Self-regulation of driving and older drivers' functional abilities

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A sample of 90 adults aged between 60 and 91 completed a questionnaire about their driving behaviour, a battery of functional tests, and a structured on-road test. The section of the questionnaire featuring items about avoidance of difficult driving situations was used as an index of self-regulation of driving behaviour. The functional test battery consisted of mood, vision, physical functioning and neuropsychological tests. The on-road test used in the study was a standard assessment procedure developed by the Driver Assessment Rehabilitation Service to determine fitness to drive. Of the 90 participants in the study, 68 passed the driving test, 8 passed but were recommended to have lessons and 14 failed the test. Driving test scores for the study were based on the number of errors committed in the driving tests, with weightings given according to the seriousness of the errors. In order to identify risk factors for inadequate driver self-regulation, comparisons were made between the functional tests most strongly related to driving performance and the functional tests most strongly related to self-regulation. It was concluded that self-regulation of driving behaviour is inadequate among older drivers with poor contrast sensitivity, poor speed of information processing and poor visuospatial ability.

INTRODUCTION

The term 'self-regulation of driving behaviour' refers to the ability to monitor one's driving ability and adjust one's driving behaviour in accordance with this assessment, reducing exposure to driving situations one finds difficult (Charlton, Oxley, Fildes, & Les, 2001). The potential for older drivers to regulate their own driving behaviour has been identified as "central to current thinking about licence reassessment because if older drivers are self-regulating adequately, then there is less need for… mandatory licence retesting" (Charlton, 2002, p51). Successful self-regulation should result in decreased older driver crashes through a reduction in exposure and, particularly, a reduction in exposure to difficult situations and conditions, whilst still allowing the maintenance of mobility (Stalvey & Owsley, 2000). Studies of self-regulation have revealed that older drivers often report deliberately avoiding a number of difficult driving situations and conditions, including night driving, inclement weather, busy traffic, high speed roads, unfamiliar areas, and unprotected turns across traffic or at complex junctions (Eberhard, 1996; Gallo, Rebok, & Lesikar, 1999; Holland & Rabbitt, 1994).

However, for self-regulation to be successful (i.e. to reduce crash involvement but not unnecessarily hinder mobility), it is important that self-regulation is practised by those drivers who are likely to have a greater than average crash risk, while those drivers with a low risk of crashing can impose less self-restriction on their driving behaviour. A study of 90 older drivers by Baldock, Mathias, McLean and Berndt (2004) found only a limited relationship between self-regulation, defined as self-reported avoidance of difficult driving situations, and performance on a structured, on-road driving test. Older drivers who performed more poorly on the test were more likely to avoid driving at night and driving in the rain but were no more likely to avoid driving alone, parallel parking, right turns across traffic, driving on freeways, driving on high traffic roads, or driving during peak hour. The correlation between overall avoidance of difficult driving situations and driving performance was $r = .20$ ($p = .055$). These results highlight the need to identify the characteristics of drivers who are less likely to self-regulate appropriately.

To this end, the present paper provides a follow-up analysis of data collected as part of the study of self-regulation and driving performance referred to above (Baldock et al., 2004). For the same sample of 90 older drivers, comparisons were made between the functional abilities related to driving performance and the functional abilities related to self-regulation. Ideally, any deficit in functioning that is related to poorer driving performance should also prompt greater self-regulation. Therefore, the analysis was designed to determine if the functional test scores that were positively correlated with errors on the on-road driving test were also positively correlated with greater avoidance of difficult driving situations.

METHOD

Participants:

A group of 90 older drivers (aged 60 years or more) were recruited from two sources: the general community and the Driver Assessment Rehabilitation Service (DARS) at the University of South Australia. Community participants were recruited through Senior Citizens' clubs and Australian Retired Persons Association clubs in metropolitan Adelaide. The drivers from the DARS client pool were referred, mostly by general practitioners, for an assessment of their ability to drive and their right to hold a driver's licence.

