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### ► To cite this version:

Laurence Paire-Ficout, Sylviane Lafont, Fanny Conte, Amandine Coquillat, Colette Fabrigoule, et al.. A naturalistic driving study investigating self-regulation behavior in early Alzheimer's disease: a pilot study. *Journal of Alzheimer's Disease*, 2018, 10.3233/JAD-171031 . hal-01801844

**HAL Id: hal-01801844**

**<https://hal.science/hal-01801844v1>**

Submitted on 28 May 2018

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# **Naturalistic Driving Study Investigating Self-Regulation Behavior in Early Alzheimer's Disease: A pilot study**

Laurence Paire-Ficout <sup>1</sup>, Sylviane Lafont <sup>2</sup>, Fanny Conte<sup>1</sup>, Amandine Coquillat <sup>2</sup>, Colette Fabrigoule<sup>3</sup>, Joël Ankri<sup>4</sup>, Frédéric Blanc<sup>5</sup>, Cécilia Gabel<sup>1</sup>, Jean-Luc Novella<sup>7</sup>, Isabella Morrone<sup>6,7</sup>, Rachid Mahmoudi <sup>6,7</sup>

<sup>1</sup> Laboratoire Ergonomie et Sciences Cognitives pour les Transports (LESCOT), IFSTTAR, TS2

<sup>2</sup> Unité Mixte de Recherche Épidémiologique et de Surveillance Transport Travail Environnement (UMRESTTE), UMR T\_9405, IFSTTAR, TS2, Université de Lyon, Lyon, France

<sup>3</sup> USR 3413 CNRS, Université Bordeaux Segalen, CHU Pellegrin, 33076 Bordeaux, France

<sup>4</sup> Center of Gerontology, Public Assistance, Hospitals of Paris, Paris, France, UMR 1168 INSERM –UVSQ

<sup>5</sup> CMRR (Memory Resources and Research Centre), University Hospital of Strasbourg, Strasbourg, France

<sup>6</sup> Department of Geriatrics and Internal Medicine, Reims University Hospitals, Maison Blanche Hospital, Reims, F-51092, France

<sup>7</sup> Faculty of Medicine, EA 3797, University of Reims Champagne-Ardenne, Reims, F-51092, France

Running title: Alzheimer's Disease and Naturalistic Driving

<http://dx.doi.org/10.3233/JAD-171031>

[Journal of Alzheimer's Disease](#), vol. Pre-press, no. Pre-press, pp. 1-10, 2018

Correspondence: Laurence Paire-Ficout

Institut français des sciences et technologies des transports, de l'aménagement et des réseaux (Ifsttar), Transport Santé Sécurité (TS2), Laboratoire Ergonomie et Sciences Cognitives pour les Transports (Lescot), 25, Avenue François Mitterrand, Case 24, 69675 Bron Cedex

Tel: (33) 4 72 14 25 32

Fax: (33) 4 72 14 68 37

Email: [laurence.paire-ficout@ifsttar.fr](mailto:laurence.paire-ficout@ifsttar.fr)

## **Abstract**

**BACKGROUND:** Because cognitive processes decline in the earliest stages of Alzheimer's disease, the driving abilities are often affected. The naturalistic driving approach is relevant to study the driving habits and behaviors in normal or critical situations in a familiar environment of participants.

**OBJECTIVE:** This pilot study analyzed in-car video recordings of naturalistic driving in patients with early-stage Alzheimer's disease and in healthy controls, with a special focus on tactical self-regulation behavior.

**METHODS:** Twenty patients with early-stage Alzheimer's disease (Diagnosis and Statistical Manual of Mental Disorders, Fourth Edition [DSM-IV] criteria), and 21 healthy older adults were included in the study. Data collection equipment was installed in their personal vehicles. Two expert psychologists assessed driving performance using a specially designed Naturalistic Driving Assessment Scale (NaDAS), paying particular attention to tactical self-regulation behavior, and they recorded all critical safety events.

**RESULTS:** Poorer driving performance was observed among Alzheimer's disease drivers: their tactical self-regulation behavior was of lower quality. AD patients had also twice as many critical events as healthy drivers and three times more "unaware" critical events.

**CONCLUSION:** This pilot study using a naturalistic approach to accurately show that Alzheimer's disease drivers have poorer tactical self-regulation behavior than healthy older drivers. Future deployment of assistance systems in vehicles should specifically target tactical self-regulation components.

