Driving assessment for maintaining mobility and safety in drivers with dementia (Review)

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Driving assessment for maintaining mobility and safety in drivers with dementia

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ABSTRACT

Background

Demographic changes are leading to an increase in the number of older drivers: as dementia is an age-related disease, there is also an increase in the numbers of drivers with dementia. Dementia can impact on both the mobility and safety of drivers, and the impact of formal assessment of driving is unknown in terms of either mobility or safety. Those involved in assessment of older drivers need to be aware of the evidence of positive and negative effects of driving assessment. Cognitive tests are felt by some authors to have poor face and construct validity for assessing driving performance; extrapolating from values in one large-scale prospective cohort study, the cognitive test that most strongly predicted future crashes would, if used as a screening tool, potentially prevent six crashes per 1000 people over 65 years of age screened, but at the price of stopping the driving of 121 people who would not have had a crash.

Objectives

Primary objectives:

1. to assess whether driving assessment facilitates continued driving in people with dementia;
2. to assess whether driving assessment reduces accidents in people with dementia.

Secondary objective:

1. to assess the quality of research on assessment of drivers with dementia.

Search methods

ALOIS, the Cochrane Dementia Group's Specialized Register was searched on 13 September 2012 using the terms: driving or driver* or "motor vehicle*" or "car accident*" or "traffic accident*" or automobile* or traffic. This register contains records from major healthcare databases, ongoing trial databases and grey literature sources and is updated regularly.

Selection criteria

We sought randomised controlled trials prospectively evaluating drivers with dementia for outcomes such as transport mobility, driving cessation or motor vehicle accidents following driving assessment.

Data collection and analysis

Each review author retrieved studies and assessed for primary and secondary outcomes, study design and study quality.

Main results

No studies were found that met the inclusion criteria. A description and discussion of the driving literature relating to assessment of drivers with dementia relating to the primary objectives is presented.

Authors' conclusions

In an area with considerable public health impact for drivers with dementia and other road users, the available literature fails to demonstrate the benefit of driver assessment for either preserving transport mobility or reducing motor vehicle accidents. Driving legislation and recommendations from medical practitioners requires further research that addresses these outcomes in order to provide the best outcomes for both drivers with dementia and the general public.

PLAIN LANGUAGE SUMMARY

Driving assessment for maintaining mobility and safety in drivers with dementia

The proportion of older people in the world is increasing and consequently the number of older drivers is also on the rise. Older people commonly depend upon private motor vehicles for their transport needs and so assessment of older drivers with cognitive impairment is becoming increasingly important. We have reviewed the literature on driving assessment in people with dementia for two reasons. First, we wished to see if assessment helped people with dementia and good driving skills continue driving. Second, we wished to discover whether assessment was useful in preventing road traffic accidents.

Although many authors have studied the motor skills, neuropsychological performance and driving behaviour of drivers with dementia, we found no study that randomised drivers to evaluate these outcomes prospectively following assessment. This highlights the need for caution in applying the literature on driving assessment to clinical settings as no benefit has yet been prospectively demonstrated. It also indicates the need for prospective evaluation of new and existing models of driver assessment to best preserve transport mobility and minimise road traffic accidents.

BACKGROUND

With an increasingly aged population, the number of older drivers is on the increase. Driving is the most common form of transport for older people, with only 3% of journeys by older people in the US undertaken by public transport. Transport and access to transport is an important factor in maintaining social inclusion and participation for older people: there is also considerable evidence that limiting this access (i.e. by driving cessation) is associated with poor health and depression (Marottoli 2000). Exclusion of elderly people from driving has been demonstrated to have many negative effects: loneliness, lower life satisfaction and lower activity levels. Drivers with dementia limit their driving and eventually withdraw, with profound negative effects on their mobility (Taylor 2001).

We do not know what interventions will maintain safe mobility for the longest period for people with dementia. A full assessment

(often including an on-road assessment) may have beneficial effects for drivers with many illnesses apart from dementia (Stutts 2003), and restricted driving licenses following assessment for people with medical conditions other than dementia are associated with a lower crash risk (Vernon 2002). An assessment in dementia also allows for advance planning of driving withdrawal and substitution of other transportation modalities, by way of the so-called modified Ulysses pact (Robinson 2004). It also allow for regular re-testing to guide this process (Duchek 2003).

Although there is no standardised neuropsychological assessment battery, most driving assessment protocols include medical, occupational therapy, neuropsychology assessment, or a combination of these, and an on-road driving assessment as required. We have no evidence that this intervention enhances either mobility or safety in people with dementia.

We sought evidence that formalised driving assessments are effective in maintaining mobility and safety in drivers with dementia rather than merely excluding those who are unfit to drive. Continued driving and outdoor mobility is important to older people and is a sufficient outcome measure in its own right. Safety is arguably a secondary end point, as crashes are relatively infrequent events, and fatal crashes even more so (1 per 50 million km). RCTs of driving assessment should involve a careful design, randomising people who drive to either formal testing or usual care and assessment, with longitudinal follow-up of satisfaction with transport ([Rosenbloom 2003](#)) and crashes or violations.

OBJECTIVES

Primary objectives:

- to assess whether driving assessment facilitates continued driving in people with dementia;
- to assess whether driving assessment reduces accidents in people with dementia.

Secondary objective:

- to assess the quality of research on assessment of drivers with dementia.

METHODS

Criteria for considering studies for this review

Types of studies

All relevant randomised controlled trials (RCTs) were included. Non-randomised trials (N-RCTs) are discussed in the [Background](#) and [Discussion](#) sections as appropriate. N-RCTs were excluded from the meta-analysis.

Types of participants

People with dementia of any type, without age restriction, were included.

Types of interventions

Any formal on-road driving assessment. The driving assessment may also involve standardised neuropsychological assessment battery, medical or occupational therapy assessment, but the intervention that is randomised should include formal on-road assessment.

Types of outcome measures

Our primary outcome was the number of people who remain driving after assessment compared to the control or placebo group. A second primary outcome was the number of road traffic accidents (RTAs) after assessment.

Search methods for identification of studies

Electronic searches

We searched ALOIS (www.medicine.ox.ac.uk/alois) - the Cochrane Dementia and Cognitive Improvement Group's Specialized Register on 13 September 2012. The search terms used were: driving or driver* or "motor vehicle*" or "car accident*" or "traffic accident*" or automobile* or traffic.

ALOIS is maintained by the Trials Search Co-ordinator of the Cochrane Dementia and Cognitive Improvement Group and contains studies in the areas of dementia prevention, dementia treatment and cognitive enhancement in healthy. The studies are identified from:

1. monthly searches of a number of major healthcare databases: MEDLINE, EMBASE, CINAHL, PsycINFO and LILACS;
2. Monthly searches of a number of trial registers: ISRCTN; UMIN (Japan's Trial Register); the World Health Organization (WHO) portal (which covers ClinicalTrials.gov; ISRCTN; the Chinese Clinical Trials Register; the German Clinical Trials Register; the Iranian Registry of Clinical Trials and the Netherlands National Trials Register, plus others);
3. quarterly search of *The Cochrane Library's* Central Register of Controlled Trials (CENTRAL);
4. six-monthly searches of a number of grey literature sources: ISI Web of Knowledge Conference Proceedings; Index to Theses; Australasian Digital Theses.

To view a list of all sources searched for ALOIS see [About ALOIS](#) on the ALOIS website.

Details of the search strategies used for the retrieval of reports of trials from the healthcare databases, CENTRAL and conference proceedings can be viewed in the 'methods used in reviews' section within the editorial information about the [Dementia and Cognitive Improvement Group](#).

Additional searches were performed in many of the sources listed above to cover the timeframe from the last searches performed for ALOIS to ensure that the search for the review was as up-to-date and as comprehensive as possible. The search strategies used can be seen in [Appendix 1](#).

The latest search (September 2012) retrieved a total of 741 results.

Data collection and analysis

Studies were selected from lists generated by the search strategy. Hard copies of all relevant studies were retrieved. Two review authors (AM, DON), blinded with respect to study authors, institution and journal, independently assessed trial quality and extracted data from studies that met the inclusion criteria. Meta-analysis and narrative review were performed where appropriate for each of the nominated outcomes. The Review Manager (RevMan 2011) software package was used where appropriate to perform the meta-analysis for continuous and dichotomous outcome measures. N-RCTs were not included in the primary analysis but are included in the discussion.