The total sample consisted of 90 adults (54 females, 36 males), 82 of whom were recruited from the general community and eight of whom were recruited from the DARS client pool. Their ages ranged from 60 to 91 ($M = 74.0$, $SD = 6.2$) and they had completed an average of 10.9 years of formal education ($SD = 3.0$).

All participants were required to be fluent in English, in possession of a full driver's licence for non-commercial motor vehicles, and to have been driving for over ten years. The latter requirement was imposed to ensure that all participants were experienced drivers. Participants were excluded if they had suffered a cerebrovascular accident (stroke), traumatic brain injury, or other event causing a sudden loss of functioning, in the past year.

Apparatus:

The participants were required to complete a questionnaire on driving habits and attitudes that was based on questionnaires used previously in studies of older drivers (Owsley, Stalvey, Wells, & Sloane, 1999; Stalvey & Owsley, 2000). Included in the questionnaire were items about avoidance of difficult driving situations. Participants were asked to report their level of avoidance of nine different situations (e.g. driving in the rain) on a five point scale, with 1 = never avoid and 5 = always avoid. These ratings were summed to create an overall avoidance score ranging from 9 (never avoid any driving situations) to 45 (always avoid all difficult driving situations). This measure of overall avoidance was used as an index of self-regulation of driving behaviour (see Baldock, 2004).

Participants' health status was determined using a questionnaire. Participants were provided with a list of 14 medical conditions and asked to indicate whether they suffered from each condition or not. The 14 conditions were chosen because they were likely to compromise driving ability. Additionally, participants were asked to name any other conditions they had that were not on the list. For each condition that they nominated, participants were asked to indicate on a three point scale how much they thought it affected their everyday functioning. A health scale of this nature has previously been used by Steinberg et al. (1994) and in a road safety context by Stalvey and Owsley (2000). The self-ratings of the extent to which medical conditions affected everyday functioning were summed for each participant to give an index of general health. Participants were also asked to list the medications they took more often than once a month. In order to classify medications according to whether they were potentially hazardous to driving, details of the medications were obtained from the Monthly Index of Medical Specialities annual (MIMS Australia, 2000). The MIMS annual is a publication providing details about currently available prescription and non-prescription medications, including likely and possible side-effects. All medications described as commonly causing drowsiness, dizziness, or disturbance of central nervous system functioning were classified as being "potentially hazardous to driving".

Participants also completed a number of functional measures. Psychological functioning was measured using the Geriatric Depression Scale (Brink et al., 1982) and State-Trait Anxiety Scale (Speilberger, 1983); vision using Snellen Static Visual Acuity, Pelli-Robson Contrast Sensitivity (Pelli, Robson, & Wilkins, 1988), and a measure of horizontal visual field; physical functioning using a measure of head-neck mobility; mental status using the Modified Mini Mental (3MS) (Teng & Chui, 1987) from which scores on the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975) can also be derived; speed of information processing using the Symbol-Digit Modalities Test (Smith, 1982); visuospatial memory using the Wechsler Spatial Span test (Wechsler, 1997); and visual attention using the Computerised Visual Attention Test. For full descriptions of these tests, refer to Baldock (2004).

Most of the functional tests were standard measures but the Computerised Visual Attention Test (CVAT) was developed specifically for the study. The CVAT requires participants to detect and react to targets in both central and peripheral vision, and was designed to measure selective and divided attention.