**Key words:** Dementia, Alzheimer's disease, Naturalistic driving, Critical events, Self-awareness

## **Introduction**

Cognitive processes can begin to slow down in the earliest stages of Alzheimer's disease (AD), and management of attentional resources and executive functions can become more challenging [1-3]. The driving abilities of subjects with AD are affected more than those of healthy older individuals [4-9]. AD patients nevertheless continue to drive for more years than people with other dementia syndromes [10, 11]. This could be explained by the fact that executive functions, although widely affected in Alzheimer's disease, are better preserved in AD than in other forms of dementia [12], making it possible to continue driving for longer. Another possible explanation could be the lower level of cognitive self-awareness in AD patients, as reported in a previous driving study [13, 14]. AD drivers may drive longer because of a deficit in self-awareness that prevents them from perceiving their driving difficulties and adapting accordingly.

The naturalistic driving approach is a highly relevant, unobtrusive approach to the study of driving habits and behaviors in normal or critical situations [15, 16]. Participants' own cars are equipped with devices that continuously record their driving activity. This allows in-depth study of driving behavior in a familiar environment over relatively long periods of time (generally between 2 weeks and 1 month). There is less pressure, because participants do not feel that they are being assessed. The naturalistic driving approach is a useful approach to the study of how individuals self-regulate their driving patterns, and how they modify their driving according to their declining health or loss of functional abilities [17-20]. This phenomenon is the so-called "tactical self-regulation" proposed by Molnar et al. [21], which is based on Michon's hierarchical model for driving skills and control [22]. Tactical self-regulation deals with the actual maneuvers drivers make in traffic (e.g., speed choice, avoiding obstacles, gap and headway acceptance, overtaking, distance between the driver's vehicle and the vehicle ahead), as well as decisions about avoiding potentially distracting secondary activities while driving

(e.g., using the radio, eating, talking on a mobile phone, and texting). Driving at slower speeds may be identified as tactical self-regulation, characterizing how older drivers compensate for age-related deficits. The fact that older drivers tend to leave more space between their vehicle and the vehicle ahead may also reflect a tactical self-regulation strategy.

A significant part of the driving and AD literature over the past three decades has used simulator and road testing to examine cognitively normal participants and those with AD. More recently, some studies have used the naturalistic driving approach to better understand driving behaviors in AD drivers.

One such study focused on mobility practices and showed that individuals with AD drove significantly fewer kilometers than controls [23]. Some researchers have recorded poorer global driving performance scores in cognitively-impaired patients using the Composite Driving Assessment Scale (CDAS) [24, 25], while others have shown that AD subjects drove as safely as the comparison group, as assessed using a different driving evaluation tool [23]. Watanabe et al. observed a significantly higher number of driving errors in patients with dementia (Alzheimer's disease, vascular dementia, and frontal-type dementia) than in controls [26]. In particular, they observed failure to stop at stop signs and lack of attention to traffic lights in the dementia group. Babulal et al. recently showed that older adults with preclinical AD drove less often, were less likely to drive at night, and had fewer aggressive behaviors such as hard braking, speeding, and sudden acceleration [27]. It should be noted that in all these studies, the samples sizes were small (between 10 and 50 participants with dementia) and that participants who had been rated as "unsafe" on a prior standardized road test were excluded from the naturalistic driving study [23-27].

The purpose of the present pilot study was to collect ecological driving data on AD patients and healthy older drivers using a naturalistic driving approach, and to design and use an assessment scale created especially for the purposes this study (i.e., the Naturalistic Driving Assessment

Scale [NaDAS]; see the Materials and Methods section for details). This is the first study to closely examine the tactical self-regulation behavior of older individuals with AD with a view to investigating their ability to regulate their driving behavior. We hypothesized that, due to a self-awareness deficit, tactical self-regulation in people with AD would be lower than in healthy older people. Consequently, we expected poorer tactical self-regulation performance in the AD group when critical events were encountered.

## **Material and Methods**

### *Participants*

All AD patients met the diagnostic criteria for probable AD according to the Diagnosis and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) [28] and the criteria of the National Institute of Neurological and Communicative Disorders and Stroke and Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA) [29]. Patients were recruited from three hospital-based geriatric wards in the French cities of Reims, Strasbourg, and Paris. Healthy older drivers were recruited from local associations for seniors. Recruitment in the three cities began in July 2012 and finished in August 2014.

