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Economou, Alexandra; Pavlou, Dimosthenis; Beratis, Ion; Andronas, Nikolaos; Papadimitriou, Eleonora; Papageorgiou, Sokratis G.; Yannis, George

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Alexandra Economou, Ph.D.[a]

Dimosthenis Pavlou, Ph.D.[b]

Ion Beratis, Ph.D.[c]

Nikolaos Andronas, M.D.[c]

Eleonora Papadimitriou, Ph.D.[d1]

Sokratis G. Papageorgiou, M.D., Ph.D.[c]

George Yannis, Ph.D.[c]

[a]Department of Psychology, School of Philosophy, National and Kapodistrian University of Athens, Athens, Greece.

[b]School of Civil Engineering, Transportation Planning and Engineering, National Technical University of Athens, Athens, Greece.

[c]Cognitive Disorders/Dementia Unit, 2nd University Department of Neurology, ATTIKON University General Hospital at Haidari, University of Athens, Athens, Greece.

[d]Delft University of Technology, Faculty of Technology, Policy and Management, Delft, The Netherlands.

Correspondence:

[1] At the time the research was conducted this author was Researcher at the School of Civil Engineering, Transportation Planning and Engineering, National Technical University of Athens.

Alexandra Economou, Ph.D.
Department of Psychology
School of Philosophy
The University of Athens
Panepistimiopolis, Ilissia 157 84
Athens, Greece
Tel.: +3210-727 7589
e-mail : aoikono@psych.uoa.gr

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Abstract

Objectives: To examine the driving variables that predict accident probability in mild dementia due to Alzheimer's disease (AD), mild cognitive impairment (MCI) and healthy older control drivers in simulated driving. To compare the three groups in mean performance and in frequency of scores exceeding 1.5 *SD* from the mean.

Methods/Design: Participants were 37 drivers with MCI, 16 drivers with AD, and 21 control drivers over the age of 52. Driving measures were derived from four rural driving conditions: moderate traffic without and with distraction and high traffic without and with distraction. The measures were z-transformed based on the performance of 90 control drivers of different ages. Two unexpected incidents occurred per condition, requiring the sudden breaking to avoid an accident.

Results: Drivers with AD showed significantly lower average speed, speed variability, greater headway distance, headway variability and average reaction time (RT) than control drivers. Drivers with MCI showed significantly lower average speed, greater headway distance and average RT than control drivers in the two conditions of distraction. No differences were found in accident probability. Drivers with AD had more deviant scores than both control drivers and drivers with MCI in most comparisons. Predictors of accident probability were average RT, speed variability and lateral position variability but MCI and AD status were not significant predictors in any of the regression models.

Conclusions: Despite significant differences in performance, drivers with MCI and AD did not differ in accident probability from control drivers. An individualized approach of examining individual driving performance is recommended.

Key words: Accidents; Driving simulator; Mild Cognitive Impairment, Alzheimer's disease

Introduction

Driving simulators are valid ways of assessing driving performance in older drivers with and without cognitive impairment[1-3] and allow for the safe testing of driving under distraction.

Both driver characteristics and driving conditions affect driving performance in simulated driving. Older drivers adopt longer headway distances[4] and slower mean speed in complex environmental conditions,[5] show higher crash risk in challenging situations,[6] and have more driving accidents and traffic light violations[7] compared to younger drivers. Age differences in driving measures are attributed to compensatory processes due to cognitive decline.[4,5,8] Persons with dementia and cognitive impairment show reduced performance on longitudinal and lateral control measures of simulated driving[9-11] and are more likely to fail an on-road test than healthy controls.[12]

Physical and cognitive distraction affects a number of driving measures in simulated driving[5,13-17] (also see review by Papantoniou et al.[18]), and is negatively associated with driver age.[19] Older drivers showed lower speed and decreased speed variability during distraction compared to middle-aged drivers in an instrumented vehicle[20] as well as on a driving simulator, compared to younger drivers.[21] Traffic volume is another driving simulator condition that affects driving.[22]

Real world crash rates of drivers with dementia are inconsistent. Car accidents and traffic violations were not significantly different between drivers with Alzheimer's disease (AD) and drivers without dementia in some studies,[23-25] and there was no association between AD and risk of being responsible for a crash,[26] but other studies showed an increased risk of crashes in drivers with dementia.[27,28] Car crashes are relatively infrequent events whereas the behavioral variables underlying them occur more frequently.[29]

The relationship between poor performance on driving measures and accident rates is not straight-forward. Although drivers with dementia had poorer performance on road tests and simulator evaluations, they did not consistently demonstrate higher crash rates (review by Man-Son-Hing et al.[30]). A population-based study revealed that drivers with dementia had a higher crash risk compared to drivers without dementia over the age of 50 three years before dementia diagnosis, but a significant decline in crash risk in the three years after diagnosis, for a variety of reasons.[31] Few studies have examined crash rates using a driving simulator. One third of the drivers with mild-moderate dementia due to AD crashed but none of the control drivers did in a simulator scenario involving approaching an intersection; visuospatial and attentional impairment and overall cognitive decline were predictors of crashes.[32] On the other hand, older drivers had fewer accidents than younger drivers in simulated urban driving scenarios with critical incidents involving left turns at intersections, in contrast to their overrepresentation in actual intersection accidents, possibly because they compensated by driving slower on the simulator.[33]

