The Use of a Naturalistic Driving Route for Characterizing Older Drivers

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Abstract

Although the vast majority of older drivers are safe, there are some older drivers who are at risk of crashes due to health-related changes in functional status. For licensing agencies worldwide it is a challenge to identify unsafe older drivers. One form of older driver assessment that can be done conducted is an on-road test. Often this occurs in an unfamiliar vehicle and on roads that are not familiar to the older driver. This could be detrimental to their driving performance and lead to an overestimation of their crash risk. **Purpose**: The purpose of the current study is to determine whether the route used for the Driving Observation Schedule (DOS), a specific driving task designed to observe and record driving performance, is actually representative of older drivers' everyday driving in Melbourne Australia. This is a sub-study of the Ozcandrive study, which is a partner study to Candrive. **Methods**: Older drivers (75+ years old) were asked to describe locations where they typically drive. A route was then devised to incorporate those locations, and the older driver was observed for their driving behaviours over this route. Older drivers' vehicles were equipped with a device that monitored their driving locations by global positioning system (GPS) technology at 1 Hz. These same older drivers were followed over several months for their everyday driving using the same device. All trips made were compared for their location against the DOS route. These results were then expressed as a percentage of the trips that included a road from the DOS route, in order to determine how representative the DOS route was of each older drivers' everyday driving. In addition to location, speed patterns were also compared between the DOS route and everyday driving. **Results**: The average distance of the DOS route was 13.8 ± 5.3 km, and on average it took 31.0 ± 7.6 minutes to drive, for the 23 older drivers that were included in the sample for this study. Over the 108 ± 18 days whereby the older drivers were monitored for their everyday driving, the older drivers drove 2384 ± 1504 km, and made 385 ± 155 trips. The roads that were part of the DOS route represented 9 ± 8 percent of roads that were used during the everyday driving trips. The DOS route and driving was similar to everyday driving in terms of speed limits of the roadways, exceeding the speed limit, and speed of driving. Drivers spent the majority of time driving on roadways that had speed limits of 50 and 60 km/hr (DOS = 80.4%, everyday = 74.1%). There was a slight

trend for everyday driving to be on roadways with faster speed limits and have faster driving than DOS driving. **Conclusions**: These results suggest that a route can be formulated that will be representative of most of the everyday driving of older drivers. Use of such a route has promise for determining the performance of older drivers under conditions which are typical for their everyday driving. Future research that combines driving behaviour observation, crash data, naturalistic driving as well as health and functional testing for individual older drivers will do much to provide more definitive information about this growing cohort of drivers.

INTRODUCTION

One target group for many road safety initiatives is the older driver. Due to health- and/or age-related changes in functional ability, they may be at increased risk for crashing [1]. Population based collision data have often shown that older drivers have an increased risk for both serious injury and fatality crashes, as compared to middle-aged drivers, when driving exposure is considered [1]. Although it has been speculated that a low mileage bias may influence these statistics [2], there are certainly individual older drivers who no longer possess the ability to drive safely and may be unaware of their poor abilities [3]. Correctly identifying older drivers who are unsafe is challenging for licensing authorities around the world.

The standard means of assessing medical fitness to drive when ability is questioned includes both off-road assessments of driving-related abilities, and on-road tests of actual driving performance [4]. On-road tests usually involve the driver driving with examiners in the vehicle and a standardized route. Although the validity of these tests have not been determined in terms of predicting crashes, they are usually considered to be the gold standard, for driving rehabilitation specialists, licensing authorities, and researchers alike, in determining actual driving abilities. Quite often though, these tests require drivers to drive unfamiliar vehicles in unfamiliar locations and circumstances. It has been previously reported that driving an unfamiliar vehicle may put drivers at a disadvantage, and therefore hamper their ability to perform well [5]. A similar case could be made for asking drivers to drive on roads that are unknown to them. For example, examining an older driver on a route that includes highways and urban situations, when they habitually restrict their trips to their local suburban area, may provide an underestimate of their actual driving abilities, and overestimate their crash risk for their everyday driving.

