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Assessment of older drivers: Relationships among on-road errors, medical conditions and test outcome

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Abstract

Problem: It is essential that driver licensing authorities have a valid and reliable system for evaluating older drivers' continuing competency; road tests are usually required as part of such a system. This study sought to find information about the nature of driving errors made during license review tests, and about relationships between error type and test outcome for older drivers. *Method:* Data from licensing authority files from 533 road tests during a 12-month period were analyzed; medical and other referral information was included. Average driver age was 76 years. Performance scores were generated for intersection negotiation, lane changing, low speed manoeuvres, positioning and speed control, safety margin, and car control. *Results:* Logistic regression analysis showed that test outcome was well predicted by a subset of driving performance scores; adding driver age to the model explained very little variance. Age alone was strongly associated with outcome. Relationships between referral information and test outcome are also reported. *Impact:* Results highlight several factors relevant to the development of more valid and reliable road tests for older drivers.
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1. Background

As the proportion of older drivers increases, driver licensing authorities and communities face the challenge of how best to preserve both road system safety and older people's independence and mobility as they age (McKnight, 2000). A key role in most systems intended to address this need is played by the on-road test, which is used when it is necessary to review an older driver's competence to continue driving. This study was part of a larger project to optimize the performance scoring system used in such tests.

Older drivers tend to have increasing numbers of functional impairments, but these do not necessarily reduce their ability to drive safely (Eby & Kostyniuk, 1998; Janke, 1994). For example, musculoskeletal impairment does not generally increase crash risk, although drivers with a major musculoskeletal impairment may need to be assessed to identify vehicle modification and related training requirements (Macdonald & Scott, 1993; Sprigle, Morris, Nowachek, & Karg, 1995; Torpey & Francis, 1992). However, when distance driven is taken into account, the risk of older drivers being involved in a reported crash is similar to that of novice drivers (Charlton, Oxley, Fildes, & Les, 2001; Macdonald, 1996; Organisation for Economic Co-operative Development, 2001). That is, the documented crash risk of older drivers, particularly in the highest age group (80 years and above), is considerably higher than the overall average. It has been pointed out that this elevation in documented crash risk does not necessarily represent their collision risk, because collisions involving older drivers are more likely to result in injury due to their greater physical frailty. Therefore, what might be an injury-free, unreported collision for a younger driver is more likely to be a documented crash, because of associated injuries or death, for an older driver (Bedard, Guyatt, Stones, & Hirdes, 2002; Guohua, Braver, & Chen, 2002; Hakamies-Blomqvist, 1998). Also, there is evidence that a higher proportion of older drivers' travel time or distance is spent in relatively high risk environments (e.g., in urban and suburban areas rather than on freeways or in rural areas), which places them at greater average risk per unit time or distance driven, compared with younger drivers. For some groups of older drivers, average trip duration is 14–26 min, and shopping or recreational destinations are the predominant reason for travel (Frith, 2002; Hildebrand & Hutchinson, 1999).

Nevertheless, it is incontrovertible that older drivers' performance tends to deteriorate significantly with increas-

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ing age, and there is accumulating research showing that a key causal factor in this deterioration is aging-related cognitive decrements (Ball, 1997; Cooper, Tallman, Tuokko, & Beattie, 1993; Daigneault, Joly, & Frigon, 2002; Lundberg, Hakamies-Blomqvist, Almkvist, & Johansson, 1998; Stutts, Stewart, & Martell, 1998). If the individual has a chronic neurological condition such as dementia, this deterioration could be expected to occur quite rapidly over time (Dubinsky, Stein, & Lyons, 2000).

There is also evidence of age-related differences in road accident type. Older drivers are evidently more law-abiding; they are more likely to be traveling within the speed limit; and they are less likely to have a high blood alcohol concentration (Fildes, 1997; Langford & O'Leary, 1997).

However, they are more likely than younger drivers to perform more attention-demanding driving manoeuvres at the time of an accident, particularly negotiating complex intersections (Ryan, Legge, & Rosman, 1998). This appears to be due to the tendency for older people to have reduced information-processing speed and reduced capacity to allocate attention optimally between different concurrent tasks (Bolstad & Hess, 2000). Cerella states that such decrements are most likely to affect performance when the task is more complex, and under stressful conditions (as cited in Robertson & Tracey, 1998). Consistent with this interpretation, Brouwer and Ponds (1994) noted that older drivers' normal compensatory mechanisms tend to break down in ambiguous and complex driving situations, especially in individuals with perceptual and cognitive deficits. Schlag (1993) commented that "elderly drivers require more information before they decide, and they need more time for their decisions. This is especially true under conditions of insecurity and complexity" (p. 54).

In addition to normal, aging-related functional impairments, older people tend to have a greater number of medical conditions, some of which (plus some drugs taken to treat them) may reduce driving abilities (Darzins & Hull, 1999; Morgan & King, 1995; Roller & Gowan, 2001). For example, diabetes, cardiac conditions (Koepsell et al., 1994), a history of falls, kidney problems or stroke (Lyman, McGwin, & Sims, 2001), and poor vision (McGwin, Chapman, & Owsley, 2000; Wood, 2002) have been associated with decrements in driver performance or with accident risk (see Eby & Kostyniuk, 1998; Janke, 1994, for extensive earlier reviews). While this body of research is slowly expanding, there is still relatively little clear evidence of relationships between medical conditions and driving performance (Fildes, 1997; Fildes et al., 2000).

Older drivers may compensate to some extent for functional impairments by becoming more selective about how, when, and where they drive, tending to avoid driving during peak hour traffic, at night, or under adverse weather conditions (Ball et al., 1998; Gallo, Rebok, & Lesikar, 1999). However, Stutts et al. (1998) concluded from a study of such risk exposure-reduction behaviors in drivers aged 65 and older, that while some with cognitive and visual impairments were reducing their exposure to compensate adequately for deteriorating capacities, such compensation did not occur in all drivers, some of whom continued to drive confidently despite a record of crash involvement. Brayne et al. (2000) studied a select group of subjects who participated in the "Cambridge City over 75 Cohort" and found that their participants were capable of making sound decisions regarding driving cessation. However, many other researchers have echoed Stutts' concerns regarding the existence of groups of individuals who continue to drive despite major functional difficulties (Cox, 1988; Eberhard, 1996; Kaszniak, Keyl, & Albert, 1991; Marotolli & Richardson, 1998; Waller, 1992).

