

EFFECTS OF FAMILIARITY AND AGE ON DRIVER SAFETY ERRORS DURING WAYFINDING

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Summary: Wayfinding is a critical skill that enables drivers to navigate from one location to another. Wayfinding abilities decline as individuals age, which may increase older driver reliance on directional cues (e.g. signs) and divert cognitive resources at the expense of vehicle control and safety. Familiarity with an environment can facilitate wayfinding due to previous knowledge of the route. This study examines the role of familiarity in driving safety errors committed during a wayfinding task. Results suggest that age-related driving difficulties can be lessened by familiarity with the environment. The results underscore the need to consider geographical license restrictions in administrative policies aimed at improving older driver safety.

INTRODUCTION

Driving a vehicle is the primary form of transportation for older drivers in the United States (Kostyniuk & Shope, 1999). With age, many navigational tasks necessary for driving, such as route learning and wayfinding, become more difficult (Barrash, 1994; Burns, 1998; Burns, 1999; Head & Isom, 2010; Iaria, Palermo, Committeri, & Barton, 2009; Wilkniss, Jones, Karol, Gold, & Manning, 1997). Wayfinding involves both the determination of a path between an origin and destination and the execution of actions necessary to follow that path (Golledge, 1999). Drivers of all ages must access a route from memory while successfully navigating the road. The difficulty of older drivers in successfully carrying out these tasks is likely to be related to aging declines in neural processes essential to navigation (Dobson, Kirasic, & Allen, 1995; Light & Zelinski, 1983; Moffat, 2009; Moffat, Zonderman, & Resnick, 2001). Drivers of all ages must concentrate on identifying signs relevant to route navigation tasks (e.g. street names) while staying alert to traffic signs relevant to safety in an unfamiliar environment (Musselwhite & Haddad, 2010). Since attention is a finite commodity, more attention given to sign identification means less attention to driving performance. This leaves elderly individuals at risk for making unsafe errors on the road (de Ridder, Elieff, Diesch, Gershenson, & Pick Jr., 2002). It is not uncommon for elderly drivers to report looking for signs, such as street signs, prior to an accident occurring (Rothe, Cooper, & de Vries, 1990). Research also suggests however, that knowledge of the environment has a positive impact on performance in wayfinding tasks. Individuals who report being familiar with a surrounding were more accurate in wayfinding than those who report being less familiar (Prestopnik & Roskos-Ewoldsen, 2000). Familiarity also helps negate effects of complex environments on wayfinding abilities (O'Neill, 1992).

Studies to date on wayfinding and navigation have primarily relied on self-reports (e.g. Burns 1998; Prestopnik & Roskos-Ewoldsen, 2000) and/or virtual environments in laboratories (Head & Isom, 2010; Wilkniss et al., 1997). Such studies provide suggestive evidence of links between

driving performance and skills associated with spatial reasoning, navigation, and wayfinding. In this study, we examined actual ability to navigate through a learned route while driving on the road in an instrumented vehicle (IV).

The current study aimed to examine navigational behavior in an elderly population compared to middle-age drivers. We hypothesized that elderly individuals make more navigational (e.g., wrong turns) and driving errors (e.g., speeding) while completing an on-road drive along a prescribed route compared to middle-age drivers. We also hypothesized that familiarity of the driver with the route and level of neurocognitive functioning (cognitive, motor, and visual sensory) are associated with better driving performance, such as fewer safety errors, while navigating through the route.

METHOD

Subjects

Subjects were 105 elderly drivers (ages 65 - 89, mean age 72.2) and 88 middle-age drivers (ages 40-64, mean age 57.0). Participants were recruited from the Iowa City area through advertisements in local newspapers, public services announcements, and visits to senior centers, and churches. All possessed a valid driver's license and were currently driving. Criteria for exclusion included brain lesions, stroke, vestibular disease, motion sickness, alcoholism, and diagnosed neurological or psychiatric diseases, including depression. Informed consent was obtained following guidelines of the Institutional Review Board of the University of Iowa.

