The On-Road Difficulties of Older Drivers and their Relationship with Self-Reported Motor Vehicle Crashes

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ABSTRACT

OBJECTIVES: To quantify the driving difficulties of older adults using a detailed assessment of driving performance and to link this with self-reported retrospective and prospective crashes.

DESIGN: Prospective cohort study.

SETTING: An on-road driving assessment.

PARTICIPANTS: Two hundred sixty seven community-living adults aged 70 to 88 randomly recruited through the electoral roll.

MEASUREMENTS: Performance on a standardized measure of driving performance.

RESULTS: Lane positioning, approach, and blindspot monitoring were the most common error types, and errors occurred most frequently in situations involving merging and manoeuvring. Drivers reporting more retrospective or prospective crashes made significantly more driving errors. Driver instructor interventions during self-navigation (where the instructor had to brake or take control of the steering to avoid an accident) were significantly associated with higher retrospective and prospective crashes; every instructor intervention almost doubled prospective crash risk.

CONCLUSION: These findings suggest that on-road driving assessment provides useful information on older driver difficulties, with the self-directed component providing the most valuable information.

Key words: older drivers, driving errors, driving assessment, crashes,
INTRODUCTION

As the population continues to age, interest in the road safety of older drivers has increased. Older adults often have physical and sensory impairments that result in everyday tasks being more difficult, demanding, or dangerous than for younger adults. Of concern is the potential for significant injuries and crashes involving older drivers, both as a danger to themselves and other road users, given that older drivers have among the highest crash rates per distance driven, and relatively high injury and mortality rates.

Importantly, not all older drivers have impaired driving performance, or high crash risk. Thus the focus of research has been to identify interventions that help to reduce the risk factors among this population, including improved licensing of older individuals to screen for unsafe drivers, and remediation training for those whose driving skills have declined.

The development of such interventions requires a comprehensive understanding of the differences between safe and unsafe older drivers. However, there is a lack of data on the specific types of driving errors and driving situations that are problematic for older drivers. Most relevant data has used crash analysis rather than observing actual on-road driver performance. While crash data provide a rich source of information, understanding how crashes may be prevented requires knowledge of the incidents leading up to crashes, unsafe driving practices, and information on those potential crashes that were avoided due to the defensive manoeuvres of other road users.

Questionnaire-based approaches have also been used to highlight the problems of older drivers, revealing useful information about the perceived difficulties and compensatory strategies adopted by older drivers. However, it is unclear whether these self-perceived difficulties actually reflect those experienced under normal driving. Without data on specific
areas of driving that are problematic in this population, neither driver licensing assessments, nor interventions to improve performance, can be optimally designed to remediate problems leading to crashes.

This study provides a detailed description of the on-road driving performance of a large group of community-dwelling older adults aged 70 years and older, providing objective measures of the types of driving errors made, as well as the driving situations in which they were made. The assessment included driving under directed navigation, where the driving instructor provides instructions about directions (for example, where to turn), and self-directed navigation, where drivers are required to find their own way to a destination based upon road signs and markings. Inclusion of self-directed navigation provides the opportunity to evaluate drivers’ ability to plan and execute manoeuvres appropriately and is representative of the challenges faced by drivers in real-world driving situations and has been shown to highlight between-group differences in age and visual status in previous studies. Older drivers who report a history of crashes over the previous five years have been reported to perform worse on the on-road test described here. In this study we identified which particular errors (either driver behaviors or situational) are associated with self-reported crashes.

The aim of this study was to document the driving difficulties of older adults using a detailed on-road driving assessment and to determine the relationship between impaired driving skills and self-reported retrospective and prospective crashes. We hypothesized that some older drivers would have higher error rates overall, particularly in the self-directed component of the assessment, and that these would relate to both retrospective and prospective crashes. It is envisaged that the data collected could be used to identify specific problems faced by older drivers under real world driving conditions. This knowledge may be incorporated into older
driver training programs, assist in designing roads which reduce the traffic conflicts facing older drivers and in the design of appropriate in-vehicle technologies that assist older drivers to drive safely for longer.