Data extraction

Data were extracted independently by two review authors (AM, DON). A data extraction form was used to record methodological and outcome data.

Quality assessment

The quality assessment of the included trials was undertaken independently and in duplicate by two review authors (AM, RM). The quality criteria that were examined are: allocation concealment (recorded as: adequate, unclear, inadequate or not used), and completeness of follow-up and intention-to-treat analysis. Given the nature of the study, blinding would not be expected.

Data analysis

No data for analysis (see Results section).

RESULTS

Description of studies

Our first search in 2007 identified 444 titles from which 202 abstracts were reviewed and in all 63 full-text papers were reviewed. Our second search in 2012 identified an additional 122 titles from which 70 abstracts and 41 full-text papers were reviewed.

Risk of bias in included studies

There were no studies that met the inclusion criteria.

Effects of interventions

There were no studies that met the inclusion criteria.

DISCUSSION

The importance of transportation to health and social inclusion of older people, and in particular, older people with dementia, must be recognised. Helpful studies in this regard are Taylor 2001, which showed an unmet shortfall in transport requirement and provision for drivers with dementia who stop driving, and a public health paper by Freeman 2006, which found that after controlling for other factors, driving cessation was associated with a higher risk of entry to nursing home. This relative lack of attention to transportation may also have societal roots, as indicated by a review of newspaper articles on older drivers, whereby the overwhelming emphasis was on safety rather than mobility (Martin 2005).

A second issue arises from a failure, as yet, to incorporate modern theories of driver behaviour (Ranney 1994; Fuller 2005) into existing driver assessment procedures, which almost invariably emphasise cognitive measures. These may play a less determining role in driving efficacy in mild to moderate dementia than is commonly understood. An exception to the cognitive approach can be seen in the work of de Raedt 2000, which uses a hierarchical and behavioural approach, and which seems to show promise in off-road assessment of drivers who have been noted to require driving assessment by physicians or state authorities.

There may be other methodological difficulties encountered in carrying out driving research. Testing may be challenging for the person, as described by Snellgrove 2000 and Clark 2005, and some may choose to give up driving rather than take a test. Faced with the threat of a test, the older driver may withdraw from driving, and enter the traffic in a more dangerous capacity, that is, as a pedestrian (Hakamies-Blomqvist 1996). One study has suggested it also led to an increase in the relative number of unsafe older drivers based on an increase in crashes per license following the introduction of mandatory testing (Langford 2004). Safety, legal and ethical implications for subjects and assessors carrying out road testing can also create significant obstacles to participation and study design. With the potential for fatal crashes at stake, the tenor of the vast majority of these narratives and descriptive studies is negative - directed towards driving cessation rather than preserving and enhancing mobility - and therefore restrictive from the point of view of the consumer undergoing assessment. They tend to focus on negative outcomes, which, although serious, are, in fact, rare and in doing so reinforce a negative stereotype on a large number of older drivers with cognitive impairment. Another methodological and practical consideration influencing the types of studies available is that identifying risk factors for crashes or cessation can be accomplished by relatively easy adaptation of existing databases or cohort studies. Intervention studies are inherently more time and cost intensive. To undertake intervention studies for rare outcomes such as crashes would require large sample sizes, a prevalent risk factor to target, and a reasonably effective intervention for that risk factor.

In order to appraise the available literature we approached the evidence from the point of view of the consumer and of evaluating physicians and used the following questions to illustrate what is known, what is inferred and what remains to be established.

1. Will assessment maintain transport mobility?

No study reviewed has discussed long-term transport mobility outcomes for people who passed or failed evaluations.

2. Will assessment prevent crashes or fatalities?

No study has evaluated this question.

In the absence of RCTs of both potential benefits and negative consequences from driving assessment, it is reasonable to consider conducting prospective trials of assessment versus no assessment, but with an independent safety committee reviewing the outcomes regularly during the course of the trial. However a trial of no assessment will not be feasible in regions with legally mandated specialised assessments for people with dementia. Another approach, in regions without standardised assessment of drivers with dementia, may be a trial of standardised testing (by office or road test) versus usual care with outcomes of transport mobility, time to driving cessation, crash or adverse driving behaviour.

3. What outcome measures might be used to measure transport mobility?

Transport mobility is poorly studied as most research focuses on driver safety, and is hampered by lack of a concise definition or screening instrument, for example, someone may have good transport support and access to services while not driving (i.e. due to good family support), or may hold a license and insurance but may not feel that they have good transportation (through fear of rush hour traffic, difficulty with hospital parking lots). Conceptual models of transport mobility have been outlined by [Rosenbloom 1993](#) and [Metz 2000](#) in an attempt to operationalise aspects of mobility not captured in existing studies but as yet there is little consensus on appropriate measures of transport mobility. [Spinney 2009](#) used data from the General Social Survey in Canada and showed a significant decline in transport mobility benefits in the domains of psychological benefits, exercise benefits, community-helping and community-socialising with increasing age. This decline in transport mobility was associated with a significant decline in quality of life but driving was not specifically measured. A further, but not co-terminous, measure is driving cessation, which may stand as a useful rough measure, particularly in jurisdictions such as the US where public transport usage by older people is very low and does not increase after driving cessation ([Giuliano 2003](#)). Increasing interest is also focusing on multi-modality of transport

in older populations, the demographic group within which dementia is most common ([Satariano 2012](#))

4. What outcome measures should be used to measure driver safety?

Crash rate?

This is an area fraught with methodological pitfalls as demonstrated by [Hakamies-Blomqvist 1998](#) and as such there is mixed evidence that drivers with mild cognitive impairment (MCI) and mild dementia will have an increased crash rate. Few authors have attempted a prospective study on crash rate. [Anderson 2005](#) found a positive correlation between neuro-psychological tests (Rey Auditory Verbal Learning Test (AVLT) and Complex Figure Test Recall (CFTR)) with prospective crash rate. They also assessed participants on a driving simulation and a composite score from all the neuropsychological tests, which correlated with each other but not with prospective crash rate. [Ott 2008](#) prospectively evaluated driving performance in participants with early Alzheimer's disease (AD) and healthy controls at six-month intervals. They found that the rate of motor vehicle accidents was not significantly different at baseline and that over the initial 18 months more crashes were observed in the control group but that after correction for miles driven this difference was not significant.

Crash rates have been suggested to be higher in retrospective studies; however, these studies are dependent on the accuracy of recalled information and results have differed considerably when data are collected from participants, carers or police records. [Stutts 1998](#) looked at cognitive performance and found that although the association with retrospective, state-recorded crashes in older adults was present the effect was small (less than two-fold increase comparing the top and bottom deciles on cognitive scores) and they were not able to identify a cut-off point that identified a significantly higher risk of crash. [Trobe 1996](#) and [Carr 2000](#) suggested that there was no increased risk of crash in people with dementia who's Clinical Dementia Rating (CDR) ([Morris 1994](#)) score was between 0.5 and 1 when looking at state recorded crash rates rather than those recalled by subjects, carers or relatives. This may represent a difference in the types of crashes reported to local authorities and although we can reasonably infer that more serious crashes are more likely to be recorded and that retrospectively recalled events may be less accurate, we have no comparative data on these systems of reporting. Parker's paper has built on previous evidence to show that driving errors are not well correlated with future crashes but previous violations were ([Parker 2000](#)). This may go some way to explain the discrepancy between high failure rates on road tests and low reported accident rates. Retrospective odds ratios (OR) for crash comparing drivers with dementia and with no dementia have been reported from 7.9 by [Friedland 1988](#) to 10.7 by [Zuin 2002](#). These studies show a marked difference

with respect to numbers of subjects, which may help explain the variable strength of the associations (Trobe: $n = 858$, Carr: $n = 121$, Zuin: $n = 87$, Friedland: $n = 50$). A much larger study involving 3238 older drivers applying for re-licensing had cognitive tests (Trail Making tests A and B, American Association of Retired Persons Reaction Time test and Short Blessed Cognitive screen) compared with State crash records for the previous three years (Stutts 1998). In that time frame there were 411 crashes including 97 crashes by 45 people, an annual average of 0.043 crashes per person. The investigators found an OR of approximately 1.5 for crashes comparing drivers with cognitive performance in the lowest decile to those in the highest decile. Unfortunately this study did not document a history of dementia in any driver or use cognitive assessments that would allow a diagnosis of dementia, so extrapolating these data to drivers with dementia is difficult. We might infer that the lowest decile of cognitive performance group included at least some people with dementia but the magnitude of the effect on crash risk is unknown.

