3-year study period; 9.3 % were involved in only 1 crash, 1% in 2 crashes, and 0.2% in 3+ crashes. Drivers who had no restrictions on their licenses or a restriction of corrective lenses only were less likely to be involved in crashes than were drivers with additional restrictions. The group having the greatest likelihood of crash involvement were those with "all other" restrictions on their license.</p>					
<p>Screening Interventions</p>					
<p>Quasi-experimental</p>					
Bedard et al., 2006 (id80)	41 (20 men/21 women)		41	Quasi-experimental study	Inhibition of Return Paradigm/ Visual Attention
<p>Main Results: IOR statistically predicted overall driving evaluation scores (p = .045) and the number of errors in scanning the environment (p = 0.31).</p>					
De Raedt & Ponjaert-Kristoffersen,	84 (24 women/60 men)		84 (24 women/60 men)	Quasi-experimental study	Fitness-to-drive evaluation/

2000 (id270)					strategic and tactical compensation
<p>Main Results: Drivers who select driving tasks below their capacities and compensate by adapting their driving style cause fewer accidents than those who do not apply these strategies. Fitness-to-drive screening procedures need a broader perspective to prevent an over-emphasis on procedures which focus more on deficit than on capacities.</p>					
De Raedt & Ponjaert-Kristoffersen, 2004 (id1411)	84		84 elderly drivers referred to the CARA fitness-to-drive assessment centre	Quasi-experimental study	Fitness-to-Drive (Cognitive/Neurophysical functioning and Compensation
<p>Main Results: The overall results highlight the relationship between cognitive functioning and driving performance, but also suggest that screening procedures must not focus solely on shortcomings but also on possibilities for maximum mobility. The neuropsychological tests that showed the strongest correlation with the road test score were the movement perception test ($r=.73$) and the shrinkage in the UFOV ($r=.66$). Movement perception, UFOV, cognitive flexibility and selective attention explained 64% of the variance in a road test score ($r=.80$). For the detailed accident analysis, the predictability of accidents, as calculated by classification functions based on discriminant models, increased from 62.9% (all accidents considered together) to 73.8% (in the most detailed categories). ANOVAs revealed that in the group of bad drivers people without accidents during the preceding 12 months had significantly higher compensation scores (both tactical and strategic) than people with an accident history.</p>					
Hoffman et al., 2005 (id112)	155		155 (68 men/87 women)	Quasi-experimental study	Visual Attention (DriverScan change detection task and UFOV)
<p>Main Results: Driving performance in a low-fidelity simulator could be significantly predicted by performance in the change detection task and by the divided and selection attention subsets of the UFOV.</p>					
Langford, 2004 (id1213)	1000		Approx. 300 on each test	Quasi-experimental study	Screening tests (vision, cognitive, physical ability)
<p>Main Results: Analyses revealed a significant relationship between performance on the on-road license test and GRIMPS, CALTEST, and DriveABLE. In the case of GRIMPS, a model including 5 sub-tests fit the data as well as a model including all 11 subtests. Similarly for CALTEST, the goodness of fit of a model with UFOV only was not significantly improved by the addition of Autotrails. All 3 tests showed high levels of acceptability by older drivers and assessors.</p>					
Lee et al., 2003 (id211)	129		129 older drivers	Quasi-experimental study	Visual Attention Skill Screening/Validation of a Driving Simulator
<p>Main Results: Visual attention skill declined with age ($p=0.002$), whereas the effect on gender was not significant. Participants increased their speed of reaction times for the first half of the testing then slowed down during the second half. The driving simulator was validated as an effective screening tool for older adult drivers.</p>					

Perry et al., 1993 (id2311)	40	20 young	20 older	Quasi-experimental study	Brief Field of View Screening
Main Results: Young drivers scored significantly higher on all measures than the elderly. Older drivers improved in visual performance from the lab to the field, whereas younger drivers deteriorated in the field as compared to their lab performance.					
Schlag, 1993 (id437)	110	30 (middle-aged)	80 (elderly)	Quasi-experimental	Screening-visual acuity, perception-reaction time
Main Results: The performance elderly drivers proved worse in all laboratory tests. In driving tests, in an overwhelming number of traffic situations, the elderly did not differ unfavorably from the middle-aged drivers.					
Wood & Troutbeck, 1994 (id1765)	46	10 young; 18 elderly visually normal	18 elderly with cataracts	Quasi-experimental study	Visual impairment screening
Main Results: The results showed that group had a significant effect ($p < .05$) on driving and vision. The cataract subjects had poorer driving performance ($p < .05$) than either the elderly normal vision or young subjects, and the elderly had poorer driving performance ($p < .05$) than the young. The visual performance of both groups of elderly was significantly worse than of young subjects. The elderly had higher disability glare, poorer letter contrast sensitivity, and reduced ability on the UFOV task.					
Case-control					
Brouwer et al., 1991 (id 465)	24 (12 women/ 12 men)	12 young	12 elderly	Case-control study	Dynamic Driving Simulator (2 simultaneous visual tasks)
Main Results: Compared with young adults, older adults showed a significantly decreased ability to divide attentions. This effect was apparent in lane tracking and in the accuracy of visual analysis. The impairment of divided attention was less pronounced in the vocal condition than in the manual one. Difficulty in integrating responses may be an important determinant of poor dual-task performance in old age.					
Edwards et al., 2003 (id1281)	24	12 (young)	12 (elderly)	Case-control study	Perception-response time and driving simulation
Main Results: Older drivers had significantly higher perception-response times (PRT) than younger drivers for $\frac{3}{4}$ scenarios. More older drivers ran the yellow light than younger drivers. The capability of older drivers to respond under time constraints is implicated. The utility of driving simulators to assess older driver performance at intersections was limited by simulator sickness.					
Gresset & Meyer, 1994 (id409)	4023 (all males)	2623	1400	Case-control study	Minimal visual acuity testing (equal to 6/12 or 6/15) and lack of binocularity
Main Results: Drivers with minimal visual acuity alone had the same risk of road accidents as other drivers (OR = 0.97 CI 95%: 0.68-1.38). The risk of accidents among drivers with both minimal visual acuity and lack of binocularity was moderately higher than among other drivers (OR = 1.23, CI 95%: 0.88-1.72).					
McGwin et al., 2005 (id113)	240	120	120	Nested case-control study	Advanced Glaucoma