For both groups, the inclusion criteria were as follows: aged  $\geq 70$  years; valid driver's license; driving a personal vehicle  $\geq 1$ /week; and acceptance of the installation of our in-vehicle recording technology. The exclusion criteria for both groups of participants included the presence of another dementia syndrome and a Mini-Mental State Examination (MMSE) [30] score  $< 24$ . All participants had to undergo a detailed clinical examination to validate the AD diagnoses and exclusion criteria. Neuropsychological tests chosen to reflect different components of cognitive processes that should be related to driving abilities and potentially concern AD were performed. They comprised the Trail Making Test [31], the Stroop test [32], the Wechsler Digit Symbol Substitution Test (DSST) [33], the useful field of view (UFOV) [34], and the Koh's blocks test [35].

All participants responded to 6 questions about their driving mobility, namely: distance driven per week (less than 10km, 10-50 km, 50-100 km, 100-300 km, more than 300 km), main driver (you exclusively, you around 75% of the time, you half the time, you around quarter of the time or less), trip frequency per week (once, 2-3 times, more than 3), difficulties reported compared to before (12 situations such as driving at night, in the rain, at intersections...), avoidance reported (same driving situations).

The study was approved by the Biomedical Ethical Committee Est-III (NANCY, No.:11.05.14), and by the French Health Products Safety Agency (AFSSAPS) for clinical trials unrelated to pharmaceutical products, on August 31, 2011, No. B111088-50. Informed consent was obtained in accordance with institutional guidelines. The informed consent process involved providing information about participant safety and assuring the participants that their confidentiality would be maintained.

#### *In-vehicle video recording technology*

The video recording device, a GPS Janus V2 Viewer (Safety Track, USA) consisting of two cameras, was placed behind the rear-view mirror of each driver's vehicle. A single camera, with a 175° viewing angle, faced the participant in order to capture his/her head and shoulders as well as the presence of front- and back-seat passengers. This provided information about driver attention and secondary task activity. The second camera, with a 120° viewing angle, provided a forward view to capture the road context and circumstances of critical events (i.e., awareness of signs, position on the road, and maneuvers). Video recording began automatically as soon as the driver started the ignition of the vehicle, and images were captured continuously on a 32Go card corresponding to 30 hours of recording. No video recording exceeded the storage, and consequently, no video data was lost. Night-time recordings of participants' faces and of the interior of the car were obtained using infra-red lighting. The cameras were the only in-vehicle monitoring equipment visible to the driver and they were unobtrusive. Participants were



recruited consecutively. We had six cameras, two on each site. Cameras and memory cards were shared across participants. The technician who installed and unpacked the cameras sent the SD card to the Ifsttar team at the end of each recording. Video data were saved to a restricted access server at Ifsttar for later analysis, and the SD cards were returned to the technician for the next recordings.

#### *Data collection*

The equipment was installed in the participant's personal vehicle for a period of 2 weeks. Participants were told to drive in their usual environment and to follow their daily routine. Recordings for three subjects could not be taken into account, comprising two recordings in the AD group that were not of sufficient quality for analysis, and the recordings for a participant in the control group who withdrew from the study. The analysis was therefore performed on a total of 41 recordings (20 for the AD group and 21 for the control group).

#### *Assessment of the videos*

Two expert psychologists, blinded to the AD status, watched the totality of the recordings and independently evaluated driving performance using a specific assessment tool, namely, the NaDAS. For the purposes of analysis, the experts could see both views at the same time (view of the road and view of the driver), and if needed, could also look more closely at a single scene. All coding rules were previously defined between raters. The coding was performed for all the trips, after all the videos had been viewed. For example, the "position on the line" item was judged as "poor" if rater record at least 5 irregular positions in 15 days (driving out of lane). Psychologists also reported all critical safety events as observed during the viewing. They then compared their evaluations in order to agree on the final driving scores for the participants.