An alternative and perhaps more ecologically valid means of determining older drivers' everyday driving behaviours could be designed. To this end, part of the Ozcandrive project involved the development of a Driver Observation Schedule (DOS), whereby older drivers drove their own vehicles on roads that were part of their familiar driving environment [6]. Ozcandrive is a companion project to Candrive (Canadian Driving Research Initiative for Vehicular Safety in the Elderly). This longitudinal project involves collecting the everyday driving patterns of all participants using in-vehicle recording devices. Given the vehicle and global positioning system (GPS) data collected, each trip for every driver can be characterized by location, speed, speed limit, duration and distance.

The purpose of the current study was to conduct a preliminary investigation of the validity of the DOS route, in terms of the representativeness of the routes selected and driven by each older driver in the sub-study. This was achieved by comparing the DOS route's characteristics to several weeks of typical driving for each participant. In addition, we were also interested in exploring whether the driving behaviour of participants would be similar during the DOS as compared to their everyday driving. To do this we examined their driving speeds and level of compliance with speed limits.

METHODS

Participants

A sub-sample of 30 participants from the Ozcandrive study participated in the Driver Observation Schedule (DOS) study [6]. In order to be eligible for the Ozcandrive study drivers had to be: 75 years or older, have a valid driver's licence, reside within 50 km of the test site in Melbourne, be an active driver (at least 4 days a week), and not have any medical condition that would preclude having a driver's licence.

Equipment

All participants' vehicles were outfitted with a device (Persentech Inc, Winnipeg, Canada) to record their driving at 1 Hz, during the DOS and for several weeks during their typical everyday driving. The device included a GPS receiver, a memory card to store data, and a central unit which communicated with the vehicle through the on-board diagnostics (OBDII) port. For participants who were not the sole driver of the vehicle, a radio frequency antenna and identification fob were also installed in order to be able to identify the trips made by the participant. See Figure 1 for a schematic diagram of the components.