Despite the fact that it is a study of older drivers and does not diagnose or identify a diagnosis of dementia in any participant or group, the Maryland Prospective Older Driver Study (Staplin 2003) can be useful to demonstrate some of the difficulties encountered in driving research. In this paper, 2508 adults over 55 years of age were screened using cognitive and physical performance measures in Maryland. Subjects were recruited by random invitation from all licensed drivers, by medical referral and at re-licensing at a senior citizens residential area. This had the advantages of a prospective follow-up for a mean of 20 months following assessment for crash and moving violation outcomes in a large population-based sample. They suggest, based on peak ORs for crash in each of four cognitive tests that cut-off points can be identified for increased risk of crash and high risk requiring intervention. ORs for crash at the following cut-points were: Motor-Free Visual Perception Test (Visual Closure subtest) (MVPT/VC): 5 incorrect, OR 4.96; Trail Making Test, Part B: 180 sec, OR 3.5; Cued/Delayed Recall: 2 incorrect, OR 2.92; Useful Field Of View subtest 2: 300 msec, OR 2.48. Using raw data in the paper we may extrapolate some values for sensitivity and specificity based on the strongest predictor, MVPT/VC, as a screening tool. MVPT/VC of 5 or more correctly predicted 18 crashes had 258 false positives, 93 false negatives and 1503 true negatives in the 1872 participants who had valid test results. This gives us a positive predictive value of 93%, negative predictive value of 94% and a sensitivity and specificity of 83% and 85%, respectively. If we look at the test as an intervention to prevent crashes, then we will need to screen 143 older drivers in order to prevent one crash in the following 20 months and an additional 20 drivers will fail testing.

Driving test performance?

There are reports that drivers with MCI and AD will have a high failure rate on driving tests from which we might infer a higher risk

of crash; however, rates of driving test failure vary considerably and, with the exception of Anderson's paper quoted above (Anderson 2005), none of these estimates have been validated prospectively. Snellgrove 2000 reported the highest driving test failure rate in a non-peer reviewed paper for the Australian Transport Safety Bureau. However, this was a highly selected group (consecutive referrals to a memory clinic) with no control group but they did demonstrate an extremely high rate of failure on their road test: 70% of the group of 117 subjects with predominantly early dementia (80%) and MCI (20%). Of particular concern was their finding that 50% of the group required a physical intervention by the assessor to prevent a crash (a finding that has not been reported in any other paper). They also found that 50% of the MCI group failed the road test. Similarly, 41% of 55 participants with dementia were reported to fail the road test in Clark 2005 and 63% of 19 subjects for Fox 1997, 36% of 96 subjects with cognitive impairment in Kay 2009, 65% of 99 subjects with dementia in Carr 2011 but only 18% of 65 drivers with dementia in Lincoln 2010. Comparative data versus controls were found in Duchek 2003, which gives test failure percentages of 30% versus 3% for people with and without dementia, and from Lincoln 2006, 37% versus 0%. Ott 2008 showed an increased hazard ratio for test failure of 3.51 in people with established dementia (CDR 1.0) versus early dementia (CDR 0.5) in a prospective study over 18 months. In addition, the CDR 1.0 group also showed a higher rate of driving cessation: only 31% of the CDR 1.0 presented for re-test at 18 months compared to 48% of CDR 0.5. Road test failure rates in Berndt 2008 were 34% for CDR 0.5, 58% for CDR 1.0 and 95% for CDR 2.0. Interestingly one person with CR 2.0 passed the road test suggesting that there may be some merit in offering a road test to people who wish to avail of the opportunity irrespective of their cognitive testing.

Driving simulator performance?

Simulators have also demonstrated higher rates of adverse driving behaviours in studies by Rebok 1994, Cox 1998, Frittelli 2009 and Vaux 2010 and also crashes (Rizzo 1997; Rizzo 2001; Uc 2006, Frittelli 2009). However, some authors believe that performance in driving simulators is not strongly related to on-road driving performance (Bylsma 1997; Rizzo 2001).

5. Is there documented evidence of negative effects of assessment?

The numbers of older people who would decline voluntary testing are significant. In the Maryland Programme of Older Driver Screening, 53% of a sample of 3974 older drivers declined driver screening offered to them (Ball 2006). There was no difference in retrospective crash rate for those screened and those who declined and, unexpectedly, participants were more likely to be involved in prospective crashes. This sample was taken from older people

presenting for re-licensing and participants were not assessed for the presence of dementia. Unfortunately there was no mention of comparative mobility and continued driving rates in the two groups. [Snellgrove 2000](#) and [Clark 2005](#) also reported on those who refused on-road testing: 36% to 54% of those who refused said that they would rather give up their license rather than re-test. Both of these studies and also [Stutts 1998](#) and [Duchek 2003](#) indicate that these subjects do not differ from the experimental group in age, sex and Mini Mental State Examination (MMSE) score so we might infer that it reflects a population of people who may have normal driving skill who are negatively influenced by the assessment process with the attendant risks of depression, isolation and social exclusion suggested by [Marottoli 1997](#), [Marottoli 2000](#) and [Ragland 2005](#) and also early entry into nursing homes ([Freeman 2006](#)). Data from both [Meuser 2009](#) and [Snyder 2009](#) show that the combination of the test failure rate and a lack of appeals or applications for re-testing meant that 90% to 96.5% of drivers reported as impaired did not resume driving. Unfortunately, neither study documented the effect on crashes or traffic violations or on the health of reported drivers. Driver screening for cognitive impairment has also been shown to lack utility and is associated with increased traffic fatalities in a study that looked at the impact of a decision by the Danish government to add a brief cognitive status examination to medical screening of older drivers ([Siren 2012](#)). This is against a background of other studies that consistently support the hypothesis that mandatory medical testing of older drivers is not associated with reduced fatalities, and indeed that older drivers in the jurisdictions without testing had a significantly safer traffic record ([Hakamies-Blomqvist 1996](#); [Langford 2004](#)).

6. What assessment measures should be used?

Neuropsychology

Although studies of older drivers without dementia have shown evidence that office-based tests correlate with future crashes, this has not been evaluated in drivers with a diagnosed dementia. What can be said is that in studies that included people with diagnosed dementia, office-based tests correlate, grossly and without helpful cut-off points, with road test performance and driving simulator performance. Also many studies have shown the strongest correlation between road testing requires a composite of multiple tests ([Rizzo 1997](#); [Anderson 2005](#); [Clark 2005](#); [Lincoln 2006](#)), which may limit their use to trained individuals and require lengthy assessments. Clark's composite was more realistic (MMSE, Trail Making test-A and Wechsler Adult Intelligence Scale-block design) with a sensitivity and specificity of 82% and 90%, respectively, but it remains to be established that such an assessment is independently adequate to disqualify drivers or merely a screening tool to identify those requiring road testing. There is little evidence

that simple tests alone are as effective as road tests. Their most likely role is in screening to identify those in need of more detailed evaluation. Even with composite tests, such as the Stroke Driver Screening Assessment (SDSA) ([Nouri 1992](#)), adjustment has been needed for stroke in international populations ([Lundberg 2003](#)), and have needed to be used in other combinations of instruments for Parkinson's disease, traumatic brain injury ([Radford 2004](#)) and dementia ([Lincoln 2006](#)). The Nordic version of the SDSA has been shown to be effective in evaluating stroke drivers but had poor sensitivity and specificity in drivers with dementia ([Selander 2010](#)).