#### *Driving assessment*

The driving assessment was mainly based on the TRIP scale (Test Ride to Investigate Practical Fitness to Drive,[36]) in which 64 items were extracted. The driving assessment was mainly based on the TRIP scale (Test Ride to Investigate Practical Fitness to Drive [37]. We also added 18 items from the CDAS (Composite Driving Assessment Scale, Ott et al. 2012) in order to evaluate other essential dimensions that occur specifically in a naturalistic driving context, such as the ability to respond to traffic, stay in the right lane, start the vehicle or do an about-turn. In addition, 13 further items that are not present in either the TRIP or CDAS scales were also included to assess lane violation (1), speed control on secondary roads (1) and management of roundabouts (11). Preliminary analyses revealed that these items were not explored, hence prompting us to include them for exploration in the current study. Consequently, a new composite scale was created, named the Naturalistic Driving Assessment Scale (NADAS), which assesses lateral position control, safety distance, speed control, visual information processing, perception and respect of traffic signals, overtaking behavior, anticipatory behavior, interaction with other traffic participants, mechanical operations. All items were rated on a four-point scale (poor = 1, fair = 2, satisfactory = 3, good = 4). The total score ranged from 95 to 373 points. The higher the total score, the better the driving performance. Three NaDAS sub-scores were also calculated, following Michon's hierarchical levels of driving behavior, namely, operational, tactical, and tactical compensation sub-scores. The operational sub-score was composed of 11 items assessing immediate reactions, such as braking and lane positioning. The tactical sub-score was composed of 12 items assessing speed adaptation, respect for safe distances, correct lane choice, and anticipatory behavior. The tactical compensation sub-score was composed of 7 items assessing driving styles regarding lateral position, safe distance, speed control, and anticipatory behavior. Tactical compensation processes refer to adaptations in driving style to mitigate the decline in cognitive driving skills. These three scores are calculated as follows: Operational score = Average of lateral position score + trajectory stability score +

operations score mechanical; Tactical score = Score choice of file + score safety distance + score speed + score anticipation; Tactical Compensation Score = Tracking Style Score + Speed Choice Score + (Score anticipation / 8) \* 10. The last two scores indicate the participants' tactical self-regulation behavior.

### *Critical events*

In accordance with the definitions proposed by Dingus et al., we considered three critical events: crashes, near-crashes, and incidents [15]. A crash was defined as a situation in which there was physical contact between one vehicle and another, a stationary object, pedestrian, cyclist, or animal. A crash often involves human injury or major property damage affecting the safety of the driver and passengers. A near-crash refers to a conflict situation involving security, in which a crash nearly occurred (but there was no impact). In these situations, two or more road users are close to a point in space and time where their paths would probably intersect if their movements remain unchanged. These situations require rapid and intense action (steering, braking, or acceleration) on the part of the participant or the other road users to avoid an accident. An incident refers to a driver error that could lead to traffic disturbance or physical contact with a fixed object (e.g. a curb) without causing damage. An incident is less critical than a near-crash from a security point of view. The analysis of critical events was performed qualitatively. Psychologists observed abrupt changes in speed and movements of the passengers' torso projected forwards, or jerks to the steering wheel to identify a critical event. According to the context and the severity of the event, the psychologist then classified them as incidents or near accidents.

Just as for the NaDAS, the two experts compared their reports in order to reach consensus on the category of each critical event that involved the participant's responsibility. The total number of critical events and their locations (roundabout, straight road, left or right turn,

priority right, pedestrian crossing, carpark) or their location were analyzed. In addition, “aware” critical events were distinguished from those that were “unaware”. An “aware” critical event was accompanied by an observed reaction such as an avoidance maneuver or use of the brake, whereas an “unaware” critical event did not lead to any reaction from the driver.

### *Analyses*

For both the AD and control groups, the TRIP, CDAS, and NaDAS scores were calculated as the total number of points, divided by the total of the items observed, multiplied by 100 (maximum 100 points). The mean NaDAS sub-scores (operational, tactical, and tactical compensatory) were also calculated sub-scores, and sub-scores for the components of the tactical compensation sub-score, i.e., lateral position, safe distance, speed control, and anticipatory behavior).

For normally distributed quantitative variables, parametric t-tests were used to compare the variables between the two groups (i.e., age, MMSE, TMT, Stroop test, UFOV, DSST, Koh's blocks test, the TRIP, CDAS, NaDAS scores and the three operational, tactical and tactical compensatory NaDAS sub-scores). For non-normally distributed quantitative variables, non-parametric Wilcoxon tests were used to compare the variables between the two groups (i.e., the mean number of critical events and mean number of “unaware” critical events). For categorical variables, chi squared tests were used to compare the variables between the two groups (i.e. education level, living arrangement, distance driven, mains driver, trips frequency, reported difficulties). Spearman's rank correlation coefficient was used to study the relationship between the number of critical events and the total NaDAS score. Pearson correlation coefficient was used to study the inter-rater reliability between the two expert psychologists. A p-value < 0.05 was considered statistically significant. All analyses were performed using PASW Statistics 21 software (SPSS Inc., Chicago, IL, USA).