METHODS

Participants

Community-dwelling individuals aged 70 years and above were recruited via the voter registration list (Australian electoral roll) to participate in a larger study on injury prevention (n = 449). Of these, 364 were current drivers and were invited to participate in this study, of whom 272 individuals agreed to participate (75% response rate) and 92 declined. Two participants were excluded because their scores on the Mini Mental-Status Examination (MMSE) were less than 24, the threshold for probable dementia. Three participants were excluded due to incomplete data on detailed elements of the driving assessment, yielding a total of 267 participants. Participants’ driving experiences and habits were assessed by a self-report questionnaire. For this study, we report general driving characteristics including length of driving experience and frequency of driving.

The study was approved by the Queensland University of Technology Human Research Ethics Committee. All participants were given a full explanation of the experimental procedures and written informed consent was obtained, with the option to withdraw from the study at any time. Participants also completed a battery of vision, cognitive and motor control tests, the results of which are reported elsewhere.
**Driving Performance**

Driving performance was assessed under in-traffic conditions in an automatic, dual-brake vehicle using a previously validated technique. An accredited professional driving instructor, who was responsible for monitoring safety, sat in the front passenger seat with access to the dual brake. Subjects were directed to drive along a 19.4 km route on the open road, which consisted of city and suburban streets, simple and complex intersections and a range of traffic densities. The driving assessment was generally 50 minutes in duration and included a short warm-up drive to become familiar with the vehicle. The drive was terminated early if the driver was considered too unsafe to proceed.

**Navigation condition**

Three quarters of the drive (75%) was conducted under directed instruction where the driving instructor provided detailed instructions of the route. The remaining 25% was conducted under self-directed navigation, in which the participant had to find their own way to a given destination. Assessments were conducted either mid-morning or mid-afternoon to avoid rush hour traffic.

**Driving behaviors observed**

Performance at each of the locations along the route was scored by an occupational therapist, experienced in driving assessment, and seated in the back seat of the vehicle. At each location, seven aspects of driving performance were scored: general observation, observation of blind-spots, indication (signaling), braking/acceleration, lane positioning, gap selection and approach to hazards (see Table 1). For each behavior type, the total number of errors as a
proportion of the total number of opportunities for error was calculated.

**Driving situations**

Each of the locations was further allocated into one of six categories, including traffic light controlled intersections, one-way traffic (straight and curved driving), two-way traffic (straight and curved driving), give-way (stop/give-way intersections, non-traffic light controlled intersections, pedestrian crossings and roundabouts), manoeuvring (reversing, parking, turnaround manoeuvre and negotiation through traffic slowing devices), and merging (lane changing, merging and entering/exiting traffic flow). This allowed identification of those situations where older drivers experience most difficulty. Again, for each participant for each situation type, a score was calculated representing the proportion of errors to total opportunities for errors.

**Instructor interventions**

The number of verbal or physical driving instructor interventions was also recorded. A verbal intervention was generally given in response to inappropriate speed or lane position in order to raise the driver’s awareness of safety issues but not to avoid an imminent incident. A physical intervention, either to apply the brakes or take the steering wheel, was generally in response to an imminent safety issue and was applied in order to avoid an immediate incident, such as a collision with another vehicle or person, or clipping the curb.

**Questionnaires**

As part of a larger health and injury questionnaire, participants were asked to report the
number of crashes they had been involved in over the previous five years.

Upon completion of the driving assessment, participants were provided with 12 monthly crash diaries, which they were asked to complete and return on a monthly basis. The number of crashes that participants were involved in during the 12 month follow-up period was recorded. Participants also reported whether police attended the crash. If participants failed to complete their monthly crash diaries they were sent reminders by mail and also received a series of follow-up phone calls.

Analyses

Driving behaviors were separated into those requiring continuous performance and monitoring (observation, braking/acceleration, lane keeping, gap selection and approach), and those only required on specific occasions (blindspot checking and indicating) (Table 1). On average there were 15 occasions (10%) where a blindspot check was required and 56 occasions (38%) where indicator use was required out of 148 locations.