For these reasons, it is essential that driver licensing authorities have a valid and reliable system for evaluating older drivers' continuing competency (Christie, 2000). A road test is usually required as part of such a system because current methods of off-road assessment are inadequate for some aspects of driving ability (British Psychological Society, 2001; Withaar, Brouwer, & Van Zomeren, 2000). Also, on-road tests have higher face validity, which is important to someone whose license may be under threat (Fildes, 1997; Hunt, Morris, Edwards, & Wilson, 1993; Korteling & Kaptein, 1996; Underwood, 1992). Therefore, on-road testing should be able to identify those older drivers whose risk has increased to an unacceptable level, whether the cause is aging-related cognitive decrements, specific medical problems, or other factors.

One of the prerequisites for development of more valid and sensitive on-road assessment systems is having more detailed information about the types of driver errors that most characterize unsafe drivers (those with an unacceptably high crash risk), as opposed to errors that common in most drivers (Dobbs, Heller, & Schopflocker, 1998; Macdonald & Scott, 1993; Marotolli & Richardson, 1998; Withaar et al., 2000). Dobbs et al. (1998) commented that:

> Any error might be very important in identifying the person as unsafe, or it might be the type of error that is characteristic of experienced drivers and not indicative of declining competence.... More detailed analyses of the errors,...and the conditions of the driving errors may help to further refine the meaning of the errors for the purposes of developing an empirically based scoring scheme. (p. 369)

In the absence of such information, there is little basis for the currently used methods of scoring driver errors in road tests. The primary purpose of this study was to address this need, using details from on-road license review test records conducted by VicRoads—the Victorian state driver licensing authority. The work is part of a larger project to develop an improved procedure for occupational therapy (OT) assessments of functionally impaired and older drivers, with a particular focus on optimizing the performance scoring system used in such tests.

The specific research questions addressed were:

1. Which types of driving errors are most strongly predictive of overall driving competence (pass/fail test outcome)?
2. What relationships are there among test performance and the number and specific types of drivers' medical conditions and other indicators of health status?
3. How is driver age related to driving competence (test performance)?
4. What relationships are there between test outcome, driver referral source, and referral information about any prior driving incident or accident leading to the referral?

2. Method

Ethical approval was obtained from the university and the licensing authority concerned. The study employed a retrospective case review methodology. Information about driver errors and test outcome was extracted from VicRoads review test file records. Details about each driver were obtained from separate license holder records, including demographic details, medical condition(s), the referral source, and reasons prompting the referral. Information was transcribed from the original sources by a research assistant (an experienced OT), working under the supervision of the first author. It was subsequently analyzed using SPSS V.11 (Green & Salkind, 2003).

For the purpose of investigating the above research questions, it has been assumed that the VicRoads review test provided valid and reliable information for determining driver competence. In justification of this assumption, the test procedure is described below, with related information concerning the driver referral process.

3. The Victorian driver license review test

In the state of Victoria, Australia, there is currently no compulsory age-based testing of older drivers. Licensed drivers of any age can be reported to VicRoads by anyone who is concerned about their driving competence. A medical "fitness to drive" assessment, using a standard proforma including reference to national medical guidelines (Austroads, 2001), may have instigated the license review process; if not, such an examination is usually requested by the licensing authority. A doctor must comment on current and past medical conditions and related issues, in addition to completing a checklist regarding specific medical conditions known to affect driving (e.g. epilepsy). VicRoads staff then determine whether further medical specialist assessment and/or a driving test are required, to assess that person's competency to continue driving.

On-road driving tests are of two types. Drivers identified as having complex medical conditions or significant cognitive impairments are tested by an OT who has primary responsibility for assessment, working in conjunction with a driving instructor (DI) whose role involves maintaining vehicle safety and guiding the driver around the route. The other form of on-road test—termed a review test—is taken by the majority of drivers not meeting the OT test criteria, which includes a large proportion of older drivers. The present research considers only review tests. They are implemented by one of two VicRoads License Testing Officers (LTO) who specialize in older driver testing. The test is conducted in an automatic, dual-control (brake and accelerator), vehicle with the LTO responsible for both driver assessment and maintenance of vehicle safety, as is the case for entry-level license testing and for comparable 'older driver' tests in other jurisdictions (Fildes et al., 2000).[1]

While entry-level license tests are conducted on standard routes with predetermined observation points, such routes are not used during older driver review tests. These tests commence from the driver's home, and encompass routine travel destinations such as the local shopping center, medical facilities, and so on; drivers are required to angle park and/or curb park at some point. Most review tests are conducted during off-peak traffic conditions. After an initial period allowing the driver to become more familiar with the vehicle, the test itself lasts between 30 and 45 minutes. Drivers who pass the test usually retain an unrestricted license; some may continue to have medically based restrictions such as no night driving.

Operationally defined performance criteria are used to score driver errors in each of six main performance categories: intersection negotiation, lane changing/diverging, speed and position on road, safety margin, car control, and low speed manoeuvre. These categories and associated evaluation criteria are derived from the Victorian entry-level license test entitled Programmed Observation Licence Assessment (POLA; VicRoads, 1999). POLA is based on the Automobile Driver On-Road Performance Test (ADOPT; Christie, 2000; Macdonald, 1987; McPherson & McKnight, 1981). The LTO uses a scoring sheet listing each performance category, and within each category there are also listed a set of specific behaviors, each of which is separately scored. For example, 'intersection negotiation' entails assessment of behaviors related to mirror use, signaling, approach, obedience to sign/signal, judgement, and turning procedures. Operational performance criteria are specified for all behaviors.[2]

[1] Despite this dual responsibility, the LTO's mental workload is maintained at an acceptable level by use of a route selected by the driver and therefore requiring no instructions, an easily usable notation method, and the general exclusion of individuals whose medical/referral details indicate major impairment.

[2] For example, performance requirements for "judgement" specify that: "The applicant is required to make a safe judgement in respect of giving way to other cars and pedestrians" (VicRoads, 1999, p.16). Scoring criteria are defined for both "yes" and "no," including reference to factors such as adaptation of vehicle speed, search behaviors, and unnecessary stops or delays.

Table 1
Driver performance scores (mean percent of observations recorded as satisfactory, i.e., no error recorded) for each of six categories of driver performance observations

	Driver performance scores					
	Intersection negotiation (IN %)	Lane-changing/ diverging (LC %)	Position and speed (PON %)	Low speed manoeuvre (LSM %)	Safety margin (SM %)	Car control (CC %)
Performance score plus the mean number (and range) of observations per test ($n = 533$)	59, 16.2 (4–30)	35, 3.2 (0–15)	60, 6.5 (0–16)	55, 1.6 (0–3)	89, 3 (0–5)	86, 2.7 (0–3)
Mean performance score for drivers who failed without any LTO interventions ($n = 9$)	41	12	42	17	87	100

The LTO observes and assesses each behavior, up to the limits specified in Table 1. Satisfactory and unsatisfactory behaviors are recorded by use of ticks or crosses, with longhand notation used only to document details. If at any time the LTO needs to maintain safety by intervening in vehicle control (e.g., applying the "dual control" brake), this "LTO intervention" is recorded in relation to the relevant driver performance category, along with information about the context in which the intervention occurred (e.g. intersection negotiation-turning right). Some contextual information may be recorded in relation to less severe driver errors; for example, if the speed is inappropriately slow, both the driver's speed and the speed limit at that point is usually noted. Verbal cues, reminders, or other prompts to the driver (e.g. "watch speed") are also noted, but there were relatively fewer of these and therefore, they were not included in the following analyses.

