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Driving cessation and self reported car crashes in older drivers: the impact of cognitive impairment and dementia in a population-based study

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Abstract

The complexity of driving activity has incited numerous developed countries to initiate evaluative procedures in the elderly, varying according to first evaluation age, frequency and screening tools. The objective of this paper is to improve the knowledge of the driving cessation process in regard to factors associated with crash involvement. Driving cessation and self-reported crashes during the past five years were analyzed with multivariate models, in a cross-sectional study including a population-based sample of 1051 drivers aged 65 years and more. Visual trouble, Parkinson disease, dementia and stroke history were associated with driving cessation. Future dementia was associated with self-reported crashes only. Attentional and executive deficits were associated with both outcomes. The detection of attentional and executive problems should be included in driving evaluation procedures in order to improve awareness of these deficits by older drivers.

Key Words: driving cessation; self-reported road crashes; attention; executive function; processing speed; dementia; epidemiology; elderly

INTRODUCTION

Driving is a complex task involving perceptual, motor and distinct cognitive abilities which are frequently altered in normal and pathological aging.[1-3] Driving constitutes one of the rare activities for which older individuals must respond over brief temporal durations, constraints that are not present for most of their other daily activities. Driving requires handling a considerable amount of information in a limited period in order to take quick decisions, and necessitates a good level of mental flexibility as well as a continuous state of alertness in order to cope with unexpected events.[2,4-6]

The driving of elderly people is only a problem of concern if those presenting deficits do not adapt their driving behavior, with driving cessation being the ultimate form of adaptation. Older drivers, faced with the decision of giving up driving, are sometimes reluctant to do so because it has become a major component of autonomy. Most developed countries have, therefore, initiated evaluative procedures of elderly people in order to detect deficits which might increase their accident risk.[7] These procedures vary according to the first evaluation age, frequency and screening tools. In countries like France, where such procedures do not exist, there is considerable debate about their eventual introduction. In order to enrich this debate, it is crucial to understand the driving cessation process in aged people, by evaluating the rate of cessation and the role of sensory, motor and cognitive deficits.

The literature has shown that visual[8-12] and motor abilities[9,13-15] constitute major factors in driving cessation. Some cognitive deficits also act as determining factors for driving cessation.[15-18] Whereas sensory and motor deficits have rarely been found to be risk factors of crashes, this is not the case for cognitive deficits, and in particular, visuo-attentional and executive impairments.[1,4,6,19] These findings suggest that individuals may perceive sensory motor deficits more readily than cognitive deficits, and the lack of awareness of cognitive deficits might explain why subjects continue to drive when they encounter such problems. This hypothesis is all the more credible as such disorders are

present among subjects with dementia, which is very frequent during ageing (Alzheimer and vascular type dementia being the most represented). These pathologies are often characterized either by the denial of such difficulties, or by anosognosy whereby subjects are unable to judge their deficits.[20,21] Diagnosis refusal, associated with denial behaviors, is also observed. With the exception of two studies,[22,23] most investigations have reported an increased crash risk among demented drivers.[24-28] If attentional and executive disorders are substantial in pathological aging, they also occur to a much lesser extent, in normal aging[29,30] and may disturb driving activity.[5,6]

In this study, we analyze the factors associated with driving cessation, as well as those associated with self-reported crashes. Specific attention will be paid to the presence of sensory, motor and cognitive deficits, and to the role of neurodegenerative diseases, including dementia.

SUBJECTS AND METHODS

Participants

Study participants were drawn from the Three Cities (3C) cohort. The characteristics and objectives of this prospective cohort study are described in detail elsewhere.[31] Briefly, the main objective of this investigation was to evaluate the risk of dementia and cognitive impairment attributable to vascular factors. Between 1999 and 2001, 9294 non-institutionalized persons aged 65 years and over were recruited from the electoral rolls of three French cities. For the purpose of the present study, only participants from the Bordeaux site were included (n=2104). They were first assessed at home by a psychologist (interview and cognitive evaluation), and then examined at a medical center in order to complete health-related data assessed by a neurologist.