The main objective of the present study was to examine the driving variables that predict accident probability in different driving scenarios. Participants with mild dementia due to AD, with mild cognitive impairment (MCI), and healthy controls were tested on a driving simulator under different traffic conditions with and without the use of distraction. Diagnosis was included in order to investigate its contribution to accident probability. A second objective was to compare the performance of the three groups using two related types of analyses: (a) comparisons of mean performance of the three groups on the driving variables; (b) comparisons of the proportion of drivers with scores exceeding 1.5 *SD* from the mean performance derived from an extended control group. Examining the proportion of drivers significantly deviating from the mean per group and condition allows for an individualized assessment of drivers at risk for unsafe driving.

Method

Participants

Research participants were unpaid volunteers with a valid driver's license, recruited by the investigators for the Distract and DriverBrain research projects (https://www.nrso.ntua.gr/geyannis/res/rn59-driverbrain-performance-of-drivers-with-cerebral-diseases-at-unexpected-incidents-in-the-framework-of-the-research-programme-aristeia-of-the-general-secretariat-for-research-and-technology-2012/ & https://www.nrso.ntua.gr/geyannis/res/rn56-distract-causes-and-impacts-of-driver-distraction-a-driving-simulator-study-in-the-framework-of-the-research-programme-thalis-for-the-ministry-of-education-lifelong-learning-and-religious-affair/); two driving simulator experiments which examined the influence of participant and driving condition on the driving performance of healthy participants and persons with neurological disorders of different ages.

A total of 143 drivers participated: 90 control participants of different ages, used for z-score computation of the driving variables; 37 people with MCI and 16 people with mild dementia due to AD. Participants were recruited from the Cognitive Disorders/Dementia Unit of the 2nd Neurology Department of the National and Kapodistrian University of Athens. The 53 participants with MCI and mild dementia due to AD were selected on the basis of diagnosis and completion of all four driving conditions employed in the present study. For purposes of comparison, 21 control participants were selected out of the 90 control participants on the basis of age over 52 years, the age of the youngest patient, and completion of all four conditions of the experiment. All participants had over 10 years of driving experience. They all provided written informed consent and were given brief written feedback on their driving simulator performance upon request.

Participants underwent a structured interview, a comprehensive neurological assessment and clinical history evaluation, a test of visual acuity, and detailed neuropsychological assessment and personality testing. Participants with MCI and mild dementia due to AD also underwent laboratory investigations and imaging. Participants with mild dementia due to AD met the DSM-IV (APA, 1994) and National Institute on Aging-Alzheimer's Association (2011) criteria.[34] Participants with MCI did not demonstrate any significant functional impairment and did not meet the NINCDS/ADRDA diagnostic criteria for probable or possible AD.[35] They all had complaints of progressive memory loss, but functioned independently in everyday activities and lived at home. The diagnosis of MCI was given following a detailed clinical interview with the patient and a relative and a detailed neurological investigation. All participants with MCI received ratings of 0.5 on the Clinical Dementia Rating scale.[36]

Table 1 shows the number of participants who completed each of the four driving conditions of the study, and the number of participants who completed all four driving conditions and thus met criteria for the study (in parentheses). Number of participants who entered the study out of the number of participants in each of the four driving conditions ranged between 64% and 84% for the control group, 79% and 84% for the MCI group and 70% and 84% for the mild dementia due to AD group, which does not indicate selective attrition. Simulator sickness was the reason for not completing all four driving conditions of the experiment.

[Insert Table 1 about here]

Table 2 shows the demographic characteristics and test scores of the participants by diagnostic category.

[Insert Table 2 about here]

The study was approved by the IRB of the Attikon University General Hospital.

Study design and procedure

A Foerst FPF simulator was employed in the study. After a 5-10 minute practice session, participants drove on urban streets with multiple lanes and on a two-lane rural road. Driving area type (rural-urban), traffic flow (moderate-high) and presence/type of distractor (no distractor, conversation, mobile phone use) were within-subject variables. Participant type was a between-subject variable. Traffic flow and distractor were fully counterbalanced across participants for each driving area type. The rural drive was always presented first, because it was shown in the pilot study that it resulted in fewer incidents of simulator sickness. In this study, data from four rural driving conditions were utilized: moderate traffic without and with distraction (conversation) (R1 & R3), and high traffic without and with distraction (conversation) (R2 & R4), because many older drivers were unwilling to use a mobile phone. In each condition, participants drove on a 2.1 km- long, single carriageway rural route with a 3 m lane width with zero gradient and mild horizontal curves.