At the end of the test, the LTO adds notes documenting traffic and weather conditions, driver performance in situations that required LTO intervention, general evaluative comments, and overall test outcome (pass or fail). During entry-level license testing, LTO interventions result in immediate failure and cessation of the test, but during review tests there is some accommodation of the "bad habits" that are common among experienced drivers, provided they do not affect safety (e.g. rolling over stop lines at intersections). It is therefore usual for the test to continue following an LTO intervention, for as long as is considered safe.

The potential data set for this study consisted of every motor-vehicle license review test undertaken during the preceding 12-month period (2000) for which there was a test record, excluding tests undertaken in the driver's own vehicle. A total of 533 cases were analyzed, representing 496 individuals (a few had been tested more than once during the sample period).

4. Results

4.1. Driver characteristics

Virtually all drivers included in the sample had been referred because their driving competence was in question; many were reported by police (63% of the total). Average age of the 496 drivers was 76.1 years, with a range from 24 to 100 years; 233 were older than 80 years, and 68% of the sample were male. The majority had one or more medical conditions noted on their medical report form, the most common being cardiac, endocrine, and musculoskeletal diagnoses. Relationships between referral sources, medical conditions, and driving performance are reported below.

Table 2
Types of error: percent of all tests ($n = 533$) on which the error type was recorded, and mean number of errors per test when such errors occurred-separately for low speed manoeuvres, intersection negotiation and lane changing

Error types	Related to low speed manoeuvres	Related to intersection negotiation	Related to lane changing
Fail to turn head to check back over shoulder	45% of tests; mean # = 1.4	N/A	62% of tests; mean # = 3.4
Fail to check mirrors	13% of tests; mean # = 1.3	69% of tests; mean # = 6.5	26% of tests; mean # = 1.9
Fail to use turn indicators	12% of tests; mean # = 1.3	49% of tests; mean # = 2.7	31% of tests; mean # = 1.8
Poor gap selection	11% of tests; mean # = 1.1	N/A	10% of tests; mean # = 1.1
Poor positioning of vehicle	10% of tests; mean # = 1.2	N/A	N/A
Poor gap selection/judgement	N/A	43% of tests; mean # = 1.9	N/A
Poor position on road/when turning	N/A	39% of tests; mean # = 2.1	N/A
Fail to obey sign/signal	N/A	30% of tests; mean # = 1.6	N/A
Poor approach (speed before an intersection)	N/A	14% of tests; mean # = 1.8	N/A
Poor speed control for lane changing	N/A	N/A	2% of tests; mean # = 1.1

Table 3
Types of error: percent of all tests ($n = 533$) on which the error type was recorded, and mean number of errors per test when such errors occurred, for the performance category position on road and speed control

Error types related to maintenance of appropriate position and speed on the road				
Unlaned clearway	Lane keeping	Too slow for conditions	Exceeding speed limit	Too fast for conditions
40% of tests; mean # = 3.2	34% of tests; mean # = 2.6	31% of tests; mean # = 3.0	17% of tests; mean # = 2.0	3% of tests; mean # = 2.5

Table 4
Types of error: percent of all tests ($n = 533$) on which the error type was recorded, and mean number of errors per test when such errors occurred, for the performance category safety margins

Error types related to maintenance of safety margins			
Parked cars	Following distance	Stop too close	Too close to object
15% of tests; mean # = 1.6	4% of tests; mean # = 1.2	2% of tests; mean # = 1.2	2% of tests; mean # = 1.2

4.2. Test outcome

Overall fail rate for the full sample of 533 license review tests was 49%. A small number of drivers within this sample were tested more than once; elimination of all second and subsequent tests reduced the number of cases to 496, with a mean fail rate of 46%.

4.3. Test performance scores

For the purpose of this study, a driver performance score was calculated for each of the six performance categories, in the form of a percentage: the total number of performance opportunities completed successfully, divided by the total number observed.[3] This score represents the percent of observations in that category that were satisfactory. Scores are shown in Table 1, along with the mean number of observations in each category per test (and the range). Also included are performance scores for the very small set of drivers who failed but whose performance had not required any LTO intervention (discussed further below), to identify any obvious difference in their performance scores that might account for their having been failed despite the absence of any hazardous behavior requiring an intervention. It can be seen that their scores were considerably lower than average for the first four of the six performance categories.

4.4. Specific driver errors

The performance scores in Table 1 were based on the percentage of satisfactory observations for each of the six types of performance categories. When performance was not satisfactory, errors were recorded. The different types of errors recorded within each of the six performance categories are shown in Tables 2–5.

Table 2 shows that for lane changing and low speed manoeuvres, the two most frequent error types related to driver observation: failure to look back over the shoulder when needed to ensure safety, and failure to check mirrors; the third most frequent was failure to use indicators. Among errors related to intersection negotiation, failure to check mirrors and to use turn indicators were the two most common, followed by poor judgement (usually relating to gap selection), vehicle positioning during a turn, failure to obey the road sign or signal, and poor approach (safe approach speed and smooth deceleration).

Table 3 shows errors relating to maintenance of appropriate position and speed. It can be seen that poor positioning of the vehicle on "clearways" (no parking allowed) without any lane markings was the most common type of error, followed by poor lane keeping, and traveling too slowly for the conditions. Exceeding the speed limit was less common, and traveling too fast for the conditions was rare.

Errors related to maintenance of adequate safety margins (separately from intersection or lane changing performance) are shown in Table 4. These were rare, except for driving too close to parked cars, which was recorded in 15% of tests.

Errors relating to car control were least common, as shown in Table 5. The small proportions of tests in which such errors were noted is not surprising given that these were experienced drivers, and car control skills are usually considered to be the most highly automatized, making them most resistant to the effects of aging-related decreases in level of attentional resources (Bolstad & Hess, 2000). Steering errors were the most frequently observed type, possibly due simply to poor habits, although medical conditions (e.g., arthritis) or inadequate attentional resources might also have had an effect.