Behaviour/driving specific

The model of assessment suggested by [Michon 1985](#) and operationalised by [de Raedt 2000](#) uses a hierarchical and behavioural approach to the driving task. Michon's model of selection, optimisation and compensation describes successful adaptive strategies in individuals with disability. Examining driving behaviour in similar terms may help identify those able to overcome increasing levels of disability - physical or psychological. De Raedt's model examined driving behaviour in three hierarchies: *strategic* behaviours involved in planning destinations and routes and avoiding hazardous weather or traffic conditions; *tactical* refers to anticipatory behaviours such as speed adaptation; *operational* behaviour is the physical performance of the task (examined in most studies). De Raedt showed high levels of strategic behaviours in those performing badly on road tests but who did not have high accident rates. High accident rates were more associated with low tactical performance scores. This adds an extra dimension to assessment and may help explain the apparent discrepancy between high test failure rates and low per capita crash rates as well as some of the variability in the studies quoted. This model was used by [Grace 2005](#) in a small study with 21 in each group comparing participants with AD, Parkinson's disease and healthy controls. In this study, test failure was rare: only two of the AD group and none of the other two groups failed the road test. However, errors were more common in AD and Parkinson's disease groups, with strategic, tactical and operational errors observed in people with AD while only tactical errors were observed in people with Parkinson's disease. This may suggest that a single standardised test will not be suitable in all older drivers or even all neurologically impaired drivers and a tailored approach may be necessary. Another approach that has more congruence with modern concepts of driver behaviour is that of self efficacy, and an early study in stroke (an illness with high levels of cognitive impairment) has shown promise ([George 2007](#)).

On-road tests

Many studies have used on-road testing as their gold standard ([Hunt 1993](#); [Fitten 1995](#); [Fox 1997](#); [Hunt 1997](#); [Dobbs 1998](#);

Snellgrove 2000; Duchek 2003; Wild 2003; Brown 2005; Clark 2005; Grace 2005; Ott 2005; Uc 2005; Lincoln 2006; Berndt 2008; Ott 2008; Dawson 2009; Kay 2009; Okonkwo 2009; Lafont 2010; Lincoln 2010; Patomella 2010; Selander 2010; Barrash 2010 Carr 2011). The road test lacks an accepted standard and considerable variation exists in term of vehicles, routes and tasks. More recent studies have begun using standardised and validated road tests such as the Sepulveda Road test (Fitten 1995), the Washington Road Test (Hunt 1997) or the Test-ride for Investigating Practical fitness to drive or TRIP (Tant 2002) designed specifically for older driver assessment. Prospective studies will be required to define cut-off scores that predict crash risk.

Driving simulators

Driving simulators have been used in many studies (Rebok 1994; Rizzo 1997; Cox 1998; Rizzo 2001; Anderson 2005; Uc 2006; Frittelli 2009; Vaux 2010). Simulators have obvious advantages, allowing detailed assessment in a safe and controlled environment; however, they have not been shown to predict prospective crashes and some authors feel they are not correlated well with the driving task in older drivers and drivers with dementia (Bylsma 1997; Rizzo 2001). There is also considerable variation in the technology involved ranging from computer-based simulations (Rebok 1994) to scale-model vehicles that simulate audiovisual data in addition to momentum (Rizzo 2001). Tolerability may also be problematic as simulators need to have verisimilitude but older people also get more motion sickness (Edwards 2003).

Dementia type

AD is specifically evaluated in most studies although many of the studies did not specify which dementia subtypes were within the experimental group or did not use consistent and clinically useful criteria (such as CDR or NINDS) to document disease severity. Vascular dementia (VaD) is rarely tested and then usually as a part of an unselected dementia population. No subgroup analysis or specific studies of driving in VaD were identified. Fitten 1995, Zuin 2002, Clark 2005 and Lincoln 2010 were the only studies identified that specifically mentioned including a number of subjects with VaD but did not look at differential outcomes due to small numbers. Fronto-temporal dementia (FTD) has only been evaluated in one study (de Simone 2007), which showed a higher rate of crashes and errors in a simulated drive but only enrolled 15 subjects and 15 controls. Zuin 2002 did comment on a particularly high incidence of adverse driving behaviour in FTD but this only accounted for two out of 87 subjects and no further analysis was attempted. Lincoln 2010 also included a small number of people with VaD, FTD and dementia with Lewy bodies (DLB) but the numbers were too small to yield significant results. Other forms of dementia are almost never evaluated in studies despite reasonable suspicion of higher risk with deficits in

perceptual skills and impaired judgement and disinhibition, for example, in DLB. It would seem logical to suggest that deficits of people with VaD, FTD and DLB may not correlate well with the studies on people with AD and would need specific studies to validate driving assessment techniques.

Dementia rating

Use of clinically relevant instruments such as CDR to rate dementia severity have helped to categorise drivers who perform poorly in some studies (Hunt 1993; Duchek 2003; Ott 2008) and by incorporating functional and behavioural measures may have stronger predictive value. As discussed earlier, Ott 2008 showed a significant difference in prospective driving performance according to CDR score reinforcing the value of road testing in earlier stages of AD and in at least one case in a person with a CDR score of 2.

Functional tests

Functional measures, such as delayed recall, Trail Making test, visual perception, useful field of view, lower limb strength, and head and neck mobility, used in the Maryland Pilot Older Driver Study (Staplin 2003a), are potentially reliable predictors of crash risk with clear cut-off scores thus far only evaluated in an unselected older driver population. It bears mentioning though in that this is the first study that had a component looking at mobility and driving cessation. Newer data from the study, however, indicate that the predictive value of functional tests may decrease with increasing time since assessment, although the predictive value of delayed recall and rapid pace walk was preserved (Staplin 2003).

Collateral history

Collateral history is useful but may be misleading and subject to positive and negative bias. Wild 2003 showed more accurate prediction of driving ability from carers than people with AD but not for healthy older people. However, carers' assessment of functional impairments can be influenced by the burden placed on a carer's time (Zanetti 1999) and carers may have vested interests in a person's continued driving, in the example of a non-driving spouse. This may explain the higher crash rates estimated by carers as found in Friedland 1988. Despite this, dementia research in other fields lends credence to the collateral history, which can be a more accurate estimate of cognitive and functional decline (Archer 2007).

Other approaches to managing driving and dementia: mandatory reporting and voluntary reporting

A study from Oregon showed that, where physician reporting of impaired drivers was linked to mandatory suspension from driving, only 18.5% of 1664 drivers requested a re-test or appeal

against suspension and that 56% of those re-tested regained driving privileges (Snyder 2009). The majority (88.8%) of these automatic suspensions were for cognitive impairment. No data have been presented on whether this measure improves safety on Oregon's roads.

Meuser 2009 described a system where introduction of voluntary reporting of impaired drivers in Missouri led to driving cessation in 96.5% of 4100 reported individuals, 50% of whom did not seek any further assessment. This measure did lead to a reduction in crashes in this group but the study did not look at the impact on mortality or morbidity outcomes for this group other than motor vehicle accidents.

Summary

Our findings, therefore, continue to demonstrate a deficit in the transport literature for people with dementia. Despite considerable international variation in the regulatory and legislative processes for driving assessment in people with dementia there is no evidence from RCTs or prospective studies that driving assessment will help maintain mobility or improve safety for drivers with dementia. The subject of mobility outcomes after driving assessment has been overlooked thus far. Drawing on the literature for the larger numbers of older driver, little evidence has, so far, been forthcoming that there is any benefit in these driver screening programmes. Studies evaluating driving skills in people with dementia are fraught with methodological difficulties and are largely focused on rare outcomes such as crashes and therefore rely on surrogate markers such as cognitive tests, driving simulators and road tests. The overwhelming majority of these tests have not been evaluated prospectively in people with dementia and so can only offer speculative data on crash risk. Finally, given the evidence of negative effects of mandatory assessment and driving cessation more prospective data are required regarding positive and negative outcomes for people with dementia who undergo driving assessment.

AUTHORS' CONCLUSIONS

Implications for practice

There is no randomised evidence to indicate whether neuropsychological, on-road or other assessments of driving ability can help support safe drivers to remain mobile, or to reduce crashes.

Implications for research

More work is required to identify the optimal assessment strategy to help preserve transport mobility. A key challenge here is the

development of a concise measure of transportation resources and quality, as suggested by Metz 2004.