Two unexpected incidents occurred per driving condition at fixed points along the drive but not at the exact same point in each condition, in order to minimize learning effects: the sudden appearance of an animal (deer or donkey) on the roadway. Outcome variable was accident probability, defined as number of accidents (collisions) out of the two unexpected incidents per driving condition.

None of the participants had had any prior experience with a driving simulator.

Data collection and analysis

Continuous vehicle data, obtained from the driving simulator every 17 msec, were recorded and their distributions were visually and psychometrically examined in the 90 control participants used for computing z-scores (see Table 3 for skewness and kurtosis values). Number of control participants used for the computation of the z-scores in each of the four driving conditions varied slightly due to some drivers not completing all four conditions of the experiment (see Table 1). The following driving simulator measures were selected based on their usefulness in past research and their representing both longitudinal and lateral control measures.

[Insert Table 3 about here]

Speed-position measures

Average speed: average speed of the vehicle in km.

Headway average: average distance of the vehicle from the vehicle ahead in m.

Lateral position: average position from the right road border in m.

Variability measures

Speed variability: standard deviation (*SD*) of average speed.

Headway variability: *SD* of headway average.

Lateral position variability: *SD* of lateral position average.

Time measure

Average reaction time (average RT): the time from the first move of the animal towards the road and braking time in msec.

As Table 3 shows, the majority of the values of the driving variables were approximately symmetric in most driving conditions (skewness values between -0.5 and +0.5), with a few values being moderately skewed (skewness values between -1.0 and +1.0). Average RT showed moderate skewness or higher in most driving conditions. All distributions except for average RT were platykurtic (kurtosis values less than 3). Average RT was leptokurtic in most driving conditions (kurtosis values higher than 3). A visual examination of the distributions with high kurtosis values showed that they were due to infrequent extreme deviations in R1, R2, and R3.

Statistical analysis

The driving measures were z-transformed based on the performance of the 90 control participants. Descriptive statistics were computed and the performance of the three groups on the driving measures was compared. Chi-square analyses were conducted to examine differences in frequency of deviant measures, as defined by performance over 1.5 *SD* from the mean, in the MCI and AD drivers compared to the control drivers. The transformed scores were entered into four hierarchical linear regression analyses, one per driving condition, with accident probability as the outcome variable. Participant group was dummy-coded, with MCI and AD entering the analysis and the control group as the reference category.

Results

Group differences in mean performance in the four driving conditions

The three groups differed in age [$F(2,73)=9.87$, $p < .001$]; paired comparisons showed that drivers with mild dementia due to AD were older than both control drivers ($p < .001$) and drivers with MCI ($p < .05$).

Significant differences among the three groups were found in most driving measures in all four conditions after controlling for age, with the exceptions of lateral position and lateral position variability (Table 4). The mild dementia due to AD group showed significantly lower average speed and speed variability, larger headway average and headway variability and larger average RT across conditions compared to the control group. The MCI group showed significantly lower average speed and larger headway average in R3, and significantly larger average RT in R4 compared to the control group.

[Insert Table 4 about here]

Accident probability did not differ among the three groups in any of the four driving conditions (Table 4). The groups were additionally compared in overall accident probability, in order to increase number of incidents, controlling for age. No significant differences were observed [$F(2,64)=1.11$, $p > .05$] but age was significantly associated with accident probability [$F(1,64)=4.04$, $p < .05$].

Small differences in degrees of freedom in average RT and accident probability compared to the remaining variables in conditions R2, R3, and R4 were due to no recorded data for the two variables from 1 driver with MCI in R2 and R3; and for 1 driver with MCI and 3 drivers with dementia due to AD in R4. Missing data for these two variables only were due to the drivers either not completing the specific section of the driving scenario where the unexpected incident occurred (e.g., due to simulator sickness), or not breaking at the incident but instead, swinging out onto the opposite lane, thereby avoiding the accident. The effect of these few missing data on accident probability is not known, although most of them occurred in R4, the most demanding driving condition.

Deviant score distributions in the four driving conditions

Differences in frequency of scores lower than -1.5 *SD* from the mean (average speed, speed variability) or higher than 1.5 *SD* from the mean (all else) by group were examined in order to compare the frequency of more extreme scores per driving condition. Of the three variability measures, speed variability varied in a negative direction; depending on the driving condition, no or very few participants scored above 1.5 *SD* from the mean.

Chi-square analyses showed significant differences in the distribution of more extreme scores in average speed, headway average, average RT, and headway variability by participant group; lateral position showed differences only in R4 and speed variability in R3 (Table 5).