4.5. License Testing Officer (LTO) interventions related to test outcome

On almost all of the 49% of tests that resulted in failure there was at least one LTO intervention, and on very few tests (9 out of 533) did the driver fail without any such intervention, as shown in Table 6. For tests with an intervention, the mean number per test was 3.6, with a maximum of 12.

Table 5
Types of error: percent of all tests ($n = 533$) on which the error type was recorded, and mean number of errors per test when such errors occurred, for the performance category car control

Error types related to car control			
Steering	Braking	Accelerator	Gear choice
12% of tests; mean # = 2.2	5% of tests; mean # = 2.0	3% of tests; mean # = 2.4	1% of tests; mean # = 1.7

[3] The LTO does not calculate a performance score, test outcome being based on a global judgement.

Table 6
Relationship between test outcome (pass/fail) and whether or not there was an LTO intervention during the test, separately for all tests and for all individuals

		Pass	Fail	*n*
All tests ($n=533$)	LTO intervention	1	253	254
	No intervention	270	9	279
	n	271	262	533
All individuals ($n=496$)	LTO intervention	1	222	223
	No intervention	265	8	273
	n	266	230	496

Table 8
Logistic regression model

Variables	Wald	Significance	Exp(*B*)
Intersection negotiation	24.68	0.000	.04
Position and speed	13.50	0.000	.15
Lane changing	2.39	*ns*	.43
Low speed manoeuvreing	0.03	*ns*	.94
Car control	1.01	*ns*	.45
Safety margin	7.10	0.008	.10
Driver age	1.15	*ns*	1.04

4.6. Predictors of test outcome (pass/fail)

Tests during which there was at least one LTO intervention almost invariably resulted in the driver failing, with only nine drivers failing in the absence of any LTO intervention. From this it appears that whether or not the LTO had to intervene was the primary determinant of test outcome.

LTOs intervened in a broad range of situations. These situations have been categorized in terms of specific combinations of driving manoeuvre-error-context, the most common of which are shown in Table 7. Aggregating across different categories, it can be seen that the most frequent problems precipitating LTO interventions involved errors associated with intersection negotiation ($n=255$), failure to give way or poor gap selection ($n=158$), failing to maintain the vehicle in an appropriate position on the road ($n=149$), inappropriate speed—either too fast or too slow ($n=116$), and problems with low speed manoeuvres ($n=59$).

LTOs do not calculate a performance score; recorded observations of errors are used to give feedback to drivers at the end of the test. It was therefore of interest to identify relationships between test outcome and the performance scores that were calculated for this study. Logistic regression analysis was used. Non-normally distributed performance scores were recoded into three or four ordinal categories for use as independent variables, and entered together into the regression model. The six performance scores predicted 93.9% of pass/fail outcomes ($\chi^2=232.7$, p=.000; Nagelkerke $R^2=0.84$). Addition of driver age to this model in a second block did not improve prediction. The full model, as shown in Tables 8 and 9, shows the bivariate correlation matrix.

In the regression model, the variables most strongly associated with test outcome (determined almost always by the LTO having to intervene) were scores related to intersection negotiation, maintenance of position and speed, and safety margin. Since these were among the most common types of performance associated with LTO interventions (as shown in Table 7), this result may not be surprising.

These results support the validity of LTO interventions as an indicator of overall test performance, and hence as a legitimate basis for determining test outcome. Assuming the validity of LTO interventions as an indicator of unsafe behavior (which is reasonable given that this is precisely the criterion for their occurrence), they also support use of these performance measures as a similarly valid indicator.

4.7. Relationships between driving performance and medical conditions

For most of the drivers in this sample, file information related to their referral included medical conditions and associated health information. However, this information

Table 7
The most frequently recorded situations (manoeuvre-error-context combinations) in which there was an LTO intervention

Situations in which LTO interventions occurred (specific manoeuvre-error-context combinations)			# of occasions across all tests ($n=533$)	# of tests with at least one of these errors
Specific manoeuvre or aspect of performance	Error	Context		
Negotiate intersection	Fail to give way	Intersection: general	78	63
Negotiate intersection	Fail to give way	Intersection: roundabouts	24	23
Negotiate intersection	Poor judgement, e.g., in gap selection	Intersection: general	28	14
Negotiate intersection	Disobey other law, e.g., travel straight head from right turn lane	Intersection: general	36	31
Lane change/merge	Poor gap selection	Lane changing	28	25
Negotiate intersection	Position on road	Intersection: turning right	45	35
Negotiate intersection	Position on road	Intersection: general	44	32
Maintain lateral position	Position on road	Straight stretch of road	60	40
Maintain appropriate speed	Speed too fast	Straight stretch of road	66	46
Maintain appropriate speed	Speed too slow	Behavior affects other vehicles	50	34
Low speed manoeuvre	Poor judgement, e.g., in clearance margins	Parking	32	28
Low speed manoeuvre	Gap selection	Parking	27	22

Table 9
Bivariate correlation matrix (Spearman's rho)

	Performance scores						Age
	Lane changing	Low speed manoeuvres	Safety margins	Car control	Intersection negotiation	Position and speed	
Low speed manoeuvres	0.11						
Safety margins	0.06	– 0.32					
Car control	0.06	– 0.04	0.16				
Intersection negotiation	0.03	– 0.29	0.54	0.15			
Position and speed	0.07	– 0.13	0.26	– 0.08	0.09		
Age	0.18	– 0.04	0.07	– 0.10	– 0.08	– 0.06	
Test outcome (0 = pass, 1 = fail)	– 0.66	– 0.59	– 0.33	– 0.40	– 0.83	– 0.63	0.39

came from many different doctors and its quality was highly variable, which limited its value for the present purpose. The available medical information was initially coded by the researchers using categories based on the International Classification of Diseases and Related Health Problems (World Health Organisation [WHO], 1992). Many people had more than one condition or health-related notation (range = 0–5; mean = 2). The most common condition categories included: cardiac (e.g., hypertension), endocrine (e.g., diabetes), musculoskeletal (e.g., soft tissue disorders), visual (e.g., only one functioning eye), arthritis (e.g., osteoarthritis), and mental or behavioral difficulties (e.g., affective disorders; see Table 10). There was no referral information for 37 individuals, and only licensing or general health-related comments for a further 48 individuals; these individuals were excluded from some of the analyses below, as indicated.

Table 10 presents performance scores separately for the most commonly reported medical conditions. It should be noted that some cases are represented within more than one category.