Screening appears to discriminate unfairly against older drivers and yet in a population who appear to have declining driving skills there is understandable concern about crash risk. Further research is required to develop assessment tools that can reliably identify unsafe drivers with dementia in an office-based setting. Behavioural models may be of benefit here.

RCTs of driving assessment should involve a careful design, randomising people who drive to either formal testing or usual care and assessment, with longitudinal follow-up of satisfaction with transport (Rosenbloom 2003) and crashes or violations. Ethically, this may not pose a public health hazard in view of some memory clinic studies that suggest no increase in crashes in those with dementia (Drachman 1993; Trobe 1996; Carr 2000). Due care will need to be given to advice to participating drivers on informing driver licensing authorities and insurance companies, depending on the jurisdiction(s) within which the study is taking place. The study should also incorporate regular data review by an independent safety committee. As it is clearly undesirable that all drivers with dementia continue driving indefinitely, the use of a measure of transport efficacy, such as the Life Space Questionnaire (Stalvey 1999), may be a better guide to the primary question posed. It is likely that a close monitoring of the study for adverse events would be the best guide to the potential hazards, as, given that crashes are infrequent events, a study based purely on the secondary objective of safety would have to be very large. Extrapolating from Staplin 2003 where 111 out of 1876 participants in the License Renewal Sample crashed in the 20 months' follow-up, giving a crash rate of 0.06 per person over 20 months. Using JMP statistical software (SAS Institute) we estimate that a sample size of 5293 in each group would be required to have an 80% power to detect a 20% difference in crash rate between an unselected older driver population and a dementia group in the same time frame. If, however, we were to choose a larger estimate of increased crash risk such as a 50% difference in crash rates, our required sample size would be 953 per group. For the primary research objective of continued driving, cessation over a 23-month period was almost 50% in a Canadian study of 200 drivers with dementia (Herrmann 2006), giving a withdrawal rate of 0.485 per person over a 23-month period. This would give us a sample size of 2625 in each group to have an 80% power to detect a 10% difference in driving cessation.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

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

Study	Reason for exclusion
Adler 2008	Non-RCT Review article
Akinwuntan 2007	Stroke cohort, no dementia cases
Anderson 2005	Non-RCT Case-control study, 222 participants (70 with mild AD, 152 controls) compared composite neuropsychological test scores and simulated driving performance with prospective crash rate
Anstey 2009	Non-RCT Only 2 people with probable dementia included
ANZSGM 2010	Non-RCT Position statement
Arai 2009	Non-RCT
Badenes 2007	Non-RCT Case control study, 187 participants, (92 MCI, 55 mild dementia, 40 controls) recruited from hospital population, compared neuropsychological testing with ASDE-driver test (a Spanish office-based measure of fitness to drive measuring: estimations of speed, coordination, reaction time, attention and concentration)
Badenes-Guia 2008	Non-RCT 92 MCI, 55 mild dementia, 40 controls, tested with RBANS, TMT, Kohs block design compared with ASDE-driver test and UFOV. No on-road test
Ball 2006	Non-RCT Population-based older driver cohort, no dementia measures included. 2114 older drivers compared initial assessment (measures of vision, gross and fine motor skills and cognitive testing) with 4-5 years' follow-up for motor vehicle accidents
Barrash 2010	Non-RCT Prospective study, self selected, advert respondents, 24 healthy, 26 probable AD, 33 PD. All active drivers with MMSE > 26. People with AD and PD recruited from registry, used neuropsychological tests and on-road, unable to blind assessors (PD). Differences on neuropsychological tests but not road test failure. Scores did correlate with number of driving errors but effect diminished by demographic adjustments
Berndt 2008	Non-RCT Road test results in 117 people with dementia stratified by CDR score. Higher road test failure rate in higher CDR score
Breen 2007	Non-RCT Review article

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Brown 2005	Non-RCT Case-control study, 75 participants (50 with mild to moderate AD, 25 controls) correlated neuropsychological tests with rating of safe or unsafe in on-road testing
Bylsma 1990	Duplicate of Rebok 1994
Bylsma 1997	Non-RCT Review article
Carr 2000	Non-RCT Retrospective case-control study of 121 participants (63 with mild AD and 58 controls) comparing state-recorded crash rates in both groups over the previous 5 years
Carr 2011	Non-RCT 99 people with dementia referred for road test. Washington road test compared with visual, motor and cognitive test. no information on dementia subtype or severity
Clark 2005	Non RCT Cross-sectional study of 55 participants (41 with AD, 6 with VaD, 2 with DLB, 4 with FTD and 2 age-associated memory loss) no controls. Correlated neuropsychological tests with a rating of safe or unsafe in on-road testing
Cooper 1993	Non-RCT Case-control study comparing retrospective crash rates of 165 older people from a dementia clinic with a random sample from the population of drivers in British Columbia
Cotrell 1999	Non-RCT Cross-sectional study of 35 people with AD (only 19 still driving), evaluated on MMSE, driving status and carer assessment of driving behaviour
Cox 1998	Non-RCT Cross-sectional study of 50 participants (29 with AD) comparing neuropsychological tests with simulated drive
Cushman 1992	Non-RCT Case-control study of 17 participants (8 with possible dementia, 9 without suspected dementia) comparing neuropsychological tests with a rating of safe or unsafe in on-road testing
Daiello 2010	Non-RCT 24 early AD before and after cholinesterase inhibitor treatment, compared on computerised tests of visual attention and executive function. Also 35 early AD treated vs. matched non-treated. NO ROAD TEST. Simulated computer-based drive. Cholinesterase inhibitor improved simulated drive and visual attention
Dawson 2009	Non-RCT Case control, comparing 40 early AD vs. 115 healthy people on cognitive, visual, motor and driving tests. AD had more driving errors 42 vs. 33. Errors associated with older age, lower cognition status, and poorer performance on BVRT, CFT-copy, TMT-A and functional reach test

(Continued)

de Simone 2007	Non-RCT Case-control study of 30 participants (15 people with FTD and 15 healthy controls) were administered a driving simulation task. Measures of driving performance and neuropsychiatric symptoms were assessed
Devos 2007	Non-RCT Case-control study of 80 participants (40 people with Parkinson's disease and 40 controls). Included 11 people with PD and 3 controls with very mild cognitive decline (CDR 0.5). Participants were assessed using a driving simulator, driving history survey and the CDR. The people with PD also underwent a clinical test battery and an evaluation of fitness to drive performed by an official centre, which included visual, cognitive and on-road tests
Dobbs 1997	Non-RCT Case-control study of 115 older drivers with cognitive decline - mostly AD compared with 35 older and 23 younger controls. Comparisons made with cognitive testing and on-road driving test
Drachman 1993	Non-RCT Retrospective questionnaire-based survey comparing annual rates of occurrence and severity of all crashes based on responses of the carers of 130 people with AD and 112 age-matched control subjects (no dementia) and their spouses
Dubinsky 1992	Non-RCT Retrospective questionnaire based survey of 67 people with AD and their families and compared them with 100 elderly, non-spousal controls focused on driving habits, continued driving and the number of accidents per year for the past 10 years
Duchek 2003	Non-RCT Prospective case control study following 108 participants (50 with AD and 58 non-dementia) with sequential on-road testing
Ernst 2010	Non-RCT Carer interviews, 30 FTD, 26 AD. Reported differences in driving behaviour: AD: unsteady driving style, FTD: aggressive/ risky/lack of insight. 37% MVA vs. 19% for AD (NS)
Fitten 1995	Non-RCT Case-control study of 84 participants (15 with AD, 12 with VaD and 57 non-dementia subjects). Correlated neuropsychological tests with Sepulveda Road test score and retrospective crash and violation rate
Fox 1997	Non-RCT Cross-sectional study of 19 participants with AD, correlating road test with physician and neuropsychologist's assessment of fitness to drive and neuropsychological scores
Friedland 1988	Non-RCT Case-control study comparing retrospective crash rate of 30 people with AD with 20 people without dementia
Frittelli 2009	Non-RCT CCT comparing 20 AD (CDR 1), 20 MCI (CDR 0.5) and 19 healthy on computer-based driving simulator (STISTIM). All active drivers and not on treatment for AD. Poorer performance on length of run, mean time to collisions, off-road events in AD vs. MCI and controls. MCI shorter time to collisions than healthy