## Results

### *Demographic cognitive and mobility characteristics*

Forty-one participants were included in this study: 20 AD patients (78.7 years $\pm$ 7.0) and 21 healthy older adults with no history of dementia (76.9 $\pm$ 3.6 years). Males were more numerous in both groups (Table 1). As expected, the two groups differed significantly in terms of the MMSE score. Patients with AD scored significantly worse than controls on all the cognitive measures (TMT, UFOV, Stroop test, Koh's blocks test). The proportion of drivers who drove >50 km/week was slightly higher in the control group, but the distance driven (<10, 10–50, or >50 km/week) was not significantly different from that in the AD group. Trip frequency per week was almost the same in both groups. The proportions of drivers who reported any difficulty in driving and the proportions who reported any change in driving was similar in both groups. Data on the total number of kilometers traveled and the 2-week driving time collected using the Janus GPS system could only be recorded for 13 patients and 14 controls. These two subgroups did not differ in terms of age, sex, or MMSE scores from the patients with available GPS data. As shown in Table 1, controls did not make longer trips or travel more kilometers than patients.

### *Driving evaluation*

Driving performance, as measured with the three scales (TRIP, CDAS, and NaDAS), was significantly lower in the AD group than in the control group (Table 2). The three NaDAS sub-scores (operational, tactical, and tactical compensatory) were also significantly lower in the AD group. The inter-rater reliability between the two expert psychologists, as assessed by the Pearson correlation coefficient, was  $r=0.66$  ( $p=0.004$ ).

### *Critical events*

As shown in Table 3, AD patients had twice as many critical events as healthy drivers ( $p=0.02$ ), and three times more “unaware” critical events ( $p=0.02$ ). The majority of critical events in AD patients involved near accidents, and they occurred most frequently at roundabouts or on straight roads. When they occurred on straight roads, it was either in town, on the motorway, or when changing lanes. Healthy drivers had as many near accidents as incidents, both occurring more frequently during left turns. In all participants, critical events were inversely correlated with the NaDAS score, according to Spearman’s rank correlation coefficient ( $\rho= -0.48$ ,  $p=0.01$ ).

### **Discussion**

Using a naturalistic driving approach, the present study is the first to show that tactical self-regulation behavior was poorer in AD patients than in healthy older drivers. Lower tactical self-regulation reflects a lesser capacity to adapt driving speed, ensure safe distances, change lanes, and appropriately anticipate or plan actions. In this study, all measurements dealing with tactical behavior revealed poorer performance in AD patients compared to healthy controls. This result is indicative of a lower ability to self-regulate.

AD drivers had more difficulty in maintaining an accurate lateral position than healthy older drivers, and this is consistent with previous observations [5, 38, 39]. These difficulties reveal a more specific problem regarding changing lane in an appropriate way. The only accident we observed was caused by an AD patient, and it occurred in this type of circumstance. The driver did not check sufficiently before making a lane change and a rear-end collision occurred. The lane change and left turn maneuvers are particularly challenging since they involve monitoring

several parameters at the same time, namely, checking the state of the traffic in the other lane, initiating the maneuver to change trajectory, and maintaining the speed of the vehicle [40]. These simultaneous actions are highly costly at the cognitive level. As attentional resources are increasingly affected in AD, decision-making and coordinating this type of action sequence can be more hazardous. The difficulty may also arise due to a specific decrease in planning and anticipatory capacity. AD patients, even in the early stages, experience problems in mentally developing logical strategies and in executing complex predetermined plans [41, 42]. This perturbation is interpreted as evidence of a malfunction related to a disconnection of the frontal lobes from the posterior cortex and hippocampal region [43].

Regarding speed control, AD patients adapted their speed less well; they were generally slower than the speed required to ensure good fluidity of traffic. In a study by Eby et al., patients were seen to travel on average around 10 mph (16 km/h) more slowly than surrounding traffic [23]. It could be considered that this general slowing down in traffic is an adaptive behavior, involving self-awareness of slower processing speed. However, this reduced speed may disturb other road users, especially since it has been observed that AD patients slow down abruptly or prematurely [39].