There are two different tasks in the CVAT: the primary task and the secondary task. The primary task requires that participants monitor a series of letters appearing on the left-hand side of the computer screen, one after another, at the rate of a new letter every 700 ms. Whenever the letter 'X' appears, participants must press the space bar on the keyboard as quickly as possible using a finger on their left hand. The secondary task requires that participants use their peripheral vision to detect the appearance of the picture of a car on the right side of the computer screen and react by clicking the mouse as quickly as possible with their right hand. In some CVAT subtests, the cars would appear by themselves, whilst, in others, participants would have to detect the cars appearing in the presence of visual distracters (pictures of houses). The visual distracters component of the task represented an assessment of selective attention. Both the primary and secondary tasks (the latter with and without visual distracters) were performed both separately and simultaneously, so that divided attention could also be assessed. Overall, there were five subtests, which were as follows:

- primary task (X-detection) only: measure of simple attention in central vision
- secondary task (car detection) only without visual distracters (houses): measure of simple attention in peripheral vision
- secondary task only with visual distracters: measure of selective attention in peripheral vision
- dual task (primary and secondary tasks) without visual distracters on the secondary task: measure of divided attention, central and peripheral vision
- dual task with visual distracters on the secondary task: measure of divided and selective attention, central and peripheral vision

For each of these subtests, the CVAT produced measures of target detection failures and reaction time. Detection failures are hereafter referred to as "detection errors".

The order of the CVAT subtests was varied across participants so that the relationship between the attention variables and other measures could not be confounded with learning or fatigue effects. This variation in the order of the five CVAT subtests was done according to Orthogonal Latin Squares tables printed in Fisher and Yates (1957) so that, across the entire sample, each subtest was performed first, second, third, fourth and fifth by an equal number of participants.

The driving assessments consisted of standardised on-road driving tests conducted by an occupational therapist from DARS with postgraduate training in driver assessment and rehabilitation, and a professional driving instructor. The driving instructor directed the participant through the driving route and used dual brakes to maintain safety, while the occupational therapist scored the participant's driving performance. A set test route based on testing procedures used in other studies (Dobbs, 1997; Hunt et al., 1997; Parasuraman & Nestor, 1991) was designed specifically for this study (Baldock, 2004). The test was broken into four sections: familiarisation, low demand, moderate demand, and high demand. The familiarisation section involved familiarising the driver with the vehicle, and assessing whether the driver could perform basic vehicle control tasks (e.g. starting a car, moving off). The low demand section was conducted on low traffic roads and mainly involved negotiating roundabouts. The moderate demand section involved driving on main roads but did not require complex manoeuvres. In this section, all intersections were negotiated by driving straight through or turning with a dedicated turning arrow. In the high demand section, drivers had to perform unprotected right turns at intersections on main roads, as well as merging manoeuvres on multi-lane roads and driving in areas featuring high pedestrian activity. The driving test, therefore, involved progressively more difficult manoeuvres completed in the presence of increasingly more complex traffic conditions. It took from 40 minutes to an hour to complete.

The on-road driving tests were all conducted in dual-controlled, medium-sized sedans (1997 Toyota Corollas), fitted with power steering and manual or automatic transmission, depending on the participant's preference. Two occupational therapists were employed for the study, and completed 57% and 43% of the assessments, respectively. The same driving instructor was available for 95% of the assessments. Assessments were conducted at 9:30am, 11:00am or 1:00pm, so that drivers were not assessed during peak hour traffic.

As is standard practice for DARS, test failure was based on agreement between the occupational therapist and driving instructor about the safety risk posed by the driver, given the types of errors they made and the level of active intervention required on the part of the driving instructor to ensure safety during the test (applying brakes, taking hold of the steering wheel, explicit verbal guidance). Errors that posed a greater safety risk, such as speeding, disregarding traffic signals and Stop or Give Way signs, drifting into other lanes, and stopping unexpectedly without reason, were most likely to lead to failure of the test.