(Continued)

	controls. Reaction times longer for AD vs. MCI and healthy control. Driving not correlated with MMSE
Gilley 1991	Non-RCT Retrospective survey of 522 people and their collateral informants from a dementia clinic. Only 322 licensed to drive at onset of dementia and 93 active drivers at time of questionnaire. Questionnaire on driving cessation and unsafe driving in previous 6 months
Grace 2005	Non-RCT 21 mild AD, 21 PD without dementia and 21 healthy controls. Compared neuro-psychological tests and on-road driving test, miles driven AD < PD < N. Poorer performance on neuro-psychological testing correlated with unsafe or marginal performance. HVLT for AD and PD, TMT-A for AD. Hoehn and Yahr correlated with marginal driving performance
Hunt 1993	Non-RCT Case-control study of 38 participants (25 with AD, 13 without suspected dementia). Correlated neuropsychological tests with a rating of safe or unsafe in on-road testing
Hunt 1997	Non-RCT Case-control study of 94 participants (56 with AD, 38 without suspected dementia). Correlated neuropsychological tests with a rating of safe or unsafe in on-road testing
Hunt 2010	Non-RCT Observational retrospective cohort
Innes 2005	Non-RCT Cross-sectional study of 50 drivers with neurological disorders (4 with AD) referred to a Driving and Vehicle Assessment Service comparing a battery of computerised sensory-motor and cognitive tests and on-road driving assessment. Developed a model of sensory-motor and cognitive tests that would predict pass or fail on-road testing
Iverson 2010	Non-RCT Consensus statement
Johansson 1997	Non-RCT Review article
Kamimura 2009	Non-RCT
Kawano 2009	Non-RCT Observational retrospective study
Kay 2009	Non-RCT Prospective multicentre study of 115 driving assessment referrals with functional impairment 96 neurological including 30 AD. Compared 2 standardised office tests with on-road assessment. Cut-offs for both scores predicted road test fail
Lafont 2010	Non-RCT Prospective population study 2104 participants, predictors of driving cessation, including neuro-psychological testing and dementia diagnosis. Dementia associated with driving cessation but not with crashes.

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	Development of dementia later in the study was associated with crashes (OR 3.4). Poor performance on TMT-B associated with crashes (OR 7.7)
Laks 1999	Non-RCT Review article
Laks 2000	Non-RCT Survey of cognitive performance and driving history (licensing and cessation) in 110 residents of sheltered accommodation for older people
Leproust 2008	Non-RCT Hypothetical study. Suggested on-road testing every 3 years for people over 85 years of age as preventing 569 crashes and inducing 270 adverse events. Based on crash risk of 2.0 for drivers with dementia
Lincoln 2006	Non-RCT Case-control study of 75 participants (42 with dementia, 33 without suspected dementia). Correlated neuropsychological tests with a rating of safe or unsafe in on-road testing. An algorithm to predict road-test failure was generated from the neuropsychological tests and validated on a cohort of 17 people with dementia
Lincoln 2010	Non-RCT Dementia cohort of 75 people with 34 AD, 14 VaD, 2 DLB, 1 FTD, 1 MCI, 4 mixed - 65 had on-road test. Dementia severity not recorded. 12 failed road test. Combination cognitive scoring gave sensitivity 80% and specificity 61.5% for predicting road test failure. Validated previous prediction rule correctly classifying 76% of people
Love 2007	Non-RCT
Lucas-Blaustein 1988	Non-RCT Retrospective survey of driving history and crashes in 72 people referred to a dementia clinic
Lukas 2009	Non-RCT Review article
Man-Son-Hing 2007	Non-RCT Review article
Meuser 2006	Non-RCT, Trial of education for health professionals
Meuser 2009	Non-RCT Driving outcomes of reported impaired drivers in Missouri. Reporting resulted in lower crash rate and mortality in reported drivers - 96.5% had license revoked
Molnar 2006	Non-RCT Review article
Molnar 2007	Non-RCT Review article

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Mosimann 2011	Non-RCT Consensus statement
Neitch 2011	Non-RCT Retrospective audit of 43 assessments comparing performance on standardised testing of 27 with and 25 without dementia
O'Connor 2010	Non-RCT More rapid decline in life space and driving in MCI vs. healthy controls, no driving assessment
Odenheimer 1994	Non-RCT Cross-sectional study of 30 licensed drivers with a broad range of cognitive skills (3 with AD, 3 with VaD), over age 60 years, were road tested on a closed course and in traffic by a driving instructor and 2 researchers. Driving instructor scores and cognitive test scores compared with research road test scores
Okonkwo 2009	Non-RCT Case-control study comparing 57 MCI vs. 68 healthy controls, on-road test as part of functional assessment. 70% vs. 50% had some difficulty on road test, non-significant difference in tendency to overestimate ability. No reported test failures
Oswanski 2007	Non-RCT Cross-sectional study of 232 drivers over 55 years referred for license renewal were given the Motor Free Visual Perceptual Test, clock test, and an on-road driving test. No dementia diagnosis included
Ott 2005	Non-RCT Cross-sectional study of 50 drivers with probable or possible AD (very mild to mild), from a longitudinal study of driving and dementia to compare office-based clinician rating of driving competence with on-road assessment. Clinician rated the drivers as safe, marginal or unsafe (based on chart review) and compared these ratings with total driving scores on a standardised road test and categorical ratings of driving competence from a professional driving instructor
Ott 2008	Non-RCT CCT: 65 probable AD, 23 possible AD (53 CDR 0.5, 35 CDR 1) and 45 healthy controls. In AD cases with CDI 0.5-1 maze test and neuropsychological test were compared to on-road testing. Road test failure noted in 1/45 controls and 17/88 AD. Road test score correlated with maze and neuropsychological tests
Parker 2000	Non-RCT Questionnaire survey of 1989 drivers aged 50 years or over (Manchester Driver Behavior Questionnaire) examined factors associated with crashes in older drivers. No dementia diagnosis
Patomella 2010	Non-RCT 205 impaired drivers referred for on-road test. 128 had stroke, 43 with MCI and 34 with dementia
Rapoport 2007	Non- RCT Review article
Rebok 1994	Non-RCT Case-control study of 22 older drivers (10 with AD and 12 controls) compared on neuro-psychological tests,

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	the Driver Performance test (subjects answer questions based on videotaped driving scenarios) and Driver Advisement System (computer-based measures of reaction time and coordination using steering wheel and pedals in front of monitor)
Reger 2004	Non-RCT Review article
Regtuijt 2007	Non-RCT Case report
Rizzo 1997	Non-RCT Case-control study of 39 drivers (21 with AD and 18 controls) comparing neuro-psychological testing with driving simulator performance and simulator crash rate
Rizzo 2001	Non-RCT Same design and participants as Rizzo 1997 but with hazards at intersections requiring rapid response to avoid crash
Ross 2009	Non-RCT Pooled data from 9 longitudinal studies in ageing, 5206 older adults no intervention, no assessment of driving ability
Silva 2009	Non-RCT Review article
Singh 2007	Non-RCT Cross-sectional study of 154 individuals with PD (22 with dementia: diagnosed by team consensus based on MMSE, 15 road sign recognition, visuospatial construction, Trail Making test, forward and reverse digit span, and a story recall) referred to a driving assessment centre. Group included 17 who stated that they had stopped driving by themselves before assessment. Driving ability determined by a combination of clinical tests, reaction times on a static test rig and an in-car driving test
Snellgrove 2000	Non-RCT Cross-sectional study of 115 community-dwelling older drivers with MCI or early dementia (recruited through a memory clinic). Participants completed the Maze Task, and immediately thereafter, a standardised on-road driving test. Results also compared with cognitive tests from memory clinic
Snyder 2009	Non-RCT Retrospective audit of 1664 impaired drivers mandatorily reported, 88% had cognitive impairment, reported by internists and general practitioners. Auto suspension all - 15% requested re-test, 3% contested and only 10% regained driving privileges. No data on impact on crashes or cessations
Soderstrom 2009	Non-RCT Retrospective audit of reasons for referral by police to medical advisor boards. 40% of all referrals for confusion disorientation but dementia only in 3%
Staplin 2003	Non-RCT Same as Staplin 2003a with further 1-year follow-up data for crashes