Driving status

At baseline, the participants completed a self-reported questionnaire including questions about leisure, physical exercise and driving activity. Subjects were asked if they were

currently driving, had stopped driving (and if so, for how long), or had never driven. Motor vehicle crashes within the previous five years were noted. Two self-reported variables of interest were defined: 1) having stopped driving during the previous five years and 2) having experienced, as a driver, at least one crash during the same period.

Sensory and motor impairments

The Parinaud reading scale was administered to subjects, with the psychologist asking each subject to read (using glasses if necessary) six paragraphs, each printed in characters of progressively smaller size. The paragraphs were given codes of 10, 8, 6, 5, 4 or 3, ranging from largest to smallest character size. The subject scores corresponded to the code of the smallest, correctly-read paragraph. A score greater than five indicated a near vision impairment (as defined by French ophthalmologists). Far vision deficit was assessed by self-reported problems in recognizing a familiar face at more than four meters. Hearing problems were defined as self-report of difficulties in hearing a person even if she/he speaks loudly. Two Rosow and Breslau[32] questions were used to determine whether subjects were limited in their ability to walk 500 meters-1 kilometer and to walk up or down two flights of stairs.

Neuropsychological evaluation

Neuropsychological tests were completed at home with a psychologist. Most tests, initially chosen to detect dementia-related cognitive impairments, also involve functions previously associated with safe driving. Global intellectual functioning was assessed using the Mini Mental State Examination (MMSE[33]). The questions are grouped into seven categories, each representing a different cognitive domain: time orientation (five points), place orientation (five points), repetition of three words (three points), attention and calculation (five points), recall of the three words (three points), language (eight points) and visual construction (one point). Visual working memory was explored using the Benton Visual Retention Test[34] presenting 15 stimulus cards of one or three geometric figures and 15 multiple-choice cards. After presentation of the stimulus card for 10 seconds, subjects are

asked to choose the initial figure from one of four possibilities. Scores range from 0 to 15. Verbal semantic fluency was explored using the Isaacs Set Test[35] in which subjects are asked to generate words in four semantic categories (colors, animals, fruits and cities) within a limited time. In the present analysis, the sum of the four categories at 60 seconds was used. Information processing speed and mental flexibility were assessed using Trail Making Test parts A and B (TMT-A and TMT-B[36]). The task of TMT-A was to connect randomly located circles with numbers (1-25) in numerical order as fast as possible. In TMT-B, the subjects had to alternately connect circles with numbers (1-13) and letters (A-L) in their respective sequences as fast as possible. Before each part of the test, a pre-test was given to ensure instructions had been understood. During the test administration, the psychologist rectified participant errors for the four first connections only. Then, contrary to the usual procedure, the psychologist allowed subjects to continue the task without any further help or rectification. The time taken to complete the test was recorded as well as each transition, correct or not, between items. As the number of transitions varies for each subject, the total is not appropriate. We therefore divided the total time by the total number of transitions in order to obtain a more accurate measure of processing speed. Each transition between any two items was then analyzed using the approach described in Amieva and al.[37] This enabled the number of correct transitions (out of 24) and the number of perseveration errors in TMT-B to be determined. These errors, which consist of failures to alternate between the series of numbers and letters, suggest a deficit in switching mechanisms. When subjects did not complete at least ten transitions, the test was classified as “no response”. Subjects with such “no response” tests were not, however, excluded from the models because refusal or inability to complete a test may be related to cognitive impairment.[38]