AD patients experienced twice as many critical events as healthy older drivers. Several naturalistic driving studies have demonstrated that the number of critical events is associated with accident risk [16, 44, 45]. Interestingly, in the present study, two-thirds of critical events were considered “unaware” events, in which the driver was observed to have no clear reaction during the event. For instance, in a situation where priority was due to the vehicle on the right, a car arrived, and although the AD participant looked at it, they did not stop, thereby forcing the other driver to brake. There are several possible explanations for the absence of reactions to critical events. Firstly, this behavior might reflect a non-application of the security rules due to a loss of semantic content [46, 47]. Although semantic impairment might not be the first or

most sensitive early indicator of AD, some deficits exist even at the beginning of the disease. This is in accordance with observations made by Barco et al., who observed difficulties in following rules of the road among AD patients [5]. Secondly, the lack of reactions could also be explained by failures to scan the environment properly and the tendency with increasing age to focus attention on a visual field that is too small [48]. Finally, AD patients who exhibited the worst self-regulation had the most critical events. This relationship between a high number of critical events and poorer self-regulation behavior has not been demonstrated before.

This work has a number of strengths. Firstly, this is the first naturalistic driving study in France to focus on AD drivers. Secondly, a major contribution of the study (and the original aim of the study) involved creating a new composite tool to assess driving performance, namely, the NaDAS. There was a good level of agreement between the two assessors in the total NaDAS score. Thirdly, the tactical self-regulation sub-score is particularly interesting for possible use in the context of driving assessments.

One limitation of this study is the sample size. However, studies of naturalistic driving generally have low numbers of participants (range 10–42) [23, 25, 27, 49, 50]. Moreover, we took into account and analyzed the full recordings of each participant, unlike many studies that only analyze samples from recordings. We could have used an automated analysis method, such as that used in recent naturalistic driving studies that actively used objective outcomes that are not reliant upon raters [27, 51, 52]. However, since automatic detection is performed based on behavioral responses and facial expressions, numerous critical events, especially unaware critical events, for which no behavioral reaction is visible, could go unnoticed.

Due to technical problems related to the Global Positioning System (GPS) recording system, our data did not allow us to consider critical events relative to travel time, as Musicant et al. did [44]. However, it can be argued that this does not call into question our results because what seems to be important is the beginning and end of the journey rather than its length [44].



## **Conclusion**

This is the first study using a naturalistic approach to accurately show that AD drivers have poorer tactical self-regulation behavior than healthy older drivers. Future deployment of assistance systems in vehicles should specifically target tactical components in order to help drivers suffering from cognitive deficits. It would be interesting to study how these systems are perceived by older drivers. Test systems could be integrated by manufacturers into driving simulators. Older drivers could thus familiarize themselves with these assistance devices, and become fully operational before taking to the road. These services could even be of use to other categories of road users besides older drivers [53].

**Acknowledgments:** The DriveCog study was conducted under a partnership between the University Hospital Center of Reims, the Strasbourg Hospital, Sainte Perrine Hospital in Paris, the French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR), the University of Lyon, and the University of Bordeaux. We are particularly grateful to Cate Dalmolin for English proofreading.

**Funding:** The DriveCog project was funded by the French National Hospital Research Program (PHRC).

**Author Contributions:** All the authors contributed significantly to the study (conception, design, and interpretation of the data, critical revision of the manuscript for important intellectual content, and approval of the final version). In addition, Laurence Paire-Ficout, Sylviane Lafont, and Fanny Conte contributed to the analysis strategy and drafted the article.

<http://dx.doi.org/10.3233/JAD-171031>

[Journal of Alzheimer's Disease](#), vol. Pre-press, no. Pre-press, pp. 1-10, 2018

**Conflicts of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Table 1: Demographic and reported car mobility characteristics of participants