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Staplin 2003a	Non-RCT Prospective cohort study of 2500 drivers over 55 years of age comparing cognitive and motor performance with prospective crash rate over 2 years following assessment. No dementia diagnosis
Stutts 1998	Non-RCT Retrospective cohort study of 3238 drivers aged 65 years and older applying for renewal of their driver's license. Compared cognitive assessments with crash involvement during the 3-year period prior to testing. No dementia diagnosis
Szlyk 2002	Non-RCT Initial survey of 292 licensed neuropsychologists on neuropsychological tests currently used to screen people for driving. Followed by development of 12-item neuropsychological battery used to screen 22 licensed drivers ranging in age from 67 to 91 years. Subjects were administered the neuropsychological battery, a driving simulator test and a Driving Habits Interview. No dementia diagnosis (subject classified as suspected dementia based on MMSE < 24)
Taylor 2001	Non-RCT Survey of 922 drivers whose licenses had been revoked or suspended due to dementia or suspected dementia. Questioned on the changes in household travel patterns and responsibilities following license revocation and on the psychological effects of these changes on affected household members. The survey was addressed to and in nearly all cases completed by the 'carer' of the former driver
Trilling 2001	Non-RCT Review article
Trobe 1996	Non-RCT Retrospective case-control study of 143 licensed people with AD and 715 licensed comparison subjects matched 5 to 1 in age ($\pm$ 6 years), sex and county of residence. Compared crashes and violations from state driving records with neuropsychological test scores. A questionnaire-based inquiry on the influence of physician, family and state interventions on driving cessation was administered
Tuokko 1995	Non-RCT Retrospective case-control study of 249 people referred to an outpatient dementia clinic. People were divided into those who met criteria for dementia and those who did not and compared with controls for retrospective crash and traffic violation rate. For each group, control subjects matched on age, gender and location of residence were randomly selected from the records of all drivers in the province
Uc 2005	Non-RCT Case-control study of 33 drivers with probable AD of mild severity and 137 neurologically normal older adults comparing a battery of visual and cognitive tests in addition to driving safety and detection of specific landmarks and traffic signs along a segment of an on-road experimental drive
Uc 2006	Non-RCT Case-control study of 61 drivers with mild AD and 115 elderly controls using a driving simulator comparing crash rate and unsafe avoidance behaviour in a driving situation with a high risk of rear end collision
Uc 2008	Non-RCT Review article

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Vaux 2010	Non-RCT Prospective case control study: 8 people with PD, 6 with AD and 18 healthy controls. Simulated drive on desktop computer tasked to identify whether moving spheres on a collisions course with them
Wadley 2009	Non-RCT Prospective case control stud: 46 MCI vs. 59 healthy controls compared on driving. MCI had more “less than optimal” performance on global measures but not outright fail
Wild 2003	Non-RCT Case-control study of 15 drivers with mild AD and 15 controls comparing questionnaire responses on self reported cognitive function and driving performance in addition to an on-road test
Withaar 2000	Non-RCT Review article
Woolf 2006	Non-RCT Review article
Zuin 2002	Non-RCT Retrospective case control study of 56 drivers with dementia (43 probable AD, 6 possible AD, 3 VaD, 1 DLB, 2 FTD, 1 unclassified). and 31 elderly controls. Motor vehicle crash and abnormal driving behaviour rates obtained from collateral informants and compared with detailed neurological, psychiatric and neuropsychological examinations

AD: Alzheimer’s dementia; ASDE: Proprietary: Manufacturers name “General ASDE, SA” ; BVRT: Benton Visual Retention Test; CCT: controlled clinical trial; CDR: Clinical Dementia Rating; CFT: Complex Figure Test; DLB: dementia with Lewy body; FTD: fronto-temporal dementia; HVL: Hopkins Verbal Learning Test; MCI: mild cognitive impairment; MMSE: Mini-Mental State Examination; MVA: motor vehicle accident; NS: not significant; OR: odds ratio; PD: Parkinson’s disease; RBANS: Repeatable Battery for the Assessment of Neuropsychological Status.; RCT: Randomised Controlled Trial ; TMT: Trail-Making Test ; UFOV: Useful Field of View; VaD: vascular dementia.

DATA AND ANALYSES

This review has no analyses.

APPENDICES

Appendix I. Search: September 2012

Source	Search strategy	Hits retrieved
1. ALOIS (www.medicine.ox.ac.uk/alois)	driving OR car OR cars OR driver OR drivers OR automobile OR vehicle	20
2. MEDLINE In-process and other non-indexed citations and MEDLINE 1950-present (Ovid SP)	1. exp Dementia/ 2. Delirium/ 3. Wernicke Encephalopathy/ 4. Delirium, Dementia, Amnestic, Cognitive Disorders/ 5. dement*.mp. 6. alzheimer*.mp. 7. (lewy* adj2 bod*).mp. 8. deliri*.mp. 9. (chronic adj2 cerebrovascular).mp. 10. ("organic brain disease" or "organic brain syndrome").mp 11. ("normal pressure hydrocephalus" and "shunt").mp. 12. "benign senescent forgetfulness".mp. 13. (cerebr* adj2 deteriorat*).mp. 14. (cerebral* adj2 insufficient*).mp. 15. (pick* adj2 disease).mp. 16. (creutzfeldt or jcd or cjd).mp. 17. huntington*.mp. 18. binswanger*.mp. 19. korsako*.mp. 20. or/1-19 21. (motor adj2 vehicle*).ti,ab. 22. (automobile adj2 driving).ti,ab. 23. (automobile adj2 driver*).ti,ab. 24. (car adj2 driver*).ti,ab. 25. (traffic adj2 accident*).ti,ab. 26. (car adj2 accident*).ti,ab. 27. Accidents, Traffic/ or Automobile Driv-	21

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	ing/ 28. (driving and (asess* or continu* or capabilit*)).ti,ab. 29. or/21-28 30. 20 and 29 31. randomized controlled trial.pt. 32. controlled clinical trial.pt. 33. randomized.ab. 34. placebo.ab. 35. randomly.ab. 36. trial.ab. 37. groups.ab. 38. or/31-37 39. 30 and 38 40. (2007* or 2008* or 2009* or 2010* or 2011* or 2012*).ed. 41. 39 and 40	
3. EMBASE 1974-2012 September 07 (Ovid SP)	1. exp dementia/ 2. Lewy body/ 3. delirium/ 4. Wernicke encephalopathy/ 5. cognitive defect/ 6. dement*.mp. 7. alzheimer*.mp. 8. (lewy* adj2 bod*).mp. 9. deliri*.mp. 10. (chronic adj2 cerebrovascular).mp. 11. ("organic brain disease" or "organic brain syndrome").mp 12. "supranuclear palsy".mp. 13. ("normal pressure hydrocephalus" and "shunt*").mp. 14. "benign senescent forgetfulness".mp. 15. (cerebr* adj2 deteriorat*).mp. 16. (cerebral* adj2 insufficient*).mp. 17. (pick* adj2 disease).mp. 18. (creutzfeldt or jcd or cjd).mp. 19. huntington*.mp. 20. binswanger*.mp. 21. korsako*.mp. 22. CADASIL.mp. 23. or/1-22 24. (motor adj2 vehicle*).ti,ab. 25. (automobile adj2 driving).ti,ab. 26. (automobile adj2 driver*).ti,ab. 27. (car adj2 driver*).ti,ab. 28. (traffic adj2 accident*).ti,ab.	97