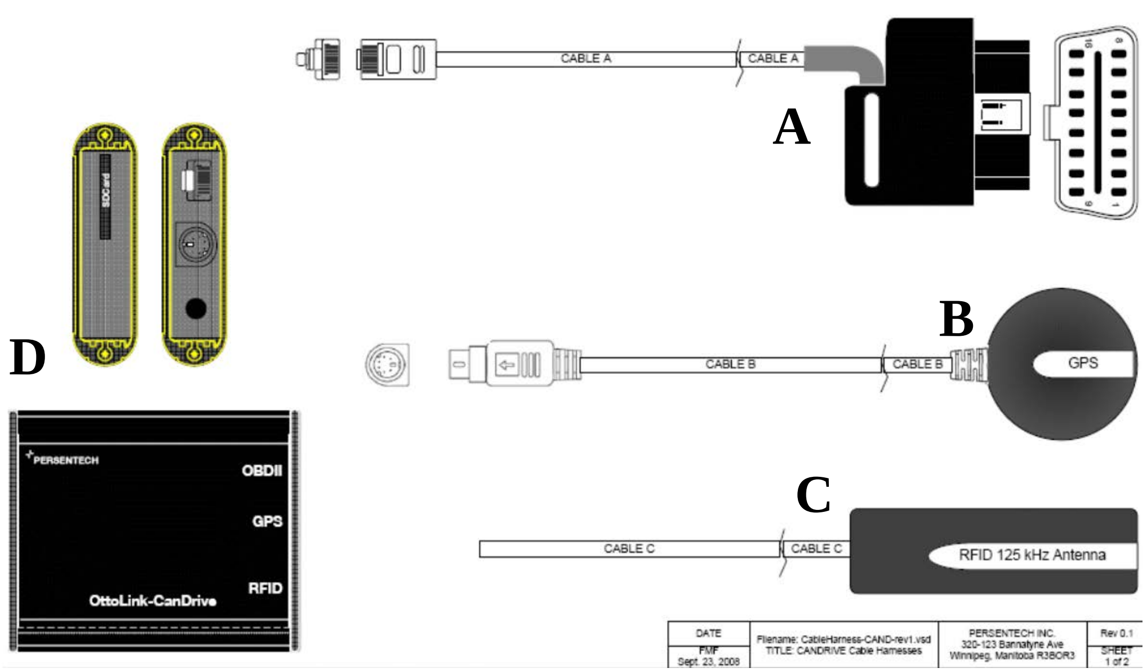

Figure 1. A schematic of the in-vehicle recording device components, where A is the plug for the on-board diagnostics (OBDII) port, B is the global positioning system (GPS) receiver, C is for the radio frequency identification (RFID) antenna, and D shows the main device where all inputs and memory card reside.

Driver Observation Schedule

The DOS was designed to commence from participants' homes and was conducted on roads familiar to and chosen by participants, to three to four nominated locations within their local area [6]. Whilst the driving route was not standardised, the DOS allowed for standardised documentation of driving behaviours (both inappropriate and appropriate) by in-vehicle observers (not reported here).

Data Analyses

Each memory card contained a file which was processed using Candrive DTS software (Persentech Inc, Winnipeg, Canada). This resulted in several files being extracted: a second by second file of all trips, a Google Earth mapping file containing all trips (see Figure 2), and a file whereby each trip was summarized in terms of duration and distance. In this case, a trip can be defined as each instance whereby the ignition was started until the vehicle was turned off with the ignition. Prior to analysing the characteristics of the trips, all participant data files needed to have the following filtered out: GPS noise, trips taken by other drivers, trips to and from the testing centre, and trips that were idling only). At this stage it was discovered that 7 participants had technical issues which meant that their data could not be used. This was due to: 1) the radio frequency device not identifying other driver trips properly (n = 6), and 2) missing data due to technical issues (n = 1).

Figure 2. A) Trip locations visualized using Google Earth. The blue line denotes the entire driver observation schedule (DOS) trip, the green line shows all everyday driving trips, and the red circles identify locations where counts were taken. B) This is a closer view of A whereby the DOS route can be seen overlaid on multiple everyday trips. The white circles indicate locations where counts were taken.

In order to determine whether the typical everyday driving of each participant was similar in terms of location to the route driven for the DOS, the DOS route was superimposed on the Google Earth map of everyday driving for each participant (see Figure 2). Then locations were examined where the DOS route coincided with a trip taken during everyday driving. Counts of the number of trips were taken at several points on different road segments. From the counts we then calculated the proportion of the total trips that used that particular roadway.

The number of trips a participant had taken along a road segment outlined by their respective DOS route, a point in circle method was applied to the participant's second by second data for the each road segment. Since the second by second data was in chronological order and labelled in terms of a specific trip number, this allowed the number of trips along a segment to be obtained by the following steps.

A point representing latitude and longitude (lat, lon), was selected in the centre of the road. This became the origin of the circle for a particular segment; another point was selected at the edge of the road (lat_r, lon_r) where the origin and this second point form the radius of the particular segment. This was then used following equation 1,

$$a(i)_j = \begin{cases} 1 & (u_i - lat_j)^2 + (v_i - lon_j)^2 \leq (lat_j - lat_{r_j})^2 + (lon_j - lon_{r_j})^2 \\ 0 & (u_i - lat_j)^2 + (v_i - lon_j)^2 > (lat_j - lat_{r_j})^2 + (lon_j - lon_{r_j})^2 \end{cases} \tag{1}$$

Where i = 1..N as the number of points in the second by second file, u_i and v_i are the latitude and longitude point in the second by second file and j is the particular road segment, where j = 1..M where M is the number of segments. This creates a list a_j where each element corresponds to either 1 being in the road segment and 0 being outside the road segment. The list, a_j, then can be broken into sublists (Figure 3), where each sublist represents the labelled trip number. In each sublist, a group of 1s represents a trip through the particular segment and these groupings can be summed from each sublist to give the total number of trips through a particular segment.