	AD N=20	Healthy N=21	p-value
Male gender, n	14	13	0.4
Age (years), m (SD)	79.0 (7.0)	77.0 (4.0)	0.3
min-max	70-91	71-85	
Education – $\geq 9$ years at school, n	12	12	0.6
Living alone, n	8	9	0.6
MMSE, m (SD)	26.2 (1.8)	29.0 (0.7)	<0.001
min-max	24-30	28-30	
UFOV*, m (SD)			
Processing speed,	45.9 (30.9)	34.4 (21.4)	0.07
Divided attention	311.2 (161.4)	143.3 (127.1)	0.001
Selective attention	378.9 (129.0)	244.3 (92.3)	0.001
Stroop, m (SD)			
Denomination (error)	1.1 (1.8)	0.1 (0.4)	0.002
Interference (error nb)	6.1 (13.6)	0.4 (0.9)	0.006
Interference (time 100 items)	225.8 (102.2)	131.6 (26.5)	<0.000
DSST, m (SD)	39.2 (14.4)	53.48 (8.6)	0.001
TMT A (s), m (SD)	51.2 (19.1)	38.8 (12.7)	0.02
TMT B (s), m (SD)	168.4 (86.4)	91.7 (25.3)	0.001
TM B error (nb), m (SD)	2.9 (4.1)	0.1 (0.5)	<0.001
Koh's blocks test, m (SD)	19.7 (12.0)	26.9 (4.6)	0.01
Main driver, n	15	12	0.4
Reported distance driven (km/week), n			
<10	5	2	
10–50	6	5	0.4
>50	9	14	
Observed km driven for 15 days, m (SD) <sup>μ</sup>	454.6 (496.9)	403.3 (355.1)	0.1
Observed driving time (h) for 15 days, m (SD) <sup>μ</sup>	8:1 (4:4)	14:6 (21:0)	0.1
Trip frequency per week, n			
Once	2	1	
2–3 times	7	9	0.7
>3 times	11	11	
No reported difficulty in driving, n, max 12	5	5	1.0
No reported avoidance in driving, n, max 12	6	5	0.7

AD, Alzheimer's disease; m, mean; SD, standard deviation; min, minimum; max, maximum; MMSE, Mini Mental State Examination.

UFOV, Useful Field Of View

DSST: Wechsler Digit Symbol Substitution Test

TMT: Trail Making Test

\*: Stimulus presentation time for which 75% of the responses are correct in ms

<sup>μ</sup>: Data from only 13 patients and 14 controls could be analyzed

<http://dx.doi.org/10.3233/JAD-171031>

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Table 2: Driving performance of AD and healthy subjects

	AD N=20	Healthy N=21	p-value
<b>TRIP<sup>1</sup></b> , m (SD)	61.6 (5.2)	66.2 (4.4)	0.005
<b>CDAS<sup>2</sup></b> , m (SD)	60.8 (5.0)	64.6 (4.5)	0.010
<b>NaDAS*</b> , m (SD)	60.8 (5.0)	65.2 (4.5)	<0.001
Operational sub-score	62.6 (8.8)	68.7 (6.4)	0.010
Tactical sub-score	58.0 (6.9)	67.9 (5.5)	0.030
Tactical compensatory sub-score	61.4 (8.4)	67.4 (9.0)	0.030
<i>Lateral position</i>	64.9 (7.2)	71.8 (5.6)	
<i>Safe distance</i>	77.7 (10.6)	80.2 (9.7)	
<i>Speed control</i>	68.6 (19.8)	73.5 (16.9)	
<i>Anticipatory behavior</i>	55.6 (18.8)	57.1 (9.3)	

AD, Alzheimer's disease; m, mean; SD, standard deviation.

<sup>1</sup> Test Ride to Investigate Practical Fitness to Drive

<sup>2</sup> Composite Driving Assessment Scale

\* Naturalistic Driving Assessment Scale



Table 3: Critical events for AD and healthy subjects

	AD N=20	Healthy N=21	p-value
CE			
Number of CEs	25	11	
m (SD)	1.2 (1.3)	0.5 (0.7)	0.02
Number of drivers with $\geq 1$ CE	14	9	
“Unaware” CEs			
Number of “unaware” CEs	18	6	
m (SD)	0.9 (1.2)	0.3 (0.5)	0.02
Number of drivers with $\geq 1$ “unaware” CE	11	6	
Type of CE, n			
Accident	1	0	
Near accident	16	6	
Incident	8	5	
Location of CE, n			
Left turn	2	4	
Right turn	4	1	
Roundabout	7	1	
Priority right	1	1	
Pedestrian crossing	1	1	
Straight road	7	1	
Car park	3	2	

AD, Alzheimer’s disease; CE, critical event; m, mean; SD, standard deviation.