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	29. (car adj2 accident*).ti,ab. 30. (driving and (ases* or continu* or capabilit* or evaluat*).ti,ab 31. car driving/ or driving ability/ or traffic accident/ 32. or/24-31 33. 23 and 32 34. randomized controlled trial/ 35. controlled clinical trial/ 36. placebo.ab. 37. trial.ti,ab. 38. randomly.ab. 39. groups.ab. 40. (RCT or CCT).ti,ab. 41. randomi?ed.ab. 42. or/34-41 43. 33 and 42 44. (2007* or 2008* or 2009* or 2010* or 2011* or 2012*).em. 45. 43 and 44	
4. PsycINFO 1806-July week 1 2012 (Ovid SP)	1. exp Dementia/ 2. exp Delirium/ 3. exp Huntingtons Disease/ 4. exp Kluver Bucy Syndrome/ 5. exp Wernickes Syndrome/ 6. exp Cognitive Impairment/ 7. dement*.mp. 8. alzheimer*.mp. 9. (lewy* adj2 bod*).mp. 10. deliri*.mp. 11. (chronic adj2 cerebrovascular).mp. 12. ("organic brain disease" or "organic brain syndrome").mp 13. "supranuclear palsy".mp. 14. ("normal pressure hydrocephalus" and "shunt*").mp. 15. "benign senescent forgetfulness".mp. 16. (cerebr* adj2 deteriorat*).mp. 17. (cerebral* adj2 insufficient*).mp. 18. (pick* adj2 disease).mp. 19. (creutzfeldt or jcd or cjd).mp. 20. huntington*.mp. 21. binswanger*.mp. 22. korsako*.mp. 23. ("parkinson* disease dementia" or PDD or "parkinson* dementia").mp 24. or/1-23	24

(Continued)

	<p>25. (motor adj2 vehicle*).ti,ab. 26. (automobile adj2 driving).ti,ab. 27. (automobile adj2 driver*).ti,ab. 28. (car adj2 driver*).ti,ab. 29. (traffic adj2 accident*).ti,ab. 30. (car adj2 accident*).ti,ab. 31. (driving and (ases* or continu* or capabilit* or evaluat*)).ti,ab 32. exp Driving Behavior/ or exp Motor Vehicles/ 33. or/25-32 34. 24 and 33 35. (2007* or 2008* or 2009* or 2010* or 2011* or 2012*).up. 36. 34 and 35 37. randomi?ed.ab. 38. exp Clinical Trials/ 39. randomly.ab. 40. (RCT or CCT).ti,ab. 41. groups.ab. 42. ("double-blind*" or "single-blind*").ti,ab. 43. placebo.ab. 44. trial.ti,ab. 45. or/37-44 46. 36 and 45</p>	
5. CINAHL (EBSCOhost)	<p>S1 (MH "Dementia+") S2 (MH "Delirium") or (MH "Delirium, Dementia, Amnestic, Cognitive Disorders") S3 (MH "Wernicke's Encephalopathy") S4 TX dement* S5 TX alzheimer* S6 TX lewy* N2 bod* S7 TX deliri* S8 TX chronic N2 cerebrovascular S9 TX "organic brain disease" or "organic brain syndrome" S10 TX "normal pressure hydrocephalus" and "shunt*" S11 TX "benign senescent forgetfulness" S12 TX cerebr* N2 deteriorat* S13 TX cerebral* N2 insufficient* S14 TX pick* N2 disease S15 TX creutzfeldt or jcd or cjd S16 TX huntington* S17 TX binswanger*</p>	144

(Continued)

	<p>S18 TX korsako*</p> <p>S19 S1 or S2 or S3 or S4 or S5 or S6 or S7 or S8 or S9 or S10 or S11 or S12 or S13 or S14 or S15 or S16 or S17 or S18</p> <p>S20 (MH "Automobile Driving") OR (MH "Drive") OR (MH "Automobile Driver Examination")</p> <p>S21 TX motor N2 vehicle*</p> <p>S22 TX automobile N2 driving</p> <p>S23 TX automobile adj2 driver*</p> <p>S24 TX car N2 driver*</p> <p>S25 TX traffic N2 accident*</p> <p>S26 TX car N2 accident*</p> <p>S27 TX driving N3 assess*</p> <p>S28 TX driving N3 continu*</p> <p>S29 TX driving N3 capabilit*</p> <p>S30 TX driving N3 evaluat*</p> <p>S31 S20 or S21 or S22 or S23 or S24 or S25 or S26 or S27 or S28 or S29 or S30</p> <p>S32 S19 and S31</p> <p>S33 EM 2007</p> <p>S34 EM 2008</p> <p>S35 EM 2009</p> <p>S36 EM 2010</p> <p>S37 EM 2011</p> <p>S38 EM 2012</p> <p>S39 S33 or S34 or S35 or S36 or S37 or S38</p> <p>S40 S32 and S39</p>	
6. Web of Science and conference proceedings	<p>Topic=(dement* OR VCI OR "vascular cognitive impairment*" OR VaD OR alzheimer* OR AD) AND Topic=(driving OR car OR vehicle* OR cars OR automobile) AND Year Published=(2007-2012) AND Topic=(randomly OR trial OR randomised OR randomized OR RCT OR "control* study" OR CCT OR placebo)</p> <p>Timespan=All Years. Databases=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH</p> <p>Lemmatization=On</p>	353
7. LILACS (BIREME)	<p>conducción OR driving OR condução OR car OR vehicle OR carro OR coche OR vehículo OR veículo [Words] and dementia OR demencia OR demência OR alzheimer OR alzheimers OR alzheimer's [Words]</p>	16

(Continued)

8. CENTRAL (<i>The Cochrane Library</i>) (Issue 2 of 4, 2012)	#1 dement* #2 alzheimer* #3 deliri* #4 chronic adj2 cerebrovascular #5 (lewy* bod*) #6 "organic brain disease" or "organic brain syndrome" #7 (pick* disease) #8 creutzfeldt or jcd or cjd #9 huntington* #10 binswanger* #11 korsako* #12 (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11) #13 driving OR driver OR drivers OR car OR vehicle OR automobile #14 MeSH descriptor Automobile Driving explode all trees #15 (#13 OR #14) #16 (#12 AND #15), from 2007 to 2012	34
9. Clinicaltrials.gov (www.clinicaltrials.gov)	(driving OR car OR vehicle OR driver OR drive Interventional Studies dementia OR alzheimers OR AD OR alzheimer's OR alzheimer OR lewy OR FTLD OR FLD OR MCI OR cognitive OR cognition received from 10/01/2007 to 09/09/2012	32
10. ICTRP Search Portal (apps.who.int/trialsearch) (includes: Australian New Zealand Clinical Trials Registry; ClinicalTrials.gov; ISRCTN; Chinese Clinical Trial Registry; Clinical Trials Registry - India; Clinical Research Information Service - Republic of Korea; German Clinical Trials Register; Iranian Registry of Clinical Trials; Japan Primary Registries Network; Pan African Clinical Trial Registry; Sri Lanka Clinical Trials Registry; The Netherlands National Trial Register)	(dementia OR alzheimers OR AD OR alzheimer's OR alzheimer OR lewy OR FTLD OR FLD OR MCI OR cognitive OR cognition) AND (driving OR driver) AND (2007-2012)	0
TOTAL before de-duplication and first assess		741
TOTAL after de-duplication and first assess		122

WHAT'S NEW

Last assessed as up-to-date: 12 March 2013.

Date	Event	Description
8 April 2013	New citation required but conclusions have not changed	Conclusions unchanged
13 March 2013	New search has been performed	An update search was performed for this review on 13 September 2012

CONTRIBUTIONS OF AUTHORS

Alan Martin and Desmond O'Neill wrote the study protocol and retrieved studies, assessed study quality, extracted and interpreted data, and wrote the discussion.

Richard Marottoli retrieved studies, assessed study quality, extracted and interpreted data as a third review author, compared and contrasted with AM and DON, and co-wrote the discussion.

Contact editor: Rupert McShane

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DECLARATIONS OF INTEREST

None known.

SOURCES OF SUPPORT

Internal sources

- Department of Medicine for the Older Person, Mater Miericordiae University Hospital, Dublin 7, Ireland.
- Department of Age-Related Health Care, Adelaide and Meath Hospital, Dublin 24, Ireland.
- Department of Geriatrics, Yale University, New Haven, USA.

External sources

- No sources of support supplied

INDEX TERMS

Medical Subject Headings (MeSH)

Accidents, Traffic [*prevention & control]; Automobile Driving [*psychology]; Dementia [*psychology]; Safety

MeSH check words

Aged; Humans