Due to the non-normal distribution of the error rates, non-parametric statistics including Friedman and Wilcoxon tests (rank-sum tests for between-subjects effects, and signed-ranks tests for the repeated measures effects) were conducted to analyze the error rates for each behavior (the proportion of errors to total number of occasions the behavior was required) and for each of the different kinds of driving situations (traffic light, one-way, two-way, give-way, manoeuvring, and merging). Error rates were also compared between self-navigation and driver-instructed navigation, and according to whether the participant had experienced a crash, either retrospectively or prospectively. One-tailed hypothesis tests were used for the analysis of crash status as it was hypothesized that those who crashed would have more driving errors.
Separate analyses were conducted to examine those errors that required a driving instructor physical intervention. The rate of instructor interventions (as a proportion of the number of occasions for errors) was compared between driver-instructed and self-directed navigation using a Wilcoxon signed-ranks test. A logistic regression then examined whether rates of instructor interventions for each component of the test (self-navigation and instructor-directed) were related to crash history.

RESULTS

The demographic details and general driving characteristics of the participants are given in Table 2 and have previously been reported. All participants would have passed the visual standard for driver licensing in Australia (20/60 or 6/12) and 255 (95.6%) had normal muscle strength as indexed by a quadriceps strength test. As previously reported, participants were younger than non-participants on average, had more driving experience, and were more likely to be male. Participants also had more years of education (M = 12.32, SD = 4.11) than non-participants (M = 10.34, SD = 3.54, P < .001). Twenty-five percent of the participants reported a retrospective crash in the previous five years, where six percent reported having experienced more than one crash. In the prospective follow-up, 11% of participants reported that they had a crash in their 12 months of diary entries.

Fourteen of the participants did not complete all 12 months of the crash diaries, so were not included in the analyses involving prospective crashes. Driving assessments were terminated prior to completion for sixteen participants because their driving was considered too unsafe to continue. These participants were older on average than the rest of the sample (with a mean age of 80.2 years, SD = 3.5), but did not differ on cognitive status based on MMSE scores. Of the
sixteen, eight had sufficient data for analysis of all components of the driving assessment, as they had completed a significant proportion of the drive prior to termination. The remaining eight were excluded because they did not have sufficient data, as their assessment was terminated at an earlier stage of the drive.

**Types of errors made: Comparison of self-navigation and driver-instructed navigation, and crash involvement**

Table 3 shows the mean driving behavior error rates for each of the driving navigation conditions (driver-instructed and self-navigation) and according to retrospective and prospective crash involvement. Of continuously monitored errors, error rates differed according to type of behavior \((P < 0.001)\). Overall, when considering the driver-instructed and self-navigation data together, the highest error rates were observed for maintaining lane position, followed by approach to hazards, appropriate brake/accelerator use, observation, and gap selection. All pairwise differences were significant using a Wilcoxon signed-ranks test except for observation and gap selection errors.

Participants reporting a previous crash made significantly more errors overall involving observation in both the self-navigation and driver-instructed conditions and made more errors using the brake or accelerator and approaching hazards in the self-navigation condition than did participants who did not report a previous crash (see Table 3). Importantly, those who subsequently experienced a crash also made more observation errors in both the self-navigation and driver-instructed navigation conditions.

Overall, participants made more errors in the self-navigation than the driver-instructed navigation condition \((P < .001)\). The rates of observation errors \((P < .001)\), brake/accelerator
errors (P = .011), lane position errors (P < .001), and approach to hazard errors (P < .001), were all significantly higher in self-navigation than in driver-instructed navigation. Participants who had previously experienced a crash had higher errors in both the self-navigation (P = 0.007) and driver instructed (P = 0.043) conditions.

The less frequent driving behaviors (blindspot checking, and indicator use) were also compared according to driving navigation conditions and crash involvement. Blindspot errors were by far the most common (P < .001), on average participants failed to make a blindspot check on 63% of occasions when one was required. In contrast, indicator errors only occurred on 12% of possible occasions. Blindspot errors were significantly more common in self-navigation than in the driver-instructed condition (P < .001), while indicator errors were more common in the driver-instructed than in the self-navigation condition (P < .001). The rate of blindspot errors in the driver-instructed condition was associated with retrospective crashes, while indicator errors were not associated with crash status.