Drivers with mild dementia due to AD had more frequent deviant scores than control drivers in 16 out of the 18 significant comparisons, and drivers with MCI in 14 out of the 18 significant comparisons. Drivers with MCI had more frequent deviant scores than control drivers in only one comparison. Over 50% of the drivers with mild dementia due to AD showed deviant scores in average speed, headway average and headway variability in all four conditions compared to less than 25% of the control drivers; over 35% of the drivers with mild dementia due to AD showed deviant scores in average RT and average speed variability in all four conditions compared to less than 10% of the control drivers. In conditions of distraction the percentage of drivers with mild dementia due to AD with deviant scores approached or exceeded 70%. Drivers with mild dementia due to AD showed more frequent deviant scores than drivers with MCI in the above measures in at least one condition but drivers with MCI showed more frequent deviant scores than control drivers in only one condition (percentages not shown).

[Insert Table 5 about here]

Predictors of accidents in the four driving conditions

Multiple stepwise linear regression analyses were performed for each driving condition to develop models for predicting accident risk. Predictors for each condition were average speed; headway average; lateral position; speed variability; headway variability; lateral position variability; average RT at unexpected incidents; age; MCI and AD. Outcome was accident probability at unexpected incidents.

[Insert Table 6 about here]

As can be observed in Table 6, average RT, speed variability, and lateral position variability accounted for accident probability. In R1, all three variables were highly significant in the third model, accounting for 32% of the variance. The Durbin-Watson statistic obtained was 2.15, within the range of 1.50 and 2.50, indicating no significant autocorrelation in the residuals. In R2, average RT and speed variability were highly significant in the second model, accounting for 46% of the variance (Durbin-Watson: 1.50). In R3, lateral position variability was significant in the first model, accounting for 12% of the variance (Durbin-Watson: 2.16). In R4, average RT and speed variability were significant in the second model, accounting for 34% of the variance (Durbin-Watson: 1.93). MCI and AD status were not significant in any of the regression models.

Discussion

This study examined the driving variables that predicted accidents occurring at unexpected incidents in controls, drivers with MCI and drivers with mild dementia due to AD, all regular drivers, and differences in means and frequency of deviant scores in the above groups. The mild dementia due to AD group differed consistently from both the control group and the MCI group in most driving variables in all four conditions: they drove slower, left larger headway distances, were slower to respond at unexpected incidents, showed smaller variability in average speed, and larger variability in headway distance. In the two more demanding conditions of distraction, drivers with MCI also drove slower (R3, R4), left larger headway distances (R3), and responded slower at unexpected incidents (R4) than control drivers, similar to Frittelli et al.[9] for the longitudinal measures.

In the present study no significant differences were observed in accident probability among the groups. In light of significant differences in most driving measures the finding raises a number of issues. The high interindividual variability of the drivers with mild dementia due to AD, as indicated by the greater proportion of deviant scores and higher *SD* values, may be important factors, underscoring the importance of individual variables rather than diagnosis. The findings show that accident probability cannot be associated with diagnostic group in a straight-forward way.

Drivers with mild dementia due to AD had more frequent deviant scores compared to control drivers and drivers with MCI in the majority of the significant comparisons. In the conditions with distraction, the percent of drivers with mild dementia due to AD showing deviant scores approached or exceeded 70% compared to less than 25% of the control drivers. Drivers with MCI showed frequencies of deviant scores between those of control drivers and drivers with mild dementia due to AD. The high proportion of drivers with mild dementia due to AD who drove excessively slowly and left greater headway distance indicates that slowing down is a compensatory behavior for these drivers. Older drivers compensate for age-related increases in response time by adopting slower speeds and longer headway distances;[4,37] drivers with mild dementia due to AD seemed to compensate in the same manner. Drivers with mild dementia due to AD varied their speed less relative to control drivers and drivers with MCI, possibly due to their lower speed, and varied their headway distance more, which may indicate difficulty regulating their distance from the vehicle ahead. Few studies have examined variability measures. Bunce and colleagues[38] found greater inconsistency in older drivers relative to younger drivers in headway distance and lateral position, especially in the faster, motorway condition. Our results reveal an increase in variability of headway distance with dementia pathology.

Simulated driving, especially in complex contexts, leads to a greater mental workload and slower speed for older drivers.[39] In the present study it led to a greater mental workload for drivers with cognitive impairment over and above that expected by age. Conversation can increase the mental workload of a driving condition, evidenced by additional mean differences between drivers with MCI and control drivers in average speed, headway distance and RT in the conditions with distraction. Healthy older adults made more concurrent driving safety errors associated with performing a secondary task during a naturalistic distraction procedure compared to middle-aged drivers.[29] Conversation with a remote person has been shown to interfere with the performance of tasks of visual attention more than listening to conversation, indicating that speaking requires higher executive function than listening.[40]

Few studies have studied predictors of crash risk in the driving simulator. In this study, larger average RT, lower speed variability, and higher lateral position variability predicted accidents but diagnosis did not. The proportion of variance explained by the predictor variables in the four conditions ranged from medium to high (as per Cohen[41]). Lateral position variability is a sensitive index of road-tracking precision and driver impairment, which is affected by age under conditions of distraction.[42] Lateral position variability did not show any group differences irrespective of analysis and scores exceeding 1.5 *SD* from the mean were infrequent in all the groups; however, it was an important predictor of accident probability in two conditions and the only important variable in one of the two.