A plausible initial indicator of a driver's impairment level might be the total number of documented medical conditions and other indicators of possible impairments (e.g., doctor notations such as "numerous medications" or "unsure about general fitness to drive"). To test the validity of this possible indicator of driving impairment, the relationship between total number of impairment indicators and test outcome was investigated. No evidence of such a relationship was found ($\chi^2 = 4.699$, $df = 4$, $p = .320$, $n = 459$). The absence of such a relationship is presumably because medical conditions vary considerably in their severity and extent of associated performance impairments likely to affect driving. This outcome is consistent with previous research findings (see below).

Relationships between type of medical condition and test outcome were then investigated. Because the reported medical conditions were numerous and unpredictable in the likely severity of their impact on driving, all individuals were first recategorized as predominantly physical, predominantly cognitive, or mixed, as shown in Table 11. Chi-square analysis showed no significant relationship between these medical categories and pass/fail outcome ($\chi^2 = 0.14$, $df = 2$, $n = 411$). It can be seen in Table 11 that the mean age of drivers with a primarily cognitive condition was 8 years less than for those in the "physical" category, which would to some degree mask any negative effect of "cognitive" conditions on test outcome, since older drivers tended to have higher fail rates (see Table 12).

Logistic regression analysis was used to determine whether driver performance scores predicted membership of the above three medical categories. After exclusion of

Table 10
Performance scores, age, LTO interventions and test outcome, separately for the most commonly reported medical conditions: total n (percentage of total with a medical condition noted [$n = 411$])

Condition	n (%)	Mean age	% fail	Mean # of DI assists	Driver performance scores (%)					
					IN	LC[a]	PS	LSM	SM	CC
Cardiac	216 (53)	80	49	3.8	59	31	59	57	89	86
Endocrine	68 (17)	77	46	3.2	62	38	62	59	93	88
M/skeletal	66 (16)	74	48	3.1	62	33	58	59	85	83
Visual[b]	61 (15)	80	49	3.8	61	42	63	54	89	86
Arthritis	49 (12)	80	61	4.0	49	23	54	49	80	78
Mental/behavioral	44 (11)	67	48	3.5	59	35	60	51	85	80
Nil noted	44	75	43	4	66	40	66	52	89	85

IN = intersection negotiation, LC = lane changing, PS = position and speed, LSM = low speed manoeuvre, SM = safety margin, CC = car control.
[a] As previously mentioned, for a proportion of drivers there were no recorded behavioral observations for some performance categories; this was particularly the case for lane changing. In such cases no performance score could be calculated. For example, only 140 of the 216 drivers with a reported cardiac condition had a performance score in this category.
[b] Category included drivers with only one eye and cataracts.

Table 11
Recoded medical categories in relation to mean age and test outcome (percent fail) for the subset of individuals with reported medical conditions ($n = 411$)

Medical category	Examples of conditions	n	Mean age	Percent failing
Primarily physical	musculo–skeletal, arthritis, fractures, visual	266	78	44
Primarily cognitive	dementia, intellectual disability, mental/behavioral disorders	68	70	57
Mixed	stroke, alcohol/drug abuse, closed head injury, neurological conditions (e.g., multiple sclerosis), "frail"	77	76	48

cases with missing data, 380 cases were available for the analysis (63.5% physical, 16.5% primarily cognitive, 20% mixed): no individual was included twice. Results did not approach significance.

The "primarily cognitive" and "mixed" groups were then combined to facilitate further analysis, since both could be expected to have some cognitive impairment and the combined group was of a more comparable size to the much larger "physical" group. Sequential logistic regression analysis was used to predict membership of these two groups, entering first the set of driver performance scores and then driver age. With just the performance variables, model fit was poor, although approaching significance ($\chi^2 = 10.74$, $n = 380$, p=.06; Nagelkerke R^2=.038). When age was added, goodness of fit improved substantially ($\chi^2 = 37.63$, p=.000; Nagelkerke R^2=.13). This result suggests that for this sample, specifically diagnosed impairments had less effect on driving performance than "normal," age-related impairment.[4] The percentage of cases correctly classified was low, rising from 65.8 with just the performance variables, to 68.7 with age added. Car control was the only performance variable to reach significance ($B = -0.379$, Wald = 4.22, p=.04), reflecting the expected difference between those with and without physical impairment. There was no evidence of any interaction between age and disability group affecting test outcome (checked by addition of an interaction factor to the above regression model).

It is evident that for this sample, which excluded people with major physical or cognitive functional impairments, driving performance did not vary significantly in relation to different types of medical conditions, except for an apparent effect of physical impairment on car control. This is consistent with the variation in fail rates between the main medical conditions shown in Table 10, where arthritis was the condition with the highest fail rate.

[4] The types of age-related impairment likely to have the greatest impact on driving are slowing of information processing rate, reduced attentional capacity, decreased capacity to allocate attention optimally and changes in visuo-perceptual function (for example, see Bolstad & Hess, 2000; Fisk & Rogers, 1997).

Table 12
Driver age and pass rate ($n = 496$)

Age category	n	Percent failing
54 years and younger	32	0
55 to 64 years	29	21
65 to 74 years	84	33
75 to 79 years	117	39
80 to 84 years	131	60
85 years and older	103	71

4.8. Effects of driver age

There was a very clear relationship between driver age and test outcome, as shown in Table 12.

Table 13 shows correlations coefficients (Spearman's rho) of performance scores with test outcome, and with the six categories of driver age from Table 16. All correlations are significant ($p < .01$), and the rank order of correlations with test outcome is almost identical to the order of correlations with age. In both cases, the lowest correlations are with safety margin, followed by car control and low speed manoeuvres; the highest are with intersection negotiation, followed by either position and speed (with test outcome), or lane changing (with age).

This similarity between age and test outcome in their correlations with performance scores is further evidence of the validity of these scores as an indicator of unsafe driver behavior, since the crash risk of older drivers is known to increase with age. Further, in the analysis of performance scores related to test outcome (Tables 8 and 9), addition to the regression model of age after entry of the performance scores explained very little additional variance, suggesting that the driver error data comprising the performance scores largely accounts for the age-related decrement in driver performance.

4.9. Relationships between test outcome and driver referral information

Police were the main source of driver referrals for license review testing (63% of cases), compared to medical referrals (23%), public referrals such as from family (8%) and "other," including self-referrals and those from other health professionals (3%). The remaining drivers had been referred by OTs or by licensing authority medical advisors. It is not

Table 13
Correlation coefficients (Spearman's rho) of performance scores with test outcome, and with the six categories of driver age shown in Table 16

	Lane changing	Low speed manouvre	Safety margin	Car control	Intersection negotiation	Position and speed
Test outcome	– 0.652	– 0.582	– 0.329	– 0.411	– 0.822	– 0.723
Age categories	– 0.371	– 0.305	– 0.143	– 0.168	– 0.414	– 0.342

surprising, given the number of police referrals, that in 54% of the cases the referral made reference to an accident or some form of inappropriate driver behavior that had raised concerns about the drivers' competence.