**Situations in which driving errors are made: Comparison according to crash involvement**

Table 4 shows the error rates for each of the driving situations encountered during the assessment, according to participants’ crash involvement. Error rates were significantly different between location types (P < 0.001). The largest number of errors was made in situations involving merging, followed by situations involving manoeuvring, give-way, one-way driving, traffic light controlled intersections, and finally when driving along two-way roads. All differences were significant with the exception of the error rates for give-way situations and one-way driving which were not significantly different.

We also examined whether errors involving particular situations discriminated between
crash-involved and non-crash-involved participants. Errors occurring at traffic light controlled intersections, in one-way driving and merging were more common among those who reported a previous crash. Those who went on to have a crash after the assessment did not differ from the other participants in terms of the situations in which their errors occurred.

**Errors requiring instructor interventions**

Driver instructor interventions were significantly more common in self-navigation than instructor-directed navigation (P < 0.001). The number of errors requiring an instructor intervention during self-navigation was significantly associated with both retrospective and prospective crashes (OR = 1.625, 95% CI, 1.104 to 2.393 for retrospective crashes, and OR = 1.936, 95% CI, 1.219 to 3.076 for prospective crashes). The odds-ratio for prospective crashes indicates that every instructor intervention required during the assessment almost doubles the risk of a driver reporting a crash in the following year (Figure 1). The number of errors requiring instructor intervention in the driver instructed component of the test was significantly associated with retrospective (OR = 1.44, 95% CI, 1.073 to 1.935) but not prospective crashes.

**DISCUSSION**

This is the first analysis of on-road older driver behavior that describes error types and relates these to self-reported crashes in a large cohort of community-dwelling older drivers. Drivers reporting more retrospective or prospective crashes made significantly more driving errors. Driver instructor interventions during self-navigation were significantly associated with higher retrospective and prospective crashes; every instructor intervention almost doubled prospective crash risk.
The behaviors with the lowest accuracy in performance were lane positioning, followed by approaching hazards, brake/accelerator use, observation, and gap selection. These findings provide novel and comprehensive data about the driving difficulties of a relatively large cohort of older individuals. Kay et al.\textsuperscript{18} also found lane positioning to be challenging for older drivers and highlighted intersections as a particular problem for unsafe older drivers. Accurate perception of road hazards has also been suggested to be an important factor in predicting crash risk in older adults,\textsuperscript{19} and the results are consistent with laboratory-based studies suggesting that hazard perception reduces with age.\textsuperscript{20} The reduction in ability to detect specific driving hazards or changes in the road and traffic conditions may be associated with the problems in dividing attention and slower speed of information processing reported in older drivers, including a decline in attentional abilities (such as selected and divided attention), and visuospatial skills.\textsuperscript{21-23} Many of these age-related cognitive declines have been linked with increased crash risk in older drivers, including reduced divided attention and visual processing speed,\textsuperscript{21, 24} deficits in memory function, visual perceptual skills, visual acuity, useful field of view and judgment.\textsuperscript{25} There is evidence to suggest that speed-of-processing training can improve visual attention and response times in at-risk older adults, which has been shown to translate into improved driver simulator performance and fewer dangerous manoeuvres during on-road driving evaluation.\textsuperscript{26}

When considering behaviors only required in specific situations, blindspot checking was more often neglected, where drivers failed to check their blindspot on 63\% of trials, with a considerable proportion of participants never, or only occasionally, making an appropriate blindspot check. Kay et al.\textsuperscript{18} also reported that their older drivers failed to check their blindspot when changing lanes. Failure to check blindspots can be related to difficulty in dividing attention between the forward view of the road and awareness of other vehicles beside and behind the
driver. It may also be due to reduced neck or upper body mobility.\textsuperscript{27} This has important implications for road safety as drivers are likely to have a reduced awareness of other traffic if they fail to check their blindspot appropriately and are unlikely to indicate their intentions to other road users when changing lanes. One potential and relatively cheap intervention is the fitting of blindspot mirrors,\textsuperscript{28} as well as in-vehicle devices which can warn drivers of the presence of other road users within the blindspot region.\textsuperscript{29}

Performance of participants was worst while pulling in and out or merging with traffic. Kay et al.\textsuperscript{18} have previously reported that lane changes are the most challenging situations encountered by older drivers. The present study also identified intersections as presenting a particular challenge for older drivers, as did Kay et al.,\textsuperscript{18} and it has been reported that older driver crashes commonly involve intersections.\textsuperscript{30} While there are some important differences between our study and that of Kay et al.,\textsuperscript{18} where their sample was younger (60-86 years) compared to ours (70-88 years) and included participants specifically recruited because they had eye problems, the finding of similar driving difficulties suggests that certain driving behaviors are problematic for older drivers generally.