$$\text{second by second summary} \begin{cases} \quad Time & 0\ 1\ 2\ 3\ 4\ 5\ 6\ 7\ 9\ \ldots\ 21\ 22\ 23\ 24\ 25\ 26\ 27 \\ \quad Trip & \boxed{0\ 0\ 0}\boxed{1\ 1\ 1}\boxed{2\ 2}3\ \ldots\ \boxed{20\ 20\ 20\ 20\ 20\ 20\ 20} \\ Latitude & \ldots \\ Longitude & \ldots \end{cases}$$

$$a(i)_j = \boxed{0\ 0\ 0}\boxed{1\ 1\ 1}\boxed{1\ 1}0\ \ldots\ \boxed{0\ 1\ 1\ 0\ 1\ 1\ 0}$$

Figure 3. The sum of trips for a road segment, j. The highlighted regions represent trips (sublists of $a(i)_j$). The orange sublist, trip 0, represents a trip in which the participant did not drive along the segment. The red and blue sublists, trips 1 and 2, represent trips in which the participant did not leave the road segment. The green sublist, trip 20, represents a case where the participant drove along the road segment twice in one trip. This represents a road segment where the participant drove a total of four times.

Statistical Analyses

In order to determine whether the roadways used during DOS were representative of the roadways where participants typically drove, we calculated a percent usage (counts / total number of trips x 100) for each roadway from everyday driving that coincided with the DOS route. For each participant we then recorded the median value for all roadways in terms of percent usage, instead of the mean, because the data were not normally distributed (see Figure 4 for an example of one participant's data).

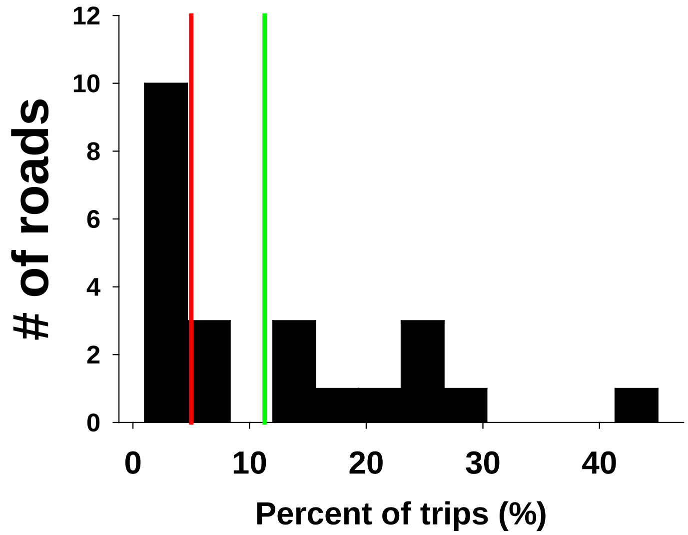

Figure 4. Distribution of trips made by one participant during everyday driving that also occurred on roadways of the DOS route. The red line is the median, the green line is the mean.

We also examined the distance and duration of the DOS route compared with everyday driving trips, using paired t tests.

The types of roadways used during everyday driving were also compared to the DOS route, to see how similar they were. The speed limits of the roadways were used to categorize the types of roadways. For each speed limit (40, 50, 60, 70, 80, 90, 100 km/hr), the percent of total driving time was calculated. Then a two way repeated measures analysis of variance (ANOVA) was performed, with speed limit of the roadway as one factor and type of driving (DOS versus everyday) as the other factor. Two other comparisons were made between the DOS route and everyday driving for the actual speeds driven and the amount of exceeding the speed limit. For driving speed the percent of total driving time driven at specific speed categories was calculated. For this analysis, a repeated measures ANOVA was performed, with the speed category as one factor and type of driving (DOS versus everyday) as the other factor. Across all speed data points for the DOS route and everyday driving the percent of the total time above the speed limit, by 5 km/hr or 10 km/hr, was calculated. A repeated measures ANOVA was performed, with the extent of speeding as one factor and type of driving (DOS versus everyday) as the other factor.