Table 14 presents results of analyses to investigate the final research question concerning relationships between test outcome, referral source, and information in the referral about an instigating driving incident or accident. It can be seen that the difference between pass and fail rates for drivers referred by health professionals was greater—with a relatively higher pass rate—than the difference between pass/fail rates for those referred by police or the public. The relatively small group referred by the public (often family members) were the only ones more likely to fail than to pass, although this difference did not reach statistical significance.

Information regarding a prior driving incident or accident that had instigated referral for testing (e.g., details from a police accident report) was present for 267 of the sample. The mere presence of such information (i.e., the occurrence of an immediately prior, documented accident) was not related to test outcome, as shown in Table 14. However, some significant relationships were found between test outcome and driver errors related to the specific nature of the prior accident or incident (for the subset of this group for whom sufficient details about the prior accident or incident were available). When sufficient details regarding the driver's behavior or role in such situations were available, these data were coded. The most frequently used coding categories are listed in the five bottom rows in Table 14. Prior "failure to obey a road law" was strongly related to probability of test failure, and "inappropriate or dangerous driving" had a similar (but only marginally significant) relationship. However, those who had been involved in a prior "collision or dangerous situation" had a significantly lower fail rate, which would not have been predicted. This result might indicate a greater random element in collision involvement than in being reported for specific behavioral faults. That is, driving impairment may be more reliably reflected by referrals based on actual observation of specific performance during driving (i.e., as in "failing to obey road law") rather than by involvement in a collision where their behavior might not have been a major contributor. It might also reflect a greater tendency for police to refer accident-involved older drivers for license review, than in the case of younger drivers.

Table 14
Referral information for individuals who passed or failed review test ($n=496$)

Source of primary referral	Drivers who fail	Drivers who pass	Difference between pass/fail rates
	% of total		
Police ($n=312$)	30.6	32.3	NS
Public/family ($n=42$)	5	3.4	$\chi^2=3.192$, $p=.074$
Medical/GP ($n=115$)	8.9	14.5	$\chi^2=4.337$, $p=.037$
Prior accident details (from police or family reports; can be >1 category per driver)			
Accident or inappropriate behavior (general) ($n=267$)	25.2	28.6	NS
Inappropriate/dangerous driving ($n=110$)	12.1	10.1	$\chi^2=3.798$, $p=.051$
Failure to obey road law ($n=43$)	5.9	2.8	$\chi^2=8.330$, $p=.004$
Failure to yield whilst completing manoeuvre ($n=37$)	2.8	4.6	NS
Other: collision[a]/dangerous situation ($n=91$)	6.3	12.1	$\chi^2=6.891$, $p=.009$
Driving too slowly ($n=21$)	2.2	2.0	NS

[a] This category included hitting cars when reversing or parking ($n=24$); colliding with a stationery vehicle or object ($n=18$); and involvement in a collision and not noticing ($n=7$).

5. Discussion

Using file data from older driver review tests conducted by the state licensing authority, performance scores based on driver errors recorded during the tests were generated by the researchers, and used to investigate relationships between driver performance and test outcome. Relationships with driver age, driver medical condition, source of test referral, and information about prior accident involvement were also investigated.

It was expected that the set of drivers in the study sample might be representative of "normally aging" drivers, since those with major physical or specific cognitive impairments were excluded (being referred for specialist assessment by an OT). However, since almost half of the group were aged over 80 years and cognitive impairment tends to increase with increasing age (Brayne et al., 1999; Collie, 2001), it is probable that some had specific cognitive impairments that were undiagnosed.

The range and rates of medical conditions in the present sample of drivers were similar to those reported by Vernon et al. (2002) in their investigation of crash and citation rates of Utah licensed drivers with recorded medical conditions. Australian data regarding medical condition prevalence in samples purporting to be representative of the age group in this study are not comparable for a number of reasons, including being based on self-reports rather than medical documentation (Australian Bureau of Statistics, 2002; Kendig et al., 1996).

However, the sample of older drivers in this study was unrepresentative of the wider population in that they had all been referred for assessment due to suspected driving impairments, and approximately half of them failed the test. In view of the even distribution of test outcomes between pass and fail, this large data set presented a good opportunity to identify those driver errors that best discriminated safe from unsafe drivers.

5.1. Factors determining test outcome

Test outcome was almost invariably determined by whether the LTO needed to intervene to maintain safety. Consistent with this, Dobbs et al. (1998) found that the driving errors most predictive of pass/fail outcomes for an impaired group were those categorized as "hazardous errors"; these were defined as errors requiring LTO intervention or accommodation by surrounding traffic. In their study, 50% of hazardous errors occurred while the vehicle was changing lanes, merging, or negotiating an intersection, while in our study 56% of LTO interventions (representing "hazardous errors") occurred under identical circumstances. The importance of hazardous errors such as our "LTO intervention" category has been reported by other researchers (Brendemuhl, Schmidt, & Schnenk, 1988; Hunt etal., 1993; Janke & Eberhard, 1998). For example, in the Area Driving Performance Evaluation (ADPE) test used by Janke and Eberhard (1998), performance criteria included "critical errors" (events such as speed violations, disobeying traffic signs, or striking an object) and the subset of "hazardous" errors, which include examiner intervention or dangerous manoeuvres.

Dobbs et al. (1998) found that, after hazardous errors, the errors most strongly associated with test outcome were positioning errors—equivalent to our "lane keeping" and "unlaned clearway" errors within the position and speed performance category (see Table 3). Major problems related to lateral positioning of the vehicle were also frequently associated with our LTO interventions (see Table 7). Next in predictive strength of the errors in that study was "overcautiousness" (comparable to our "speed too slow" within the position and speed performance category (Table 3), followed by "turn positioning error" (similar to our "position on road" errors within the intersection category; see Table 2). Their "scanning errors," including failure to perform head checks, correspond most closely with our "fail to check mirrors" and "fail to turn head to check back over shoulder" errors, which fall within three of our performance categories: lane changing, intersection negotiation (mirror checks only), and low speed manoeuvres.

These errors of Dobbs et al. (1998) together predicted 57% of variance in a composite global performance rating based on ordinal ratings of accident risk, driver skill, and defensive driving. In this study, there was no comparable rating, but a regression model based on the six performance scores accounted for 94% of variance in test outcome (pass/fail). The strongest predictors were performance scores for intersection negotiation and for maintenance of position and speed, followed by safety margin. These aspects of driver performance were also commonly associated with LTO interventions (the single most important predictor of test outcome; see Table 7), so the strong relationship between performance scores and test outcome is unsurprising. However, it supports the validity of LTO interventions as an indicator of overall test performance—and, hence, as a legitimate basis for determining test outcome.