Burns\textsuperscript{31} reported from a questionnaire-based study that way-finding and navigation become more difficult with age and this increased difficulty results in reduced mobility in the elderly. In our sample, older drivers also made more driving errors when they were required to find their own way to a particular location (self-directed navigation), rather than when the driving instructor gave them specific instructions (driver-instructed navigation). All driving behavior errors except gap selection and indicating were significantly higher in self-directed than driver-instructed navigation. This is in general agreement with Kline et al\textsuperscript{10} who found that older drivers report problems finding a particular traffic sign and making an appropriate manoeuvre in
time. These findings of self-navigation interfering with driving performance are also consistent with those for older drivers with visual impairment,\textsuperscript{13,14} and Parkinson’s Disease.\textsuperscript{32} Importantly, difficulties during self-navigation reflect problems in undertaking concurrent tasks, and may reflect deficits in executive function.\textsuperscript{25} It is possible that some of the drivers in our sample may have had some early cognitive changes that were not revealed by their MMSE score, however, they are a representative sample of older adults living independently in the community who drive regularly on our roads. Self-directed navigation conditions are also likely to better reflect the demands of normal driving, where the driver has to make strategic and tactical decisions about the driving environment and is actively engaged in multiple tasks involving visual scanning, divided attention, planning and judgment.

One quarter of the older drivers in this study reported having a crash in the previous five years. This value falls within the range reported in previous studies of older drivers which vary from 8\%\textsuperscript{33} to 45\% ,\textsuperscript{34} dependent on the sample characteristics (some samples were specifically recruited to have high state recorded crash data), as well as the time span over which the crashes were considered, ranging from the previous year\textsuperscript{33} to five years.\textsuperscript{34} A tenth of our drivers reported having a crash in the 12 months following the study visit.

Both the error rates for the driving behaviors and the number of instructor interventions were significantly associated with both self-reported retrospective and prospective crashes. This association is an important finding and provides important validation that what is being measured in an on-road assessment is linked with some aspect of driver safety. Self-reported crashes were used in this study because state crash records have been shown to represent no more than half (or even fewer) of the actual crashes reported in population-based samples of older drivers .\textsuperscript{35} Our findings are in general support of those of Keall and Frith\textsuperscript{36} who reported
among older drivers in New Zealand that a failing grade on a standardized on-road driving test was associated with a 33% increase in the odds of crash involvement (95% CI, 14% to 55%). Further studies which explore this relationship are required.

The finding that the number of instructor interventions made during self-navigation was significantly associated with self-reported retrospective and prospective crashes highlights the importance of including a self-navigation component in on-road driving assessments. It also suggests the potential for in-vehicle navigation systems which provide drivers with directions to a particular destination and avoids the difficulty that older drivers have in using road signs and markings to find their way. Research on older drivers and their identified co-pilots provides some support for this, where the presence of the co-pilot passenger was shown to be critical when travelling in unfamiliar areas, reducing driver cognitive load and decreasing anxiety levels.37

Importantly, many of the more common driving errors identified in this study can be potentially remediated through driver training and education, for example, errors involving visual attention can be improved through speed of processing training, and blindspot monitoring can be partly ameliorated through blindspot mirrors and in-vehicle technologies. These interventions have the potential to prolong the length of time that older adults can drive safely and thus maintain their independence for longer. However, there is evidence to suggest that driver education and training do not necessarily translate into reduced crash risk in older adults.38 Hence it is essential that the efficacy of any interventions for younger drivers be fully explored in studies of older drivers, rather than assuming that their benefits in younger drivers will necessarily apply to other age-groups.