Diagnosis of dementia

All participants were examined by a neurologist in accordance with a standardized clinical protocol. Further data on cognitive functioning and daily activities, severity of cognitive

disorders (Clinical Dementia Rating Scale)[39] and, whenever possible, magnetic resonance images were collected. Finally, the diagnosis and classification of prevalent dementia cases were established by the 3C-Study investigators on the basis of DSM-IV criteria.[40] In the follow-up examination, conducted two years after the baseline examination, the same procedure was used to detect incident dementia cases. This follow-up allowed us to determine retrospectively which drivers had a future dementia status at baseline (normal at baseline but having reached a demented stage two years later). All the prevalent and future cases were classified according to dementia subtypes (Alzheimer, vascular, frontotemporal, and Lewy Body dementia). At baseline, as well as two years later, these diagnoses were further validated by a group of independent expert neurologists.

Medical conditions and drug use

Health variables were collected by a nurse and a neurologist at the medical evaluation. Central Nervous System (CNS) diseases were included in the analyses in order to determine whether they have an effect on driving cessation and crash involvement independently of cognitive performance. Self-reported variables related to stroke, head trauma with amnesic disorders lasting more than 24 hours, Parkinson's disease and diagnoses of prevalent and future dementia were combined in the following way: when dementia occurred either alone or with one of the three other pathologies, subjects were classified in the dementia category; when Parkinson's disease occurred either alone or with stroke or head trauma, subjects were classified as having Parkinson's disease; when stroke occurred alone or associated with head trauma, subjects were included in the stroke category. Diabetes and heart disease, found in the literature to be associated with driving cessation,[10-12] were also taken into account. Depression, assessed by the psychologist using the 20-item Center for Epidemiologic Studies Depression Scale (score between 0 and 60),[41] was also analyzed. We used validated scores of over 16 for men and 22 for women, to indicate a depressive symptomatology.[42] The examination included an inventory of all drugs used during the preceding month; these were coded in accordance with the French

translation of the WHO ATC classification.[43] We were particularly interested in drugs with central nervous system effects, in particular epileptic and psychiatric medications (e.g. antidepressants and benzodiazepines). Drugs with skeletal relaxants or anti-inflammatory effects were also analyzed.

Socio-demographic and driving exposure variables

Socio-demographic variables were collected at home by a psychologist: age, gender, living arrangements (living alone or not) and education. Age was considered as a continuous variable and education was coded into two levels: no schooling or primary school level was considered as equivalent to 0-5 years of schooling, and secondary school or university level was considered as equivalent to 6 years of schooling and over. Participants were asked about their driving exposure if they were still driving at baseline. Driving frequency was assessed in number of days per week: 0-1 day per week, 2-3 days, or every day. Driving distance was coded into four classes based on the number of kilometers driven yearly: <3500 kms per year, 3500-7000, 7000-20000, or >20000. An additional class of “no response” was created for each variable.

Statistical analysis

Driving cessation analyses were conducted for current drivers who were still driving at baseline, and also for subjects who had stopped driving within the previous five years. Crash involvement in the same interval of five years was explored for current drivers only. Given the retrospective design of our study, it appeared important not to exceed five years between the cognitive evaluation and driving cessation or a crash. The characteristics of subjects who had ceased driving and those who had not were compared using t-test for quantitative variables and Chi-2 or Fisher exact tests for qualitative variables. Cognitive variables were analyzed as qualitative variables rather than quantitative variables. It is generally considered that a difference of five points between 25 and 30 on the MMSE, for example, is not equivalent in terms of deficits to a difference of five points between 18 and 23. Consequently, as continuous variables suppose a linearity of calculated risks, the

concept of deficit threshold with a two-modality variable (good / poor performance), was more adapted to our aims. Moreover, qualitative treatment of the variables makes it possible not to exclude those subjects who refused or did not complete the test. Previous work has shown that such subjects have a lower cognitive level than those who complete the test.[38] In the context of the present study, it appeared interesting to include the total population of subjects. In order to determine the two modalities, the threshold which displayed the best separation between subjects who had ceased driving and those who continued driving, was computed using the maximum likelihood for the univariate logistic regression model. The -2 Log Likelihood statistic has a chi-square distribution under the null hypothesis (the explanatory effect in the model is zero). A one-point step was used for the MMSE, Benton, Isaac set test, for correct transitions in TMT-A and B, and also for perseverations in TMT-B; a 0.5-second step was used for time per transition in TMT-A and B.