In keeping with other studies of driving performance and aging (Dobbs, Heller, & Schopflocher, 1998; Janke & Eberhard, 1998; Staplin, Gish, Decina, Lococo, & McKnight, 1998) in which different weightings were given for different road test errors, a scoring system was developed that assigned different weightings to different errors in order to produce an overall score that more closely matched the outcomes of the assessments (i.e. pass or fail). Greater weightings were assigned to errors requiring the intervention of the driving instructor, with lesser weightings given to what were termed "hazardous" errors (exceeding the speed limit, inappropriate high speed, unsafe gap selection, unsafe positioning, disobeying Stop signs or traffic lights) and no extra weightings given for what were termed "habitual" errors (e.g. failure to check mirrors or blind spots, failure to indicate, inappropriate lane selection, poor parking ability). It was found that, using a weighting of 10 for driving instructor interventions, five for hazardous errors and one for habitual errors, it was possible to accurately predict test outcomes in 94% of cases, with 79% sensitivity (correctly identified failures) and 97% specificity (correctly identified passes). This weighted error score was used as the outcome measure for the driving assessment.

Procedure:

The questionnaire (self-regulation; health) was mailed out to participants who then completed it at home. Next, participants attended a functional testing session with the investigator at the University of Adelaide. This session would take approximately two hours. The driving assessment was completed on another day within two weeks of the functional testing session. For the general community participants, feedback on the driving assessment was given by the occupational therapist immediately following the test. Drivers recruited from the general community who failed the on-road test did not have their licence cancelled. Instead, a letter was sent to their general practitioner who would decide what, if any, action was required. Formal written consent to participate was given by all drivers. Analyses were based on Pearson's Product Moment Correlations, with an alpha level set at a conservative level of .01 to reduce the likelihood of Type I errors.

RESULTS

The mean self-reported level of avoidance of difficult driving situations, on a possible scale from 9 to 45 was 13.2 (*SD* = 5.6), indicating a low level of overall of self-regulation.

The outcomes of the 90 driving tests, in terms of recommendations by the assessor, were 68 passes (75.6%), eight passes with recommendations for lessons (8.9%) and 14 failures (15.6%). Scores were calculated for interventions by the driving instructor, hazardous errors and habitual errors. The mean number of driving instructor interventions per test was 1.1 (*SD* = 1.7), the mean number of hazardous errors was 10.5 (*SD* = 10.9) and the mean number of habitual errors was 54.0 (*SD* = 17.5). These results show that interventions by the driving instructor were rare and that hazardous errors were a lot less common than habitual errors. To create a continuous variable for use as the outcome measure from the driving test, a weighted error score for the test was calculated. The scores on this measure ranged between 18 and 443, with a mean of 117.6 (*SD* = 78.3).

The means and standard deviations and the range of possible scores for the functional measures are provided in Table 1. Note that medians and ranges are provided for visual acuity, as means and standard deviations are inappropriate for an ordinal scale such as the Snellen visual acuity scale. Table 2 provides the Pearson's Product-Moment Correlations between each functional test score and both overall avoidance of difficult driving situations and the weighted error score on the on-road driving test. Note that there were very few target detection errors in the single task conditions of the CVAT and this resulted in low test-retest reliability for these variables. For this reason, correlations were not calculated between these scores and the two outcome measures.

The results of the correlational analyses show that the error score on the test of on-road driving performance was significantly associated with contrast sensitivity, speed of information processing, visuospatial memory, and various measures of visual attention. Avoidance of difficult driving situations was significantly correlated with general health, medication use, visual acuity in the right eye, and various measures of visual attention.