In summary, our study highlighted the driving behaviors and situations with which a
cohort of community-dwelling older drivers had most problems. On-road driving performance was significantly associated with both self-reported retrospective and prospective crashes providing strong support for the practical driving assessment of older drivers. Indeed, it is worth considering on the basis of this, whether voluntary assessment by concerned older drivers should be encouraged, and where possible also reimbursed, since these driving assessments clearly have predictive validity in mitigating future crash risk. The findings also suggest that on-road assessments should include a self-directed component, as well as a directed component, as driving under self-directed navigation challenges the driver and highlights the potential problems faced under normal driving conditions. However, while the data provide strong support for the inclusion of on-road driving assessment in assisting the licensing decisions for older drivers, it is acknowledged that on-road assessments do have some limitations, including cost and safety. There is also the possibility that naturalistic observations under real world traffic conditions might lead to some imbalance in terms of opportunities for the various errors, potentially influencing the outcomes. These potential biases are, however, an inevitable limitation of any study conducted under real world conditions. Given that the underlying functional problems of older drivers predispose to certain kinds of driving errors, it would be worth investigating which specific behaviors are associated with different kinds of functional problems. Such knowledge could provide a basis for multi-tiered assessments in which on-road testing is targeted for those individuals who are likely to have specific problems, and obviate the need for mandatory assessment of all older drivers.\textsuperscript{39, 40}
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CONFLICT OF INTEREST

Financial Disclosure(s):

Joanne M. Wood: No conflict of interest

Kaarin J. Anstey: No conflict of interest

Philippe F. Lacherez: No conflict of interest

Graham K. Kerr: No conflict of interest

Kerry Mallon: No conflict of interest

Stephen Lord: No conflict of interest

Author Contributions:

Joanne M. Wood: Conceptualized and coordinated overall driving study, designed strategy for analyses, and was primarily responsible for writing of the manuscript.

Kaarin J. Anstey: Contributed to the conceptualization of the study, statistical analyses, and drafting of the manuscript.
Philippe F. Lacherez: Responsible for statistical analyses, interpretation and draft of results and assisted with manuscript preparation.

Graham K. Kerr: Contributed to the conceptualization and coordination of overall driving study and assisted with manuscript preparation.

Kerry Mallon: Assisted with design and implementation of driving assessment, performed assessments, and assisted with interpretation and preparation of the manuscript.

Stephen Lord: Assisted with the conceptualization and coordination of overall driving study and assisted with manuscript preparation.

Sponsor’s Role:

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REFERENCES

Table 1. Classification scheme for behaviors scored at each location during the drive. N represents the number of times the situation was encountered or behavior considered during a normal drive; signalling and blindspot checking behaviors are dictated by road conditions, and therefore vary between participants.