Neuropsychological Battery

Cognitive, motor, and visual skills were assessed using a battery of tests, as described in Dawson, Uc, Anderson, Johnson, and Rizzo, 2010.

On-Road Drive Test

The on-road drive was conducted in the Automobile for Research in Ergonomics and Safety (ARGOS). This approximate 45-minute drive was conducted in Iowa City and the surrounding areas. Videos taken by on-board cameras (Rizzo, McGehee, Peterson, & Dingus, 1997) were reviewed by a professional driving instructor, who counted the number type, and location of safety errors made by each driver, as detailed in (Dawson, Rizzo, Anderson, Dastrup, & Uc, 2009b). For this report, we focused on the total number of safety errors made during the navigation task.

Route-following task. While parked, participants were given navigation instructions verbally and were required to recite the directions twice correctly before the drive commenced. The instructions stated: 1) From the main hospital entrance, turn left onto Hawkins Drive; 2) Right onto Melrose Avenue; 3) Left on Koser Avenue; 4) Left on George Street. The route was approximately one mile in distance. Subjects were informed the experimenter would not give the directions again once the task had begun. After completing a correct turn, subjects were informed they had made a correct turn. After a navigational error, participants were allowed to drive for

approximately one block before the experimenter informed them of their error and were instructed to correct the error. If the subjects were unable to find their way back to the route, the experimenter repeated the initial directions. During the drive, the experimenter kept track of the number of navigation errors, and whether or not the subject had to be told that they were off course. After completing the task, subjects were asked about their familiarity with the driven area using a standard question coded as yes or no.

Predictor Variables and Outcomes

Predictor variables included demographics (age, education, frequency of driving, and familiarity with the route), cognitive tests, visual tests, and motor tests. A composite measure of cognition (“Cogstat”) was calculated based on adding standardized cognitive scores (each with mean 50 and standard deviation of 10, with high values representing better cognition). This approach has been used by us in previous studies of elderly and impaired drivers (Dawson, Anderson, Uc, Dastrup, & Rizzo, 2009a; Dawson et al., 2010). Four outcome measures were considered: 1) The number of navigation errors made, (dichotomized as at least one versus zero), 2) Whether or not the subject got lost (i.e., the driver did not recognize that a navigation error had been made), 3) The amount of time required to navigate this section of the course, and 4) The number of safety errors committed by the driver during this task. Note that the first three of these outcomes are measures of task performance, while the fourth is a measure of driving safety. Those four measures were combined into an overall composite such that high scores represented worse performance (using procedures similar to those used to develop the “Cogstat” composite).

Statistical Analyses

Descriptive statistics of predictor variables and outcomes were calculated, stratified by age group (elderly vs. middle age). Comparisons between groups of numeric variables were made using the Wilcoxon-Mann-Whitney rank-sum statistic to ensure robustness to any departure from normality; dichotomous outcomes were compared using Fisher’s exact test. The four numeric outcomes (amount of time required, the number of safety errors made, and the composite) were analyzed using locally-weighted regression plots (a.k.a., loess curves [Cleveland and Devlin, 1988]) to assess the effects of age across groups. Within the elderly group, we used linear and logistic regression to test for the effects of demographic, cognitive, visual, and motor variables on the four individual outcomes and on the driving composite score.

RESULTS

Table 1 presents means (SDs) of numeric variables and percents of dichotomous variables within each age group, along with the comparison p-values. The age groups were similar with respect to education, gender, driving frequency, and driving distance. The elderly drivers may have been less familiar with the route, but this was not significant. The elderly drivers had worse scores on many of the cognitive, vision, and motor tests. In the route-following task outcomes, elderly drivers made more safety errors, appeared to make more navigation errors, and took longer to complete the task. Very few drivers got lost during the task. The elderly drivers did worse overall in performance and safety, as measured by the driving composite score. Figure 1 shows how the average driving scores got worse with age. Note that the majority of the drivers were clustered at

fairly low levels, but several had scores upwardly skewed. Because of this lack of normality, we applied the logarithmic transformation, but found that our results were similar in the original and log scales.