For all ANOVAs performed, post hoc tests were done using the Holm-Sidak method. Significance was deemed to be met when $p < 0.05$.

RESULTS

The DOS route ranged from 5.5 to 26.3 km (13.8 ± 5.3 km), and took 16.2 to 45.0 minutes (31.0 ± 7.6 minutes) to complete. Everyday driving was collected over 75 to 133 days. Over that time participants made 385 ± 155 trips, with an average distance of 6.5 ± 3.0 km, and an average duration of 13.8 ± 4.1 minutes. The difference in distance and duration between the DOS and everyday driving trips was significant ($p < 0.0001$). The number of roadways which were common across the DOS route and everyday driving for each participant ranged from 4 to 24. The trip utilization of DOS roadways in everyday driving ranged from 2 to 41% across the participants, with a mean value of 9 ± 8% for the group.

The vast majority of time during everyday driving was spent on roadways with speed limits of 50 km/hr (38 ± 15 %) and 60 km/hr (37 ± 16 %) (i.e., residential streets). The same was true for the DOS route, with values of 42 ± 16 % and 39 ± 18 %, for 50 and 60 km/hr, respectively (see Figure 5). The differences between the DOS route and everyday driving were significant ($p < 0.05$) for 50 km/hr (DOS > everyday) and 80 km/hr (everyday > DOS), but no significant differences were found for 40, 60, 70, 90 and 100 km/hr speed limit roadways.

We also examined the amount of time drivers were exceeding the speed limit, and found that the mean percent of driving time that the participants drove over the speed limit was greater during everyday driving than during the DOS route, both for 5 km/hr and 10 km/hr over the speed limit ($p<0.05$). The values were 0.8 % versus 2.6 % for 5 km/hr over the speed limit for the DOS and everyday driving. For 10 km/hr the values were 0.3 % versus 1.4 % for the DOS and everyday driving.

As can be seen in Figure 6, participants drove at 40-50 km/hr for a greater proportion of time for the DOS route compared with everyday driving trips ($p< 0.05$). There were no significant differences between the DOS route and everyday driving trips for any other speed categories.

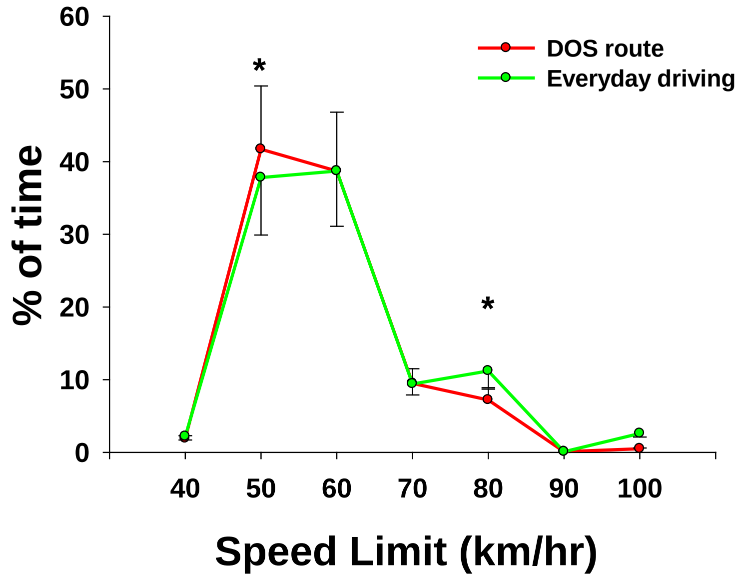

Figure 5. The percent of time driving (mean ± SE) on roadways with different speed limits for the Driver Observation Schedule (DOS) route and everyday driving (* $p < 0.05$).