Study strengths, limitations and future directions

The present study is one of the few to examine predictors of crash risk using a driving simulator. The analysis of deviant scores underscores the importance of interindividual variability in group performance. The driving variables were strong predictors of accident probability but diagnostic category was not, likely due to interindividual variability.

Only those drivers who completed all four driving conditions were included in the study, who may have been the most capable ones. However, there was no indication of selective attrition from any one participant group. The small sample size of the group of drivers with mild dementia due to AD is a shortcoming of the study. A future study should incorporate intraindividual variability to further the understanding of driving performance in dementia.

Conclusion

The examination of driving performance by diagnostic group revealed significant differences in mean performance and frequency of deviant scores but diagnosis was not by itself sufficient for estimating individual accident risk. A more individualized approach of examining the specific driving patterns of drivers irrespective of diagnostic group is recommended.

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Conflict of interest: None known.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Key points:

- Drivers with mild dementia due to AD differed from control drivers on most driving simulator measures; drivers with MCI differed from control drivers in the conditions with distraction
- Drivers with mild dementia due to AD showed greater interindividual variability than MCI and control drivers on most driving simulator measures
- The driver groups did not differ in accident probability in any of the comparisons
- Performance on driving variables rather than diagnosis predicted accident probability

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Table 1. *Participation in the four driving conditions by diagnostic category*

Driving condition	Controls total for z-scores	Control (included)	MCI (included)	Mild AD (included)
R1	84	32 (21)	45 (37)	19 (16)
R2	86	33 (21)	47 (37)	22 (16)
R3	79	25 (21)	44 (37)	22 (16)
R4	81	28 (21)	46 (37)	23 (16)

R1: Moderate traffic, no distraction; R2: High traffic, no distraction; R3: Moderate traffic, distraction (conversation); R4: High traffic, distraction (conversation); MCI: Mild Cognitive Impairment; mild AD: mild dementia due to Alzheimer's disease. Controls total shows the control participants of all ages who were used for computing z-scores. Shown in parentheses are the numbers of participants who were included in the analyses.

Table 2. *Demographic characteristics and test scores of the participants by group*

Participant type		N	W	Age Mean (*SD*)	Education Mean (*SD*)	MMSE Mean (*SD*)	FAB Mean (*SD*)
Control (total)		90	45	46 (16.04)	15.46 (3.08)		
In the analyses	Control	21	13	63.52 (8.38)	14.62 (3.29)	29.30 (0.80)	16.40 (1.19)
	MCI	37	13	68.43 (9.15)	12.86 (4.08)	28.03 (1.66)	13.33 (3.14)
	Mild AD	16	0	75.38 (4.86)	10.69 (4.13)	22.81 (3.97)	9.75 (2.84)
	Total	74	26				

MCI: Mild Cognitive Impairment; mild AD: mild dementia due to Alzheimer's disease; N: number of participants; W: women; SD: standard deviation; MMSE: Mini Mental State Examination; FAB: Frontal Assessment Battery. Education is given in years.

Table 3. *Distribution characteristics of the driving measures for the control participants*

	Avg. Speed	Hway Avg.	Lat. Position	SD Avg. Speed	SD Head Avg.	SD Lat. Pos.	Avg. RT
R1 Skewness	-0.04	0.48	-0.16	0.73	0.70	0.76	1.62
R1 Kurtosis	-0.36	0.22	-0.61	1.48	0.38	1.43	4.21
R2 Skewness	-1.09	0.94	0.05	0.38	0.56	0.71	2.24
R2 Kurtosis	0.06	0.34	-0.77	1.04	-0.61	1.21	7.84
R3 Skewness	-0.48	1.39	0.33	0.25	0.82	0.43	4.89
R3 Kurtosis	0.26	4.44	-0.50	-0.07	1.36	-0.27	33.81
R4 Skewness	-1.16	1.20	0.18	0.14	1.29	0.64	0.27
R4 Kurtosis	1.17	1.70	-0.37	-0.45	2.08	0.31	0.08

Avg. Speed: average speed; Hway Avg.: headway average; Lat. position: lateral position; Avg. RT: average reaction time; SD: standard deviation; R1: Moderate traffic, no distraction; R2: High traffic, no distraction; R3: Moderate traffic, distraction (conversation); R4: High traffic, distraction (conversation). Values are provided in z-scores.