<table>
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<tbody>
<tr>
<td>Includes scanning, attention to signs and road markings and other road users. It also includes use of mirrors.</td>
<td>Designates that the driver used their directional indicator appropriately.</td>
<td>Designates that driver correctly performed shoulder checks for vehicles in the car’s blind-spot.</td>
<td>Refers to the speed of the manoeuvre, whether driving was over the marked speed limit or whether there was heavy, sudden braking without due cause. Errors</td>
<td>Refers to the position of the driver’s vehicle within the lane, or the lane in which the driver’s planning and preparation were appropriate to “buffer” driving</td>
<td>Refers to the gap between the driver’s vehicle and the one in front, (commonly known as the “buffer” driving</td>
<td>Designates that the driver’s planning and preparation were appropriate to a particular driving</td>
<td></td>
</tr>
<tr>
<td>Where applicable, i.e. lane changes, pulling in or out of traffic, blind spot observation must also be assessed and recorded.</td>
<td>also include driving with both feet on the pedals simultaneously or taking a corner within the marked speed limit but at a speed that is excessive for the conditions.</td>
<td>vehicle is located. For example, if the driver veers left or right instead of staying within the lane lines on a straight driving section or when cornering. Similarly, errors</td>
<td>zone”), or the gap selected by the driver when entering traffic, e.g. at an intersection or roundabout.</td>
<td>situation or manoeuvre.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
include the driver choosing to make a turn from the incorrect lane for that situation, turning into the incorrect lane or veering too close to the kerb or guttering.
<table>
<thead>
<tr>
<th>Situation Type</th>
<th>Traffic Light N = 36</th>
<th>One-way N = 14</th>
<th>Two-way N = 41</th>
<th>Give-way N = 31</th>
<th>Manoeuvring N = 9</th>
<th>Merging N = 17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negotiating an intersection with traffic lights.</td>
<td>Straight or curved driving in a road with 1-way traffic</td>
<td>Straight or curved driving in a road with 2-way traffic.</td>
<td>Entering traffic from an intersection at which there is a stop or give-way sign, or where there are no traffic lights, negotiating a pedestrian crossing, roadside shopping strip, or roundabout.</td>
<td>Executing a turnaround manoeuvre, driving through traffic slowing devices, negotiating a car park, or reversing.</td>
<td>Changing from one lane to another or merging into traffic, entering traffic from a turn-left-with-care intersection, or pulling into or out of traffic from the side of the road.</td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Demographic characteristics of the sample.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample (n)</th>
<th>270</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Mean ± SD)</td>
<td>75.85 (3.95)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>71%</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>29%</td>
</tr>
<tr>
<td>Number of years driving experience</td>
<td>21-30</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>31-40</td>
<td>7%</td>
</tr>
<tr>
<td></td>
<td>41-50</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>&gt;50</td>
<td>73%</td>
</tr>
<tr>
<td>How many kms would you drive per week?</td>
<td>&lt;10km</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>10-30km</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td>31-60km</td>
<td>21%</td>
</tr>
<tr>
<td></td>
<td>61-100km</td>
<td>22%</td>
</tr>
<tr>
<td></td>
<td>101-150km</td>
<td>21%</td>
</tr>
<tr>
<td></td>
<td>&gt;150km</td>
<td>28%</td>
</tr>
<tr>
<td>How often do you usually drive a car?</td>
<td>Less than</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>once/week</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Once/week</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>Twice/week</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td>3 times/week</td>
<td>4%</td>
</tr>
<tr>
<td>How often do you drive alone?</td>
<td>Never</td>
<td>Occasionally</td>
</tr>
<tr>
<td>------------------------------</td>
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</tr>
<tr>
<td>4-6 times/week</td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td>Every Day</td>
<td>46%</td>
<td></td>
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</tbody>
</table>
Table 3. Mean error rates for driving behaviors monitored during the assessment (standard deviation in brackets) for each of the driving conditions (driver-instructed versus self-navigation) and according to previous and prospective crash involvement.

<table>
<thead>
<tr>
<th>Navigation Condition</th>
<th>Participant Crash Status</th>
<th>Observation</th>
<th>Brake/accelerator</th>
<th>Lane position</th>
<th>Gap selection</th>
<th>Approach</th>
<th>Blindspot</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Driver-Instructed</td>
<td></td>
<td>1.05 (1.31)</td>
<td>1.48 (2.01)</td>
<td>1.07 (1.32)</td>
<td>1.61 (1.70)</td>
<td>0.047*</td>
<td>0.047*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.93 (2.92)</td>
<td>4 (4.04)</td>
<td>3.16 (3.16)</td>
<td>3.18 (3.56)</td>
<td>0.063</td>
<td>0.435</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.03 (2.42)</td>
<td>3.61 (3.44)</td>
<td>3.16 (2.72)</td>
<td>3.34 (2.23)</td>
<td>0.264</td>
<td>0.210</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.49 (1.38)</td>
<td>1.74 (1.54)</td>
<td>1.52 (1.41)</td>
<td>1.47 (1.28)</td>
<td>0.165</td>
<td>0.386</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.82 (2.37)</td>
<td>3.67 (3.58)</td>
<td>3.01 (2.59)</td>
<td>2.74 (2.69)</td>
<td>0.132</td>
<td>0.309</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>57.84 (19.68)</td>
<td>63.93 (17.54)</td>
<td>58.43 (19.71)</td>
<td>64.13 (16.73)</td>
<td>0.022*</td>
<td>0.110</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.63</td>
<td>13.41 (5.00)</td>
<td>13.53 (7.64)</td>
<td>13.62 (4.66)</td>
<td>0.345</td>
<td>0.187</td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Mean</td>
<td>Lower CI</td>
<td>Upper CI</td>
<td>p-value</td>
<td>* p &lt; .05 (one-tailed)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>-------------------</td>
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<td>----------</td>
<td>---------</td>
<td>------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-Navigation</td>
<td>(8.00)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td>2.45 (3.47)</td>
<td>4.02 (4.56)</td>
<td>2.66 (3.63)</td>
<td>4.68 (5.08)</td>
<td>0.006*</td>
<td>0.006*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brake/accelerator</td>
<td>3.67 (4.56)</td>
<td>6.01 (7.48)</td>
<td>4.27 (5.20)</td>
<td>4.13 (4.89)</td>
<td>0.021*</td>
<td>0.464</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane position</td>
<td>8.66 (6.74)</td>
<td>10.31 (7.94)</td>
<td>9.01 (7.01)</td>
<td>9.78 (8.07)</td>
<td>0.117</td>
<td>0.391</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gap selection</td>
<td>1.83 (2.90)</td>
<td>1.93 (2.51)</td>
<td>1.86 (2.85)</td>
<td>1.98 (2.66)</td>
<td>0.293</td>
<td>0.356</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach</td>
<td>6.24 (6.35)</td>
<td>8.41 (7.17)</td>
<td>6.65 (6.44)</td>
<td>7.84 (6.37)</td>
<td>0.007*</td>
<td>0.139</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blindspot</td>
<td>64.18 (26.71)</td>
<td>69.12 (21.62)</td>
<td>65.38 (25.59)</td>
<td>67.47 (24.04)</td>
<td>0.179</td>
<td>0.393</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indicator</td>
<td>5.91 (9.86)</td>
<td>5.82 (7.50)</td>
<td>6.10 (9.82)</td>
<td>4.96 (5.76)</td>
<td>0.474</td>
<td>0.404</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* \( p < .05 \) (one-tailed)
Table 4. Mean error rates for driving situations encountered during the assessment (standard deviation in brackets) according to previous and prospective crash involvement