Table 1:*Means and standard deviations for the health and functional measures*

Measure	Mean	*SD*	Possible range
Health			
General health	2.4	1.8	0-
Medication use	1.6	1.9	0-
Hazardous medication	0.6	0.9	0-
Psychological functioning			
Geriatric Depression Scale	3.8	3.3	0-30
State-Trait Anxiety Inventory			
State Anxiety	31.3	8.0	20-80
Trait Anxiety	30.8	7.9	20-80
Vision			
Visual acuity, left eye	6/6	6/24-6/5	6/60-6/5
Visual acuity, right eye	6/6	6/60-6/5	6/60-6/5
Visual acuity, binocular	6/5	6/18-6/5	6/60-6/5
Contrast sensitivity, left eye	1.61	0.13	0.00-2.25
Contrast sensitivity, right eye	1.61	0.15	0.00-2.25
Contrast sensitivity, binocular	1.77	0.14	0.00-2.25
Visual field, total	173.1	12.3	0-180
Physical functioning			
Total neck mobility	138.9	25.6	0-180
Mental status			
MMSE	28.7	1.4	0-30
3MS	95.0	4.6	0-100
Speed of information processing			
Symbol Digit Modalities Test	37.7	9.7	0-110
Visuospatial memory			
Total Spatial Span	13.5	3.1	0-32
Visual attention			
CVAT reaction time			
Single task:			
Primary task	433.3	43.6	0-1999
Secondary task, no distract	411.1	48.4	0-1999
Secondary task, distract	535.7	71.4	0-1999
Dual task:			
Primary, no distract	466.7	51.0	0-1999
Secondary, no distract	477.8	64.6	0-1999
Primary, distract	495.0	50.0	0-1999
Secondary, distract	630.1	106.6	0-1999
CVAT target detection errors (%)			
Single task:			
Primary task	0.3	0.8	0-100%
Secondary task, no distract	<0.1	0.4	0-100%
Secondary task, distract	1.5	3.3	0-100%
Dual task:			
Primary, no distract	2.0	3.2	0-100%
Secondary, no distract	0.5	1.7	0-100%
Primary, distract	5.1	5.3	0-100%
Secondary, distract	5.3	7.9	0-100%

Note: distract = visual distracters on secondary task

Note: CVAT scores calculated for both primary and secondary tasks in dual task subtests

Table 2: *Correlations between health and functional measures, and both the weighted error score on the on-road driving test (driving performance) and overall avoidance of difficult driving situations (avoidance)*

Measure	*r* (driving performance)	*r* (avoidance)
Health		
General health	.21	.32**
Medication use	.19	.27*
Hazardous medication	.22	.06
Psychological functioning		
Geriatric Depression Scale	.24	.08
State-Trait Anxiety Inventory		
State Anxiety	.09	.13
Trait Anxiety	.20	.21
Vision		
Visual acuity, left eye	.19	-.06
Visual acuity, right eye	.12	.25*
Visual acuity, binocular	.25	.08
Contrast sensitivity, left eye	-.36**	-.13
Contrast sensitivity, right eye	-.22	-.23
Contrast sensitivity, binocular	-.33*	-.12
Visual field, total	.05	-.02
Physical functioning		
Total neck mobility	-.19	-.09
Mental status		
MMSE	-.19	.02
3MS	-.26	-.03
Speed of information processing		
Symbol Digit Modalities Test	-.32*	-.18
Visuospatial memory		
Total Spatial Span	-.30*	-.07
Visual attention		
CVAT reaction time		
Single task:		
Primary task	.38**	.25
Secondary task, no distract	.35*	.28*
Secondary task, distract	.43**	.14
Dual task:		
Primary, no distract	.33*	.14
Secondary, no distract	.32*	.21
Primary, distract	.30*	.11
Secondary, distract	.46**	.28*
CVAT target detection errors (%)		
Single task:		
Primary task	-	-
Secondary task, no distract	-	-
Secondary task, distract	-	-
Dual task:		
Primary, no distract	.24	.04
Secondary, no distract	.02	.10
Primary, distract	.32*	.01
Secondary, distract	.36**	.35**

* $p < .01$, ** $p < .001$

DISCUSSION

The completion of a questionnaire about driving behaviour, an on-road test of driving performance and a battery of functional tests by a sample of older drivers enabled a comparison between the functional abilities related to driving performance and the abilities related to choices about avoidance of difficult driving situations. This analysis, the first of its type, revealed a number of differences in the deficits in functioning that disrupt driving ability and the deficits in functioning that may prompt changes in driving behaviour.