Table 4. *Performance on the driving variables by group in the 4 conditions*

R1	Control Mean (*SD*)	MCI Mean (*SD*)	Mild AD Mean (*SD*)	ANOVA	Comparisons Reference: controls
Avg. Speed	-0.43 (0.97)	-0.80 (0.78)	-1.79 (0.97)	$F(2,70) = 8.32$ $p<.001$ $\eta_p^2=.19$	AD vs Cn: $p < .001$
Headway Avg.	0.52 (1.05)	0.75 (0.97)	1.88 (1.38)	$F(2,70) = 5.88$ $p = .004$ $\eta_p^2=.14$	AD vs Cn: $p = .002$
Lat. Position	0.21 (1.96)	0.39 (0.99)	0.29 (1.52)	$F(2,70) = 0.40$ $p > .05$	
SD Avg. Speed	-0.39 (0.85)	-0.51 (0.69)	-1.10 (0.85)	$F(2,70) = 4.16$ $p = .02$ $\eta_p^2=.11$	AD vs Cn: $p = .009$
SD Head. Avg.	0.57 (1.19)	0.68 (1.13)	2.07 (1.56)	$F(2,70) = 6.76$ $p = .002$ $\eta_p^2=.16$	AD vs Cn: $p = .002$
SD Lat. Pos.	0.15 (0.93)	0.36 (0.70)	0.57 (0.97)	$F(2,70) = 0.75$ $p > .05$	
Average RT	0.33 (1.05)	0.92 (1.32)	2.85 (2.17)	$F(2,70) = 9.74$ $p < .001$ $\eta_p^2=.22$	AD vs Cn: $p < .001$
Accident Prob.	0.29 (0.46)	0.27 (0.45)	0.56 (0.81)	$F(2,70) = 0.71$ $p > .05$	
R2					
Avg. Speed	-0.19 (1.04)	-0.88 (1.01)	-2.02 (1.31)	$F(2,70) = 8.08$ $p = .001$ $\eta_p^2=.19$	AD vs Cn: $p < .001$ MCI vs Cn: $p = .051$
Headway Avg.	0.18 (1.02)	0.64 (0.81)	1.97 (1.66)	$F(2,70) = 8.92$ $p < .001$ $\eta_p^2=.20$	AD vs Cn: $p < .001$
Lat. Position	0.25 (1.08)	0.22 (0.88)	0.41 (1.15)	$F(2,70) = 0.32$ $p > .05$	

SD Avg. Speed	-0.17 (1.13)	-0.45 (1.00)	-1.22 (0.94)	$F(2,70) = 3.67$ $p = .031$ η_p^2=.10	AD vs Cn: $p = .011$
SD Head. Avg.	0.26 (1.11)	0.60 (0.96)	1.81 (1.39)	$F(2,70) = 5.75$ $p = .005$ η_p^2=.14	AD vs Cn: $p < .002$
SD Lat. Pos.	0.15 (0.93)	0.36 (0.70)	0.57 (0.97)	$F(2,70)$ =0.21 $p > .05$	
Average RT	0.10 (0.69)	0.86 (1.23)	1.67 (1.39)	$F(2,69) = 4.68$ $p = .012$ η_p^2=.12	MCI vs Cn: $p = .053$ AD vs Cn: $p = .003$
Accident Prob.	0.05 (0.22)	0.25 (0.55)	0.44 (0.63)	$F(2,69) = 0.93$ $p > .05$	
R3					
Avg. Speed	-0.36 (1.03)	-1.18 (0.84)	-2.07 (0.90)	$F(2,70) = 12.32$ $p < .001$ η_p^2=.26	MCI vs Cn: $p = .003$ AD vs Cn: $p < .001$
Headway Avg.	0.23 (0.93)	1.09 (1.21)	2.38 (1.04)	$F(2,70) = 10.05$ $p < .001$ η_p^2=.22	MCI vs Cn: $p = .021$ AD vs Cn: $p < .001$
Lat. Position	0.17 (1.06)	0.90 (1.09)	0.03 (1.35)	$F(2,70)$ =0.03 $p > .05$	
SD Avg. Speed	-0.31 (1.06)	-0.61 (0.77)	-1.26 (0.89)	$F(2,70) = 3.83$ $p = .026$ η_p^2=.10	AD vs Cn: $p = .008$
SD Head. Avg.	0.33 (1.10)	1.04 (1.36)	2.86 (1.48)	$F(2,70) = 10.46$ $p < .001$ η_p^2=.23	AD vs Cn: $p < .001$
SD Lat. Pos.	0.15 (0.98)	0.25 (1.11)	0.54 (1.03)	$F(2,70)$ =0.03 $p > .05$	
Average RT	0.42 (1.62)	0.82 (0.84)	2.04 (1.65)	$F(2,69) = 3.70$ $p = .03$ η_p^2=.10	AD vs Cn: $p = .014$
Accident Prob.	0.33 (0.58)	0.17 (0.38)	0.38 (0.62)	$F(2,69)$ =1.25	