Our results concerning the types of errors that were most strongly related to test outcome are consistent with other published findings. In particular, older drivers are known to have difficulty coping with intersections (Daigneault et al., 2002), and they are more likely than others to be involved in intersection accidents (Fildes, 1997; Hakamies-Blomqvist, 1993; Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998; Ryan et al., 1998), and such findings are usually interpreted as evidence of older drivers' decreased information processing capacity and related propensity to become cognitively overloaded in complex situations. Also, Hunt et al. (1997) found that a group of older drivers with early dementia had greater difficulties at intersections, drove more slowly, displayed worse lane control, and had more unexpected and frequent braking than an age-matched control group.

Further evidence of the validity of these types of driving errors as indicators of substantially reduced competence among older drivers is provided by Preusser et al. (1998), who compared the crash risk of older drivers relative to that of middle-aged drivers. They found that older drivers were 2.26 times more at risk for multiple-vehicle involvements at intersections compared with 1.29 times more at risk in all other situations. For drivers aged 85 and older, the risks were 10.62 times for multiple-vehicle involvements. The relative crash risk for older drivers was particularly high for uncontrolled intersections and those controlled by stop signs, when traveling straight or when just starting to enter an intersection, and when the main driver error in the crash was a failure to yield. Consistent with this, "failure to yield" at intersections was the most commonly reported error associated with LTO interventions in the present study (see Table 7).

5.2. Effects of driver age

In this study, fail rate increased sharply and consistently with increasing age, from 0% for those aged under 54 years, through 38% for those 75 to 79 years, to 71% for those 85 years and older, as shown in Table 12. Since the older drivers in this sample did not appear to have medically documented major medical problems that could account for their progressively higher failure rate with increasing age, the most likely underlying causes for the increase appear to be the "normal" age-related declines in some of the capacities that underlie safe driving performance. In addition, the rate of undiagnosed medical conditions that would impair driving ability was probably highest among the oldest drivers.

As noted earlier, some cognitive decline associated with aging is a normal phenomenon. Brayne et al. (2000) measured cognitive changes over a 9-year period with a sample of 2,106 people in "The Cambridge City over 75 Cohort." They concluded that cognitive decline in the very old has been considerably underestimated by previous longitudinal studies because of methodological problems. However, in

identifying causal links between cognitive decline, driving performance deficiencies and road safety risk, it is important to remember that

> ...we do not know precisely which declines contribute directly to an elderly person's increased risk of becoming involved in a serious accident. Research has indicated that a host of abilities...decline with age...science cannot yet distinguish abilities whose decline actually contributes to bad driving from declines that just accompany bad driving (McKnight, 2000, p. 67).

Perryman and Fitten (1996) studied three small groups of healthy adults (aged 24 to 34, 64 to 69, and 69 to 91 years) on a closed circuit road route using an instrumented vehicle. Older drivers made fewer steering and eye movement excursions and drifted across the center line more frequently than the young control group. The authors suggested that declining visual–spatial attentional abilities or more restricted UFOV may be related to the decreased eye movement excursions in the healthy elderly drivers. Regardless of the underlying capacities involved, such behavioral changes are presumably related to older drivers' relatively poor performance in maintaining appropriate lateral position of their vehicle and to their poorer observational performance—both of which were documented in this study.

5.3. Medical status

Driving performance did not vary significantly in relation to different types of medical conditions within the present sample, except for an apparent effect of physical impairment on car control, consistent with the variation in fail rates between the main medical conditions shown in Table 10, where arthritis was seen to be the condition with the highest fail rate. Similarly, Gallo et al. (1999) found that very few self-reported medical or functional conditions were associated with reports of adverse driving events for a large group of community dwelling individuals. They concluded that "...except for heart disease, our study found few strong associations of driving behavior with specific medical conditions" (p. 340). A similar conclusion was drawn by Hu, Trumble, Foley, Eberhard, and Wallace (1998) in their longitudinal study where they sought to identify factors that influenced the crash risk of older drivers. They stated that "...the mere presence of any disease is not as significant a predictor of crash risk as the functional limitations caused by the disease" (p. 579).

In this study the lack of any strong relationship between medical conditions and driving performance was not surprising since drivers with major physical or cognitive impairments would have been referred for assessment by an OT, rather than by an LTO in a review test as considered here. However, researchers working with groups of drivers with reliably diagnosed cognitive impairment have certainly found them to perform more poorly on road tests (Dobbs et al., 1998; Duchek, Hunt, Ball, Buckles, & Morris, 1998; Hunt et al., 1993).

6. Relationships between referral source and test outcome

Police were the main source of referrals for the drivers in this sample; the majority of drivers had been referred as a result of involvement in an accident. Other referrers included doctors and other health professionals, and families. As previously mentioned, the licensing authority requires all drivers to undergo a special "fitness to drive" medical assessment from their doctor prior to any road test; it is only in a minority of cases that the event instigating the license review process is a medical report from a doctor or other health professional; it is only this latter group who were categorized here as "medical referral."

Drivers tested following medical referrals had a relatively higher pass rate than those referred by police or the public. This might reflect the difficulties experienced by doctors in assessing driving capacity based on a standard clinical assessment, combined with a conservative referral strategy whereby they tend to refer patients for driver reassessment if they are in any doubt (Fitten et al., 1996; Johansson et al., 1996). The relatively small group referred by the public (often family members) were the only ones tending to fail more often than to pass, although this tendency did not reach statistical significance. The importance of family observations in identifying at-risk drivers has been previously noted (Lloyd et al., 2001; Messinger Rapport & Rader, 2000). Wiseman and Souder (1996) placed considerable weight on such information, encouraging physicians to identify discrepancies between the views of family/care givers and the driver's self-rating as part of their checklist for identifying "at risk" drivers.

7. Relationships between prior accident report information and test outcome

Evidence based only on participation in an "event," that is, that a driver had been involved in an immediately prior accident (as was the case for over half the sample) was not related to road test performance. However, more specific details regarding the event, such as prior "failure to obey a road law" was strongly related to probability of test failure, and "inappropriate or dangerous driving" had a similar (but only marginally significant) relationship. These findings are consistent with documented patterns of older driver accidents, which typically involve failure to give way (Zhang, Lindsay, Clarke, Robbins, & Mao, 2000) and intersections more generally (Hakamies-Blomqvist, 1993), particularly turning movements (Ryan et al., 1998). They are also consistent with the findings of McKnight and McKnight (1999) concerning significant relationships be-

tween previously reported unsafe driving incidents and performance indicating a range of driving-related deficiencies in attentional, perceptual, cognitive, and psychomotor performance.