All measures can be classified according to their relationships with driving performance and driving avoidance (self-regulation). Ideally, functional abilities would either be related to both (i.e. affect driving performance but also prompt self-regulation) or neither (i.e. do not affect driving performance and do not prompt self-regulation). However, some abilities were found to be related to self-regulation only (i.e. prompt drivers to self-regulate when there is questionable need) or to be related to driving performance only (i.e. does not prompt drivers to self-regulate when they should).

The ability that was found to be related to both driving performance and self-regulation was visual attention. Drivers whose reaction time to visually presented targets was longer or who were more likely to fail to detect the targets were more likely to perform poorly on the on-road driving test but were also more likely to avoid difficult driving situations. Indeed, the measure most strongly correlated with driving performance was reaction time to targets in the peripheral visual field, presented with visual distracters and in a dual task condition. The target detection error score for the same subtest of the CVAT was the measure most strongly related to self-regulation. However, it must be noted that relationships between visual attention and driving performance were stronger than those between visual attention and self-regulation, suggesting that the trend for appropriate self-regulation with regard to deficits in visual attention is not as strong as would be optimal.

Measures that were related to neither driving performance nor self-regulation included depressed mood and anxiety, visual field, head-neck mobility and mental status. However, caution should be applied when interpreting these results. Scores for depressed mood and anxiety were generally low, and it may be that different results would have been found with a sample that included drivers with depression or anxiety disorders. Similarly, few drivers in the study were affected by cognitive impairment and so a restricted range of scores on the measures of mental status would have made it unlikely that mental status was found to be related to driving performance in this study. Previous studies have found that declines in mental status are related to losses of driving ability (Clark et al., 2000; Cushman, 1996; Fitten et al., 1995; Rizzo, McGehee, Dawson, & Anderson, 2001) but that drivers affected by such declines lack the necessary insight to enact self-regulation (Adler, Rottunda, & Kuskowski, 1999; Ball et al., 1998; Eberhard, 1996).

Measures related to self-regulation but not driving performance included measures of health and medication use, and a measure of visual acuity. Therefore, drivers have a tendency to restrict their driving when affected by declines in visual acuity, despite the lack of a relationship between this variable and the ability to drive. Responding to increasing health problems with greater self-regulation of driving may reflect the use by older drivers of medical diagnoses as a proxy measure for functional declines. Instead of self-regulating in response to declines in functioning, older drivers may take the reasonable step of self-regulating in response to diagnoses of medical conditions that are likely to have effects on functioning.

The findings of most concern were those related to measures that were found to affect driving performance but which did not prompt self-regulation. These functional abilities were contrast sensitivity, speed of information processing, and visuospatial memory. This indicates that drivers with deficits in contrast sensitivity, speed of information processing or visuospatial memory are more likely to have problems when driving but are not more likely to restrict their driving than drivers without these problems. Contrast sensitivity (Janke & Eberhard, 1998; Wood, 2002), speed of information processing (Janke, 2001) and visuospatial memory (De Raedt & Ponjaert-Kristoffersen, 2000) have all been found previously to be related to on-road driving performance.

These three functional abilities, therefore, could be useful to assess in any educative interventions aimed at increasing self-regulation of driving behaviour among older drivers. Drivers who have difficulties with measures of these abilities are likely to self-regulate less than would be ideal. Contrast sensitivity, given its stronger relationship to driving ability than visual acuity, would be useful in medical assessments of fitness to drive. Wider use of tests of contrast sensitivity could increase awareness among older adults of the importance of this aspect of vision, which may, in turn, increase the likelihood that self-regulation is practised when contrast sensitivity declines. Both the speed of information processing and visuospatial memory measures used in this study are simple to administer and so could also be used to identify drivers who may experience difficulties driving but not be self-regulating appropriately. Additionally, speed of information processing has been found to be associated with cognitive impairment (Spreen & Strauss, 1997), which is also related to poorer driving ability but not greater self-regulation.

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