				$p > .05$	
R4					
Avg. Speed	-0.33 (1.27)	-1.08 (1.13)	-2.37 (1.49)	$F(2,70) = 7.89$ $p = .001\ \eta_p^2=.18$	AD vs Cn: $p < .001$
Headway Avg.	0.34 (1.23)	0.90 (1.03)	2.26 (1.52)	$F(2,70) = 7.22$ $p = .001\ \eta_p^2=.17$	AD vs Cn: $p < .001$
Lat. Position	0.21 (1.15)	0.16 (0.98)	0.34 (1.38)	$F(2,70) =0.41$ $p > .05$	
SD Avg. Speed	-0.18 (1.12)	-0.65 (1.01)	-1.43 (1.08)	$F(2,70) = 5.44$ $p = .006\ \eta_p^2=.14$	AD vs Cn: $p = .002$
SD Head. Avg.	0.29 (1.26)	0.87 (0.99)	2.32 (1.76)	$F(2,70) = 7.63$ $p = .001\ \eta_p^2=.18$	AD vs Cn: $p < .001$
SD Lat. Pos.	0.27 (0.99)	0.36 (0.80)	0.54 (0.99)	$F(2,70) =0.04$ $p > .05$	
Average RT	0.13 (0.79)	1.65 (1.91)	3.27 (1.85)	$F(2,66) = 10.06$ $p < .001\ \eta_p^2=.23$	MCI vs Cn: $p = .004$ AD vs Cn: $p < .001$
Accident Prob.	0.10 (0.30)	0.17 (0.51)	0.54 (0.78)	$F(2,66) = 1.50$ $p > .05$	

Avg. Speed: average speed; Hway Avg.: headway average; Lat. position: lateral position; Avg. RT: average reaction time; SD: standard deviation; R1: Moderate traffic, no distraction; R2: High traffic, no distraction; R3: Moderate traffic, distraction (conversation); R4: High traffic, distraction (conversation). MCI: Mild Cognitive Impairment; mild AD: mild dementia due to Alzheimer's disease. Values are provided in z-scores, except for accident probability.

Table 5. *Analyses of proportions of participants with scores <-1.5 (Average Speed, SD Average Speed) or > 1.5 (all else) SD from the mean*

	Average Speed	Headway Average	Lateral position	Average RT
R1	$\chi^2(2, N=74) = 6.90, p = .032$ AD>Cn, AD>MCI	$\chi^2(2, N=74) = 8.81, p = .012$ AD>Cn, AD>MCI	$\chi^2(2, N=74) = 0.20, p > .05$	$\chi^2(2, N=74) = 20.16, p < .001$ AD>Cn, AD>MCI
R2	$\chi^2(2, N=74) = 7.53, p = .023$ AD>Cn, AD>MCI	$\chi^2(2, N=74) = 8.46, p = .015$ AD>Cn, AD>MCI	$\chi^2(2, N=74) = 3.94, p > .05$	$\chi^2(2, N=74) = 6.08, p = .048$ AD>Cn
R3	$\chi^2(2, N=74) = 13.98, p = .001$ AD>Cn	$\chi^2(2, N=74) = 14.30, p = .001$ AD>Cn, AD>MCI	$\chi^2(2, N=74) = 1.25, p > .05$	$\chi^2(2, N=74) = 8.51, p = .014$ AD>Cn
R4	$\chi^2(2, N=74) = 12.19, p = .002$ AD>Cn, AD>MCI	$\chi^2(2, N=74) = 10.21, p = .006$ AD>Cn, AD>MCI	$\chi^2(2, N=74) = 6.48, p = .39$ AD>MCI	$\chi^2(2, N=74) = 15.81, p < .001$ AD>Cn, MCI>Cn
	SD Average Speed	SD Headway Avg.	*SD* Lateral Position	
R1	$\chi^2(2, N=74) = 0.41, p > .05$	$\chi^2(2, N=74) = 8.42, p = .015$ AD>MCI	no participant >1.5 *SD*	
R2	$\chi^2(2, N=74) = 6.82, p = .033$ -	$\chi^2(2, N=74) = 10.15, p = .006$ AD>Cn, AD>MCI	$\chi^2(2, N=74) = 5.14, p > .05$	
R3	$\chi^2(2, N=74) = 8.34, p = .015$ AD>Cn, AD>MCI	$\chi^2(2, N=74) = 17.32, p < .001$ AD>Cn, AD>MCI	$\chi^2(2, N=74) = 1.83, p > .05$	
R4	$\chi^2(2, N=74) = 5.04, p > .05$	$\chi^2(2, N=74) = 7.76, p = .021$ AD>Cn	$\chi^2(2, N=74) = 0.62, p > .05$	

R1: Moderate traffic, no distraction; R2: High traffic, no distraction; R3: Moderate traffic, distraction (conversation); R4: High traffic, distraction (conversation). Cn: control; MCI: Mild Cognitive Impairment; AD: mild Alzheimer's disease.