<table>
<thead>
<tr>
<th>Participant Crash Status</th>
<th>No Crash History</th>
<th>Crash History</th>
<th>No Prospective Crash</th>
<th>Prospective Crash</th>
<th>Crash vs No Crash History</th>
<th>Prospective Crash vs No Crash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situational Type</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Significance</td>
<td>Significance</td>
</tr>
<tr>
<td>Traffic Light</td>
<td>9.5 (6.73)</td>
<td>11.71 (7.58)</td>
<td>10.05 (7.16)</td>
<td>9.72 (6.23)</td>
<td>0.02*</td>
<td>0.47</td>
</tr>
<tr>
<td>One-way</td>
<td>17.28 (17.43)</td>
<td>22.13 (17.58)</td>
<td>18.83 (17.54)</td>
<td>17.2 (17.73)</td>
<td>0.01*</td>
<td>0.29</td>
</tr>
<tr>
<td>Two-way</td>
<td>6.69 (6.79)</td>
<td>8.44 (8.32)</td>
<td>7.08 (6.83)</td>
<td>7.59 (8.74)</td>
<td>0.06</td>
<td>0.47</td>
</tr>
<tr>
<td>Give-way</td>
<td>19.3 (8.08)</td>
<td>21.27 (9.18)</td>
<td>19.57 (8.09)</td>
<td>19.09 (8.75)</td>
<td>0.10</td>
<td>0.33</td>
</tr>
<tr>
<td>Manoeuvring</td>
<td>34.69 (18.35)</td>
<td>35.93 (20.34)</td>
<td>35.05 (18.00)</td>
<td>35.34 (23.33)</td>
<td>0.49</td>
<td>0.46</td>
</tr>
<tr>
<td>Merging</td>
<td>71.3 (17.53)</td>
<td>76.18 (15.78)</td>
<td>71.91 (17.59)</td>
<td>75.81 (14.7)</td>
<td>0.03*</td>
<td>0.17</td>
</tr>
</tbody>
</table>

* $p < .05$ (one-tailed)
Figure 1: Mean percentage error rate for instructor interventions as a function of navigation type for those who reported a crash during the 12 month follow up period, compared to those who did not. In the driver-instructed condition the driving instructor provided detailed instructions of the route. In the self-directed navigation, the participant had to find their own way to a given destination. Error bars are +1 standard error.
Percentage of instructor interventions to total locations

Error rate (proportion)

Navigation type

Driver Instructed

Self-Navigation

No Crash

Crash