However, a subset of drivers who had been involved in a prior accident or incident (most common events: hitting cars when reversing or parking; colliding with a stationery vehicle or object; involvement in a collision and not noticing) had a significantly lower fail rate, possibly due to the greater random element in collision involvement than in being reported for specific behavioral faults, as noted above. In addition, it may be relevant that these types of accidents (particularly the latter two) typify drivers of any age who are affected by alcohol and/or excessive fatigue—neither of which necessarily indicates chronic impairment. These results highlight the importance of considering the nature of any prior accident when such information is being reviewed as part of an individual risk assessment.

8. Implications for older driver testing

Considerable efforts are currently being devoted to the development of off-road screening and assessment tools to identify older drivers whose suspected or known impairments may present an unacceptable road safety risk (Charlton, 2002; Hakamies-Blomqvist, 2002). However, at least until such systems are considerably more effective than at present, road tests will continue to form a major component of driver competency tests (Withaar et al., 2000).

Many researchers have identified the general requirements of a road test to achieve adequate validity and reliability, either for assessing impaired or entry level drivers. A valid test must include a representative range of road traffic conditions, enabling the assessor to observe key aspects of driver performance ranging from situation awareness and hazard perception through to vehicle control and manoeuvreing at an appropriate level of difficulty. To ensure test reliability, various aspects of behavior should be observed several times under a range of conditions, by trained assessors, using standardized, operationally defined scoring criteria (Christie, 2000; Fox, Bowden, & Smith, 1998; Siegrist, 1999; Withaar et al., 2000). These reliability requirements are most easily met if a standardized test route is used, with predetermined observation points.

Interrater reliability is another aspect that needs to be considered. In this study, interrater reliability could not be evaluated as there were systematic differences in the subsamples tested by the two assessors in terms both of driver referral characteristics and test locations (city vs. rural). Their overall pass rates were similar: 53.2% and 52.3%, respectively.

An additional requirement when assessing older drivers is that the scoring system should not place undue weight on "errors," which stem primarily from habitual behaviors and do not threaten safety. This is particularly important when testing older drivers because, having had a significant amount of driving experience without recent formal training, they are likely to exhibit a range of bad habits that are unrelated to possible age-related impairments. For example, Dobbs et al. (1998) found that the error of rolling past stop signs was made equally often by impaired and unimpaired drivers. However, such errors cannot necessarily be discounted; the context in which they occur needs to be considered. Rolling past a stop sign might normally be safe, but in the context of a pedestrian starting to cross the road in front of the car, or when approaching close to an intersecting stream of fast moving traffic, a rolled stop might be clearly unsafe, justifying an LTO intervention and converting an ordinary "bad habit" error into something much more significant. The challenge is to maintain test reliability without degrading validity. Reliability is maximized by clearly specified testing procedures and scoring criteria (Macdonald, 1987, 1992; McKnight, 1989). However, too rigid a specification of scoring criteria precludes the necessary flexibility to take into account varying error contexts. Provision for additional, more flexible scoring category such as the VicRoads "LTO intervention," may represent a satisfactory compromise in this regard.

Another threat to the reliability of the present license review test for older drivers was the absence of a standard test route, since the test is usually conducted in the vicinity of drivers' homes and many drivers (especially in rural locations) may live some distance from a testing office. Withaar et al. (2000) argue that such tests nevertheless have some advantages over those using standard routes, because they provide greater "ecological" validity: "...a free field test ride in natural conditions most closely approaches everyday driving performance" (p. 488). Also, a test undertaken in familiar surroundings may reduce the older driver's probable high level of anxiety and offer high face validity—a particularly important consideration if the driver fails the test. To compensate as much as possible for the lack of a standard route, it is suggested that there should be a minimum required number of observations per major performance category, although this may well be problematic in nonurban driving environments or where there is low traffic density. Indeed, inadequate numbers of recorded observations was a problem in some cases in this data set, particularly in relation to safety margin. In cases where a local area test provides an inadequate range of test situations, consideration should be given to offering the driver a choice of either a license restricting their driving to their own local area (assuming that they pass the test), or another test on a more representative test route. In addition, consideration could be given to the inclusion of a navigational task or some other such task requiring some planning, short term memory, and problem solving, as recommended for use when assessing cognitively impaired drivers (Dobbs et al., 1998; Janke, 2001). Consideration might also be given to the inclusion of measures of tactical compensation, although such additions would require further research.

Overall, the set of performance scores developed in this study provide a generally valid indicator of the unsafe behaviors most typical of older drivers. First, the relationship between performance scores and LTO interventions (which determine test outcome) provides such evidence, based on the assumption that LTO interventions are a valid indicator of unsafe behavior. This is a reasonable assumption since unsafe behavior is precisely the criterion for LTO intervention. Second, considering the magnitude of correlation coefficients between performance scores and age, and between performance scores and outcome, it can be seen that the rank orders of these correlations are almost identical. Given that the crash risk of older drivers is known to increase with age, these similar patterns provide further evidence of the validity of performance measures as an index of crash risk. Third, in the analysis of performance scores related to test outcome (Tables 8 and 9), addition of age to the regression model after entry of the performance scores explained very little additional variance, suggesting that the driver error data comprising the performance scores largely accounts for the expected age-related decrement in driver performance. On this basis, it is evident that the types of errors recorded in this license review test are suitable for use in assessing older drivers, or at least for assessing those without major physical or cognitive impairments as in this sample.

9. Future research

In view of the central role played by LTO interventions in the present license review test, and the issues concerning test reliability as discussed above, there is a need for further research to document the factors related to road traffic context that influence the nature and frequency of such interventions. A better understanding of the role of such factors is important in specifying requirements for the routes to be used in assessing older drivers who wish to retain an unrestricted license.

It would also be beneficial to replicate this study using somewhat different driver samples, to test the consistency of error patterns and performance patterns. The present sample of drivers was representative of a major segment of the older driver population. However, they did not include those with major physical impairments nor, more importantly from a safety viewpoint, those who prima facie are at greatest risk due to a specifically diagnosed cognitive impairment. It would therefore be very useful to extend the present analysis methods to encompass these groups, to identify possible differences in different types of error rates, including factors leading to LTO interventions, and their relationships with test outcome. Longitudinal studies are also required to examine citation rates and crash risk of those individuals who retain their license posttesting, for the purpose of evaluating and improving the test's predictive validity.

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