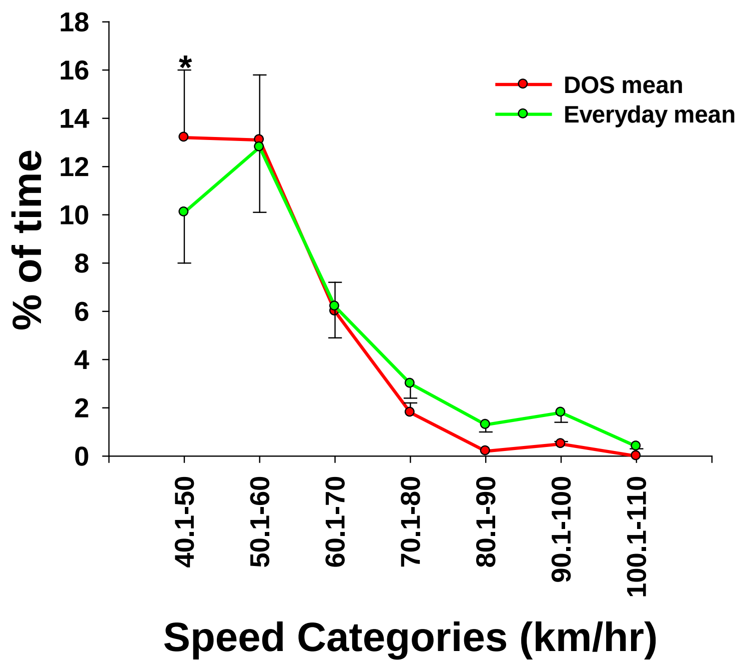

Figure 6. The percent of time (mean ± SE) , spent travelling at different speeds for the Driver Observation Schedule (DOS) route and everyday driving (* $p < 0.05$).

CONCLUSIONS

The purpose of this study was to examine the characteristics of the DOS route as compared to everyday driving for a sub-group of older drivers in the Ozcandrive study. The main impetus for designing the DOS was to provide an ecologically valid way to characterize the driving behaviours of older drivers. The preliminary data provided in this paper showed that the roadways used in the DOS were often used by older drivers in their everyday driving. Although the DOS route was longer in both duration and time than trips during everyday driving, this was expected as the DOS was designed by combining several typical destinations into one route. In future, the focus of analyses will be on the first and the last portion of the DOS route, as these are likely to be more representative of everyday short trips made to and from home, rather than the locations in between where we artificially created linkages that may not be typical of everyday driving.

Both the DOS route and everyday driving were done primarily on roadways with speed limits of 50 or 60 km/hr, on average 80.4% vs 74.1% respectively. There was a significant difference between DOS and everyday driving in the actual percent values, but this could potentially be explained by longer trips taken on highways or other roadways with higher speed limits during everyday driving. These long trips, of course, could not be part of the DOS route, by design.

Exceeding the speed limit was also significantly different between the DOS and everyday driving, with more 'speeding' occurring during everyday driving. A possible explanation for this finding could be that during the DOS, when observers were in the vehicle, the participants were more vigilant in driving at or below the speed limit. Notably though, across all the drivers, most were very seldom driving above the speed limit, and the extent of 'speeding' that we examined was very low (on average < 3 % of driving time).

For the actual speeds that were driven on both the DOS and during everyday driving, there were only two instances where there were significant differences. Similar to the above findings, there was a trend for the DOS to be characterized by slower driving than everyday driving. Again, a possible explanation could be related to slight differences in the types of roadways used in the DOS compared to everyday driving. Because the DOS route was relatively short, approximately half an hour, it would not be expected that the DOS route would be representative of all the driving that an older driver would undertake over several weeks.

Overall the results of the current study demonstrate that the DOS route and older drivers' driving during the DOS route were quite similar to their everyday driving. Therefore, the DOS appears to provide an ecologically valid way to characterize the driving of older drivers.

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