Table 6. *Summary of stepwise hierarchical regression analyses for variables predicting accident rate*

R1	Model 1					Model 2					Model 3				
Variable	*B*	*SE B*	*β*	*t*	*p*-value	*B*	*SE B*	*β*	*t*	*p*-value	*B*	*SE B*	*β*	*t*	*p*-value
(constant)	0.34	0.06		5.62	< .001	0.22	0.07		3.15	.002	0.30	0.07		4.08	< .001
Average RT	0.32			3.13	.003	**0.10**	**0.03**	**0.32**	**3.13**	**.003**	**0.15**	**0.04**	**0.46**	**4.10**	**< .001**
Average speed z	-0.15			-1.31	.19	0.06			0.46	.65	-0.21			-1.33	.19
Headway avg z	0.15			0.30	.20	-0.02			-0.13	.89	0.27			1.84	.07
Lateral position z	0.04			0.32	.75	0.00			-0.00	1.00	-0.07			-0.69	.49
SD Avg speed z	0.08			0.72	.48	0.31			2.62	.011	**0.22**	**0.08**	**0.31**	**2.66**	**.011**
SD Headway avg z	0.14			1.24	.22	-0.06			-0.45	.66	0.22			1.45	.15
SD Lateral posz	**0.30**	**0.08**	**0.39**	**3.54**	**.001**	**0.30**	**0.08**	**0.39**	**3.76**	**< .001**	**0.21**	**0.08**	**0.27**	**2.53**	**.014**
MCI	-0.07			-0.63	.53	-0.02			-0.21	.84	-0.06			-0.56	.58
AD	0.16			1.42	.16	-0.02			-0.16	.86	0.05			0.45	.66
R^2			**0.15**					**0.25**					**0.32**		
R^2 change			0.15					0.10					0.07		
F for change in R^2			12.53		.001			9.77		.003			6.88		.011

R2	Model 1					Model 2				
Variable	*B*	*SE B*	*β*	*t*	*p*-value	*B*	*SE B*	*β*	*t*	*p*-value
(constant)	0.05	0.06		0.80	.43	0.10	0.05		1.75	.09
Average RT	**0.23**	**0.04**	**0.55**	**5.56**	**< .001**	**0.30**	**0.04**	**0.74**	**7.56**	**< .001**
Average speed z	0.34			3.06	.003	0.03			0.17	.87
Headway avg z	-0.33			-3.08	.003	-0.12			-0.96	.34
Lateral position z	0.09			0.92	.36	0.08			0.88	.38
SD Avg speed z	0.44			4.44	< .001	**0.21**	**0.05**	**0.44**	**4.44**	**< .001**
SD Headway avg z	-0.33			-2.90	.005	-0.05			-0.35	.73
SD Lateral pos z	0.22			2.23	.03	0.06			0.57	.57
MCI	0.17			0.17	.87	-0.03			-0.28	.78
AD	0.14			0.13	.89	0.11			1.11	.27
R^2			**0.30**					**0.45**		
R^2 change			0.30					0.15		
F for change in R^2		30.91			< .001		19.71			< .001

R3			Model 1		
Variable	*B*	*SE B*	*β*	*t*	*p*-value
(constant)	0.22	0.06		3.75	< .001
Average RT	0.09			0.81	.42
Average speed z	0.17			1.41	.16
Headway avg z	-0.18			-1.58	.12
Lateral position z	0.09			0.74	.47
SD Avg speed z	0.23			1.96	.053
SD Headway avg z	-0.12			-1.06	.29
SD Lateral pos z	**0.16**	**0.05**	**0.34**	**3.04**	**.003**
MCI	-0.17			-1.57	.12
AD	0.08			0.70	.48
R^2			**0.12**		
R^2 change			0.12		
F for change in R^2		9.26			.003

R4			Model 1					Model 2		
Variable	*B*	*SE B*	*β*	*t*	*p*-value	*B*	*SE B*	*β*	*t*	*p*-value
(constant)	-0.01	0.07		0.14	.89	0.02	0.07		0.35	.73
Average RT	**0.15**	**0.03**	**0.55**	**5.37**	**< .001**	**0.17**	**0.03**	**0.63**	**5.91**	**< .001**
Average speed z	0.16			1.37	.18	-0.00			-0.01	.99
Headway avg z	-0.20			-1.75	.09	-0.10			-0.71	.46
Lateral position z	0.02			0.22	.82	0.01			0.11	.91
SD Avg speed z	0.23			2.14	.036	**0.11**	**0.05**	**0.23**	**2.14**	**.036**
SD Headway avg z	-0.16			-1.39	.17	-0.05			-0.33	.74
SD Lateral pos z	-0.03			-0.26	.80	-0.03			-0.26	.80
MCI	-0.14			-1.35	.18	-0.14			-1.43	.16
AD	0.06			0.56	.58	0.10			0.91	.37
R^2			**0.30**					**0.34**		
R^2 change			0.30					0.04		
F for change in R^2		28.84			< .001		4.59			.036

Avg. Speed: average speed; Hway Avg.: headway average; Lat. position: lateral position; Avg. RT: average reaction time; SD: standard deviation; R1: Moderate traffic, no distraction; R2: High traffic, no distraction; R3: Moderate traffic, distraction (conversation); R4: High traffic, distraction (conversation).