Multivariate analyses were performed using logistic regression models. Socio-demographic, sensory-motor, medical conditions and cognitive variables, found to be statistically significant at p=.10 level in bivariate comparisons, were included in the multivariable model. Odd Ratios (OR) with corresponding 95% confidence intervals (CI 95%) were calculated. Factors associated with crash involvement were analyzed following the same procedure. Finally, two complementary analyses were carried out in order to test the robustness of our results. In the first of these analyses, demented and future demented subjects were excluded from the sample. In the second analysis, subjects with poor episodic memory - subjects who did not recall any of the three words of the MMSE or just one word only - were excluded. These complementary analyses were applied to each of the two outcomes, driving cessation and crash involvement. All the analyses were performed using SAS, version 9.1 (SAS Institute, Inc., Cary, NC).

RESULTS

Sample description

Out of 2104 participants in the 3C-Bordeaux cohort, 1649 completed the whole questionnaire, including the part devoted to driving safety. Respondents were significantly younger than non-respondents (73.7 years ± 4.9, 75.6 years ± 5.6, p<.001); they were more often male (40.1% vs. 34.1%, p<.02); and their educational level was higher (66.7 % of secondary level or more vs. 52.8 %, p<.001). Of the 1649 respondents, 76.0 % had a driving licence and among them 21.4 % no longer drove at baseline. The mean age at the time of driving cessation was 75.1 years (SD=5.2). Of the sixty-two percent of women who had a driving licence, 34 % had stopped driving at 74.5 years old (SD=4.9). Almost all the men (96 %) had a driving licence, with 9 % of them having ceased driving at 77.5 years old (SD=5.4).

Of the 1051 subjects who had driven during the past five years, 16 individuals were diagnosed as demented at baseline (MMSE mean=23.1, SD=3.6), eight had Alzheimer's disease, four had mixed dementia, three had vascular dementia and one had Lewy-body dementia. Of these 16 prevalent demented subjects, eight were driving at baseline (MMSE mean=25.2, SD=2.9). Seventeen individuals were diagnosed as demented two years after their inclusion (MMSE mean=25.8, SD=1.5), nine with Alzheimer's disease, one with mixed dementia, three with vascular dementia, one with dementia associated with Parkinson's disease, one with Lewy-body dementia and two with other types of dementia. Of these 17 future demented subjects, 14 were driving at baseline.

Driving cessation

Of the 1051 subjects who drove during the previous five years, 65 had ceased driving activity at the time of inclusion (6.2 %). With the except of education, crash history, hearing impairments, head traumatisms, diabetes, psychotropic and inflammatory drugs, all the other variables differed significantly for those subjects who continued driving and those who stopped (Table 1).

Insert Table 1 here

The significant thresholds of cognitive variables found to best describe driving cessation were: MMSE < 27, BVRT < 11, IST < 57, TMT-A: time/transition ≥ 3.5, correct transition < 23, TMT-B: time/transition ≥ 7, correct transition < 22, perseveration ≥ 2 (Table 2). Individuals who stopped driving had lower performances for all cognitive variables compared to those who pursued their driving activity.