Table 1. Descriptive statistics and between-group comparisons

Variable	Middle-age (n=77)	Elderly (n=105)	P-value
Demographics			
Age (years)	57.0 (6.9)	72.2 (5.1)	<0.001
Education (years)	15.7 (2.3)	16.0 (2.6)	0.306
Male gender	45.6%	54.3%	0.294
Driving frequency (days/wk)	6.1 (1.4)	6.2 (1.2)	0.733
Driving distance (miles/wk)	134 (117)	155 (184)	0.875
Familiar with route	88.2%	78.6%	0.109
Cognitive tests			
CFT-copy	31.2 (3.5)	31.2 (3.8)	0.752
CFT-recall	16.8 (6.2)	15.2 (5.2)	0.0973
Block design	43.7 (9.9)	38.4 (10.1)	<0.001
BVRT errors	3.8 (2.1)	4.6 (2.5)	0.058
Trails-B (sec)	67.5 (25.2)	86.2 (40.4)	<0.001
AVLT Recall	11.3 (2.8)	9.6 (3.3)	<0.001
Judgment of Line Orientation	27.2 (2.6)	25.9 (3.7)	0.031
COWA	41.6 (11.4)	37.0 (10.2)	0.006
Cogstat composite	429 (40)	400 (43)	<0.001
Vision tests			
UFOV total	484 (209)	701 (198)	<0.001
Contrast sensitivity	1.89 (0.12)	1.79 (0.16)	<0.001
FVA (logmar scale)	-0.13 (0.10)	-0.04 (0.11)	<0.001
NVA (logmar scale)	0.01 (0.03)	0.02 (0.04)	0.066
Structure from motion	10.3 (3.0)	10.2 (2.7)	0.665
Motor tests			
Functional reach (in)	13.9 (2.5)	12.5 (2.7)	<0.001
Get-up-and-go (sec)	8.3 (1.4)	9.2 (2.6)	0.012
Grooved pegboard (sec)	72.3 (10.7)	90.9 (16.9)	<0.001
Route-following task outcomes			
1 or more navigation error	9.1%	20.0%	0.060
Getting lost	1.3%	6.7%	0.141
Time to completion (min)	3.0 (0.9)	3.3 (1.3)	0.085
Safety errors	3.5 (1.6)	4.6 (2.8)	0.005
Driving composite score	189 (18)	200 (30)	0.007

When looking for associations between our predictor and outcome variables, we focused first on our driving composite score outcome, in order to reduce the chances of Type I errors due to multiple testing. For this outcome, none of the neuropsychological test scores were significant predictors; however, drivers who were familiar with the route scored 33 points better on the

driving composite than those who were unfamiliar ($p < 0.001$). Looking at individual outcomes, the familiar drivers were less likely to make a navigation error (OR=0.12; 95% CI 0.04 to 0.36; $p < 0.001$), were less likely to get lost (OR=0.04; 95% CI 0.01 to 0.39; $p = 0.005$), took longer to complete the task (1.2 minutes; 95% CI 0.7 to 1.8; $p < 0.001$); and had a tendency to make more safety errors ($p = 0.094$).