					Intervention Study (AGIS) Score/ Automated visual field defect testing
Main Results: Patients with glaucoma who have moderate or severe visual field impairment in the central 24 degrees radius field in the worse-functioning eye are at increased risk of involvement in a vehicle crash.					
Owsley et al., 1998 (id330)	294 elderly drivers	115	78 + 101	Case-control Study	Vision impairment and eye disease screening
Main Results: The main results were that restricted UFOV and glaucoma were the only significant independent predictors of injurious crash involvement. OR's for reductions in the UFOV of 23-40%, 41-60%, and greater than 60% were 4.2 (95% CI, 1.5-11.8), 13.6 (95% CI, 5.8-39.7) and 17.2 (95% CI, 5.3-55.6), respectively, compared to reductions of less than 23% (p for trend <.001). The OR for glaucoma was 3.6 (95% CI, 1.0 -12.6). UFOV impairment was the only variable independently associated with non-injurious crash involvement.					
Owsley et al., 1999 (id300)	384	105 (without cataracts)	279 (with cataracts)	Case-control study	Cataracts visual functional tests or screening
Main Results: Older drivers with cataracts experience a restriction in their driving mobility and a decrease in their safety on the road. Drivers with cataracts were 2.5 times more likely to have a history of at-fault crash involvement in the prior 5 years.					
Rizzo et al., 2003 (id1248)	160	78 neurologically normal	82 impairments on selective attention	Case control study	Paced Auditory Serial Addition Task (PASAT)
Main Results: Measurements aboard the instrumented vehicle ARGOS (Automobile for Research in Ergonomics and Safety) showed that performing the PASAT reduced speed and steering control of the older drivers relative to baseline and was associated with greater counts of at-fault safety errors. Interference produced by PASAT, like that of cell phone operation might become more evident during demanding driving conditions, as at busy traffic intersections.					
Skaar et al., 2001 (id1417)	40	18 (52.6% male)	22 (65.4% male)	Case Control study	Useful Field of View (UFOV) Screening-training of visual speed of processing
Main Results: Training of speed of visual processing improved performance on visual attention tasks. Preliminary evidence was found on cross-modal transfer of these training effects leading to improvement on the PASAT, a task that commands both auditory attention and working memory.					
Wood & Mallon, 2001 (id264)	137	90 subjects with normal vision	47 older subjects with visual impairment	Case-control study	Visual Impairment Screening
Main Results: Group allocation significantly affected driving performance as assessed by the driving instructor and occupational therapist (p<.05). Of the drivers who were scored as being unsafe, all were older and the					