Insert Table 2 here

The two TMT-A variables were combined before their inclusion in the multivariate models. In the multivariate model, higher age, female gender, far vision deficit, TMT-A (time per transition ≥ 3.5 or correct transition ≤ 22) and anti-epileptic consumption were significantly associated with driving cessation (Table 3). A difference of 10 years in age increased the probability of driving cessation by more than fivefold. Parkinson's disease, stroke history, or dementia diagnosis at baseline were strongly associated with driving cessation. Living arrangements, near vision, motor deficits, heart disease, depressive symptomatology, drug use, BVRT and future dementia, were no longer associated with driving cessation.
When demented and future demented drivers were excluded (n=34), visual working memory, explored using the BVRT, was associated with driving cessation in the multivariate model (OR=2.0, IC95%=1.1-3.7, p<.03). The same non-cognitive variables were significantly associated with driving cessation. When subjects with poor episodic memory were excluded (n=375), the validity of the model fit was questionable, even if the same tendencies were found, because only 35 of the remaining subjects had ceased driving.

Insert Table 3 here

Crash involvement

Some 240 current drivers had experienced at least one crash within the last five years (24.3 %), with 19 of them having been involved in a crash with at least one injured individual (7.9 %). Fifteen percent had experienced one crash, 5.6 % two crashes, 2.0 % three crashes and 1.5 % four or more crashes. Drivers who had experienced crashes were older, less educated, and drove more frequently than those who did not (Table 1). Men and future demented drivers had crashes more frequently. Although driving distance was also significant, it was not retained in multivariate analysis because the likelihood criterion was smaller than that of driving frequency. Drivers who consumed skeletal relaxants or anti-inflammatory drugs had crashes more frequently (significant limit, p<.10). Significant thresholds of these cognitive variables were the following: IST < 45, TMT-B: correct transitions < 6, perseverations ≥ 5. The poor cognitive performances rates of persons with crashes and those without were respectively 3.4 % and 7.2 % for IST, 0.6 % and 3.1 % for the correct transitions, 0.4 % and 2.6 % for perseverations.

In the multivariate model, greater age, poor education, high frequency driving and poor performance at the TMT-B (correct transitions < 6 or perseverations ≥ 5) were significantly associated with crash involvement (table 4). As for pathologies, future dementia was the only one significantly associated with crash involvement.

When demented and future demented drivers were excluded (n=22), the same variables were found to be significantly associated with crash involvement; as was poor performance at the TMT-B (correct transitions < 6 or perseverations ≥ 5, OR=8.3, IC95%=2.4-29.0, p<.001). When subjects with poor episodic memory were excluded (n=347), the threshold for perseveration errors was lower (≥ 3). The same variables were significant with a lower odd ratio for the combined variable of the TMT-B (OR=2.1, IC95%=1.0-4.3, p<.001).

Insert Table 4 here

DISCUSSION

The results of this study showed that for this population living at home, with a mean age of 75, driving cessation is not rare: 21 % of the population had ceased driving since they had first obtained their licence, and 6 % within the last five years. Despite several limitations, our study nonetheless provides a new contribution to the knowledge base regarding the decision to stop driving. The results suggest that deficits uniquely associated with driving cessation are perceived by the subjects or their family circle, and taken into account in the process of giving up driving. Conversely, deficits associated with self-reported crashes seem to be insufficiently taken into account.

Factors associated with driving cessation only

Female gender, near-sightedness, dementia, Parkinson's disease and stroke were exclusively associated with driving cessation. Women ceased driving more readily than men and those who continued did not have a higher crash risk than men. Hakamies-Blomqvist and Wahlström have shown that women reported more frequently feelings of stress in traffic than men.[44] Furthermore**,** for their generation, they often had less driving experience than men, which may explain a greater lack of confidence in their driving abilities.

As in our study, other authors have found that subjects with visual problems quit driving[8-10,45] and do not have a higher crash risk.[1,19,46,47] A recent review shows that findings about the associations between various measures of visual function and driving safety are inconsistent, and the authors concluded that visual tests used in isolation are not strong predictors of crash involvement.[48] This pattern of results suggests that visual deficits frequently lead to the decision to cease driving.