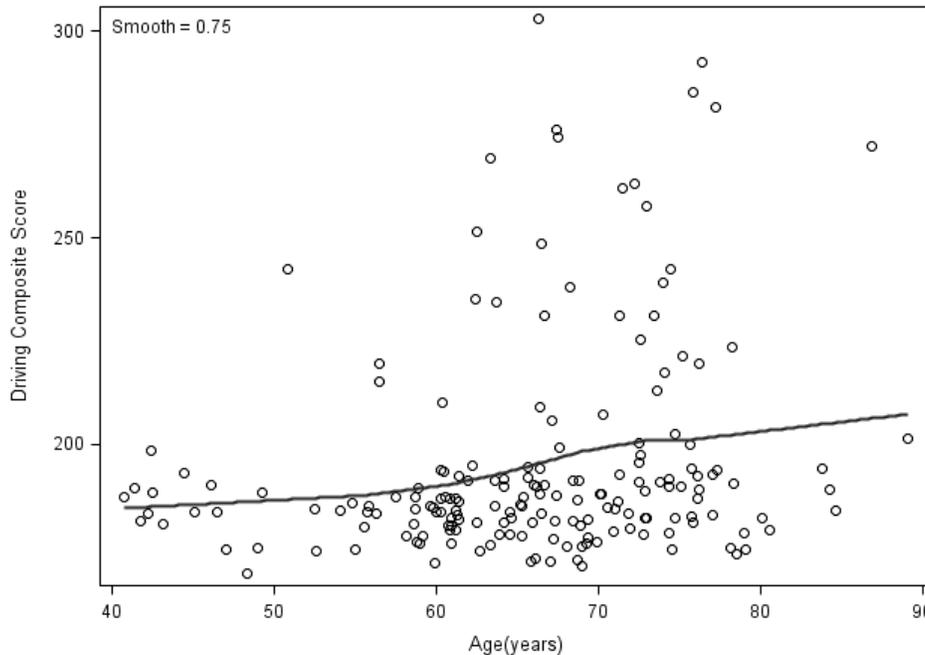


Figure 1. Locally-weighted regression (“loess”) plot of the driving composite score across ages

DISCUSSION

Elderly individuals comprise an ever-increasing proportion of drivers and are expected to contribute to growing numbers of crashes (Evans, 2000; Lyman, Ferguson, Braver, & Williams, 2002). Studies relying on self-report and virtual environment methodologies have shown that elderly have greater difficulty negotiating the demands of route learning and wayfinding (Barrash, 1994; Head & Isom, 2010; Moffet et al., 2001; Wilkniss et al., 1997). The current study investigated whether driving performance of elderly significantly differed from middle-aged drivers during an actual on-road driving test while navigating through a learned route. In this experiment the route directions were presented by auditory verbal means until the driver could learn the route to criterion, similar to the ecological situation in which a driver obtains information when asking for directions while driving. The results showed that elderly performed more poorly than middle-aged drivers while trying to navigate to a destination (de Ridder et al., 2002; Rothe et al., 1990). For example, elderly drivers made more safety errors while driving through the route, tended to make more navigation errors and took longer to complete driving through the route.

Findings also showed that elderly performed worse than middle-aged drivers on many of the cognitive, motor and vision tests consistent with earlier studies (Dobson et al., 1995; Iaria et al., 2009; Moffat, 2009; Moffat et al., 2001; Wilkniss et al., 1997). Furthermore, familiarity of

drivers, young or old, was associated with better performance. However, neuropsychological functioning did not account for unique additive variance in driving performance during the navigation task over and above familiarity and age. It is possible that because majority of drivers were familiar with the route, we had reduced power to detect the effects of neuropsychological functioning on driver performance during the navigation task. Given that we have shown neuropsychological functioning to be relevant to driving performance in previous studies (e.g. Dawson et al., 2010), lack of prediction in this study would seem to be consistent with that explanation.

Our findings have implications for driver safety policies. To date, there is little research on the effects of policies on older driver safety (Morrisey & Grabowski, 2005). Few states have implemented restrictions on older drivers based on the geographical area they can drive. However, existing data suggest three-fourths of drivers with limits on driving location do not comply with those restrictions (Braitman, Chaudhary, & McCartt, 2010). The findings of the current study show that irrespective of age, familiarity reduces safety errors on the road. One of the future challenges will be to identify those drivers who are most likely to struggle with wayfinding and the other will be to increase driver compliance with geographical restrictions.

We believe one of the critical elements in addressing such challenges effectively is methodological in nature. It is now possible to conduct naturalistic driving studies in which we can observe individuals' driving performance in their own vehicles and during the course of every-day routines, and link those data with specific location information from global positioning systems. Reliance on such methodologies to model driver behavior and performance will allow us to better understand the impact of familiarity and neuropsychological functioning on driver safety and craft better informed policies that increase safety on the roads.

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