majority had visual impairment (75%). Older drivers with or without visual impairment were rated as being less safe than the younger and middle-aged drivers with normal vision.					
Cohort					
Ball & Rebok, 1994 (id1102)	294 (136 male/ 158 female)		294	Cohort study	Visual Attention/ Useful Field of View (UFOV)
Main Results: Only 2 variables, UFOV and mental status, had direct effects on crash frequency, jointly accounting for 28% of its variance. Central & peripheral vision accounted for 30% of UFOV variance. ROC (Receiver Operating Curves clearly indicate that the UFOV was much better at identifying crash-involved older drivers than were the other independent variables evaluated. The effect of visual impairment in the elderly on crash frequency is indirect. Mental status is strongly related to performance in the UFOV task, which has the strongest relationship to crashes in the model. UFOV reduction is substantially better than chronological age at differentiating drivers who are at risk for crashes from those who are not.					
Ball et al., 1993 (id413)	294 (136 men/ 158 women)		294	Cohort Study	Visual Attention Screening (eye health status/ visual sensory function/ UFOV/ cognitive status)
Main Results: The size of the UFOV (visual attention) had high sensitivity (89%) and specificity (81%) in predicting which drivers had a history of crash problems. Policies that restrict driving privileges based solely on age or on common stereotypes of age-related declines in vision and cognition are scientifically unfounded.					
Ball et al., 2006 (id102)	1910		1910	Prospective cohort study	Performance Tests (Trails B; MVPT; UFOV subtest 2)
Main Results: Age, sex, history of falls, and poorer cognitive performance were predictive of future at-fault MVC involvement. Participants aged 78 and older 2.11 times more likely to be involved in an at-fault MVC, those who made 4 or more errors on the MVPT were 2.10 times as likely to crash, those who took 147 seconds or longer to complete Trails B were 2.01 times as likely to crash, and those who took 353 ms or longer on subtest 2 of the UFOV were 2.02 times as likely to incur an at-fault MVC. Older adults, men, and individuals with a history of falls were more likely to be involved in subsequent at-fault MVCs. Performance-based cognitive measures are predictive of future at-fault MVCs in older adults.					
Decina & Staplin, 1993 (id421)	12, 400		12, 400 drivers in Pennsylvania at time of license renewal	Cohort study	Vision screening visual acuity/ horizontal visual field/ contrast sensitivity
Main Results: Neither visual acuity nor horizontal visual field measures in isolation were significantly related to crash involvement. The combination of all 3 tests (addition of broad contrast sensitivity criteria) was significantly related to increasing crash involvement for drivers					
Freud et al., 2005 (id943)	119		119 elderly (56 men/ 63 women)	Prospective Cohort study	Brief tests of cognition to screen driving competency (Clock

					Drawing Test; CDT)
<p>Main Results: The CDT showed a high level of accuracy in predicting driving simulation outcome (area under the receiver-operator curve, 0.90; 95%CI, 0.82-0.95). CDT scoring scales were comparable and all correlations between CDT scores and driving performance were negative, implying that as the CDT score decreases, the number of errors increases. Subjects scoring less than 5 out of 7 points on the CDT made significantly more driving errors, hazardous and in total ($p < .001$).</p>					
Goode et al., 1998 (id1045)	239		239 elderly (112 female/ 127 male)	Cohort study	UFOV and Neuro- cognitive indicators
<p>Main Results: Among all cognitive tests administered, UFOV was most strongly related to crash involvement, with high levels of sensitivity (86.3%) and specificity (84.3%) at the standard cut-off score of 40% reduction.</p>					
Owsley et al., 1998 (id349)	294		294 elderly	Prospective Cohort Study	Visual Processing Screening (UFOV)
<p>Main Results: Older drivers with a 40% or greater impairment in the UFOV were 2.2 times (95% CI, 1.2-4.1) more likely to incur a crash during 3 years of follow-up. This association was primarily mediated by difficulty in dividing attention under brief target durations. Reduction in the UFOV increases crash risk in older drivers.</p>					
Sims et al., 2000 (id289)	174		174 older drivers	Prospective Cohort Study	Medical and functional screening factors
<p>Main Results: 61 subjects experienced between 1 and 4 police-reported vehicle crashes during the study period. The following variables are associated with crash involvement: reported difficulty with yardwork or light housework (RR=2.1; 95% CI, 1.1-4.0; $p = .02$) or opening a jar (RR=3.1; 95% CI, 1.4-6.7; $p = .004$) at least one crash before 1991 (RR=2.1; 95% CI, 1.2-3.7; $p = .008$) using hypnotic medication (RR=2.9; 95% CI, 1.3-6.6; $p = .01$) self-reported stroke or transient ischemic attack (RR=2.7; 95% CI, 1.1-6.6; $p = .03$) scoring within depressed range on the Geriatric Depression Scale (RR=2.5; 95% CI, 1.1-6.0; $p = .03$) and failing to use the UFOV test (RR=1.9; 95% CI, 1.0-3.5; $p = .05$). Multifactorial assessments are warranted to identify at-risk older drivers.</p>					
Staplin et al., 2003 (id1332)	2508 drivers		2508	Cohort Study	Functional Capacity Screening/ Safe Mobility for Older People Network
<p>Main Results: Among the analyses of moving violations, the strongest relationships were found for "all moving violations without speeding and occupant restraint citations". The strongest relationships were consistently demonstrated between functional status and at-fault crashes. Among the physical measures, the Rapid Pace Walk and Head/Neck Rotation appear to have the greatest potential value as predictors of driving impairment. The results of the study reinforce the proposition that loss of key functional abilities predicts an increase in driving impairment and higher risk of crash involvement. To fail a screen test means that the individual's functional status places him or her at greater risk of a motor vehicle crash, and may establish a need for follow-up to more accurately diagnose underlying medical problems etc.</p>					
Stutts et al., 1998	3238		3238 older	Cohort study	Cognitive

(id338)			drivers applying for license renewal		Function tests/ Screening
<p>Main Results: The individual tests were not found to be effective screening tools, however, cognitive test performance remained significantly associated with crash risk. Drivers who scored in the lowest 10% on the cognitive tests were approximately 1.5 times more likely to be in crashes than were drivers who scored in the highest 10%.</p>					