Dementia, Parkinson's disease and stroke were major factors involved in driving cessation. When they did not stop driving, subjects with these pathologies did not report more crashes than drivers without these pathologies. Parkinson's disease has previously been found as a

major factor of driving cessation[49] and as a non-significant factor in crashes.[50,51] But Zesiewicz et al. have shown that advanced Parkinson's disease patients were more at risk of crashes, owing to both motor and cognitive dysfunctions.[52] The high rate of driving cessation after a stroke was consistent with other studies.[11,12,49,53] Stroke survivors seemed to limit their driving exposure and/or rely on others for transportation, suggesting self-regulated behavior. As in our study, two studies failed to find a significant association between strokes and road crashes,[46,50] but two others did.[47,54] Differences in stroke prevalence, ranging from 2.5 % to 10 %, could explain this controversial result.

Finally, consistently with several authors, we found dementia to be a major factor of driving cessation.[9,55] But**,** unlike our study and that of two others,[22,23] most studies have found an increased crash risk among demented drivers.[24-28] However, comparing the results of the different studies is difficult due to variability in study design, as well as the type and/or the severity of dementia examined. In our study, demented subjects who had ceased driving were more impaired (mean MMSE =20.7, SD=2.8) than those who continued driving (mean MMSE=25.2, SD=2.9). For the latter group, it is possible that some of them had reduced their driving activity because of self or family-imposed restrictions, either of which may explain the absence of a significant association with crashes. One cannot, however, totally exclude a potential recall bias as demented patients have memory deficits. Although we did not collect additional information from the informant's family, six of the eight demented subjects at baseline were living with their spouses. As couples were included in the 3C-study and both individuals were visited at home within the same day, it would seem reasonable to suppose that the couples filled out the questionnaire together. In addition, the responses of six of the eight demented subjects were judged reliable by the psychologist.

<u>Factors associated with self-reported crashes</u>

Greater age and poor attentional and executive performances were associated with both crash involvement and driving cessation.

Despite the high rate of driving cessation with advancing years, the oldest individuals who maintained their driving activity seemed to be slightly more at risk of an accident. Age has been found to be a major factor of driving cessation in most studies, whereas the relationship between age and crash involvement is more controversial, with significant associations in some investigations [6,46,56,57] and non-significant associations in others.[19,47,54] In our study, despite adjustments for age-related factors such as neurodegenerative pathologies, the association between age and crash involvement remained significant among the oldest participants. A difference of 10 years in age increased the risk of crash involvement by 50%.

Poor attentional and executive performances, assessed using TMT, constituted the second variable after age to be most associated with both driving cessation and self-reported crashes. A reduction in processing speed or failure at the TMT-A emerged as the best cognitive indicators of driving cessation, independently of the presence of CNS diseases. Few authors have explored the effects of cognitive performances on driving cessation, but a recent prospective study showed than poor symbol recall, poor processing speed and immediate recall were the strongest predictors of driving cessation at two years.[15] Stutts et al. have also demonstrated that slower individuals at TMT-A reduced their mobility and avoided certain driving situations.[6] It is reasonable to hypothesize that the reduction in processing speed is not perceivable in itself, perhaps because it progresses slowly in the course of aging. It may, however, render driving tasks more difficult, especially tasks where multiple sources of information need to be processed in a limited time. This increased difficulty may lead some subjects to avoid such situations and ultimately to cease driving. On the other hand, individuals with five perseverations or more, or with fewer than six correct transitions at TMT-B (corresponding to very low performance) were more likely to be involved in a crash. Low performances at TMT-B have already been shown to be associated with crash risk in older people.[5,6,58] TMT, with its two parts**,** A and B, is one of the most popular neuropsychological tests. Part A and part B share common components

such as visual scanning, visual search, processing speed, selective attention and planning. TMT-A is however much easier, because the subjects have to follow the automatic order of numbers. TMT-B is more difficult because it involves additional components such as inhibition and mental flexibility, with subjects having to counteract the automatic following of both number and letter series in order to alternate between them. The decrease in the common components involved in both parts of TMT may render driving a particularly arduous task, and encourage some drivers to cease driving altogether. On the other hand, the cognitive deficits of those who do not stop may reach a stage where flexibility errors appear, thereby putting them more at risk of a crash.

Male gender, poor education and future dementia were exclusively associated with self-reported crashes. Men ceased driving less frequently than women, and those who continued had a higher crash risk. Whatever their age, men are known to have a higher crash risk.[54,59,60] It is not rare in couples to see women stop driving before their husbands, whereas the husbands more often drive as long as possible to maintain family mobility. The social representation of the driving activity for men may also make it more difficult to stop driving. In our study, drivers with a low educational level have a significantly increased crash risk compared to drivers with secondary educational level or above. In spite of the strong relationship between education and cognitive performances,[61,62] no study has taken education into account in determining crash risk. As for driving cessation, our results are consistent with two studies that also failed to find a significant association with education,[14,15] although one study found that older adults who restrict their driving had fewer years of education.[45]

Finally, future dementia was the only pathology found to be significantly associated with self-reported crashes in our study. The relationship was not explained by age, gender, education, driving frequency, speed of treatment and executive function as explored here. Indeed, mild attentional and executive dysfunctions were repeatedly found many years

before dementia diagnosis.[63] Vogel et al. have demonstrated an impaired awareness of cognitive deficits among patients with mild cognitive impairments,[64] which may partly explain an insufficient adaptation of drivers with mild attentional and executive impairments.

Limitations

Our findings, based on cross-sectional data analyses, do not permit conclusions relative to the causal relationships underlying driving cessation or crash involvement. On the other hand, although the follow-up of the cohort was not sufficiently advanced to analyze driving cessation prospectively, the retrospective design spanned 5 years and allowed a sufficient number of cases of driving cessation to be analyzed (n=65). The source of information used to identify drivers involved in a crash may be a second limitation in our study. In France, links with individual crash records or insurance data are not available. Self-reports therefore constitute the only way to obtain information about crashes for specified individuals. Two studies have analyzed the discrepancy between self-reported and official crash data[65,66] and concluded that self-reports may provide a reasonable alternative to state-records, while some reservations have been voiced concerning the different level of risk that may exist between the two sources.[66] In the case of demented subjects, as previously mentioned, we can not exclude a potential recall bias. However, two complementary analyses (one excluding the demented and future demented subjects, and one excluding subjects with poor episodic memory) showed that if such a recall bias did existed, it did not invalidate the results for non-demented drivers.

Another limitation of this investigation is that we have no information about crash responsibility. According to the percentages given by Foley et al., only half of our drivers would be held responsible. [54] However, the legal concept of responsibility does not directly reflect driving ability. The capacity to avoid other people's driving errors and, more generally, the ability to anticipate their behaviors, are both vital for driving activity.

A final limitation of our findings relates to the low prevalence of certain pathologies or deficits in the population, possibly leading to reduced statistical power.

Conclusion

The presence in older drivers of vision difficulties, Parkinson disease, dementia and stroke history were associated with driving cessation. These findings suggest that deficits and/or their repercussions on driving tasks are perceived either by subjects themselves or by their family circle. Future dementia was the only pathology likely to be associated with self-reported crashes but not associated with driving cessation. Cognitive deficits may not be salient enough to be perceived and acknowledged either by subjects or their families at this stage. Attentional and executive deficits were associated with both driving cessation and crash involvement. Such deficits, which are more difficult to perceive than visual or motor problems, may become increasingly obvious when drivers encounter greater difficulty and fatigue when driving. Aside from awareness of disorder, social characteristics such as gender and educational level also seem to interfere with both outcomes. The detection of attentional and executive deficits should be included in driving evaluative procedures in order to help older drivers to become aware of their specific vulnerabilities and encourage them to modify their driving habits accordingly.

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Table 1. Characteristics of Study Subjects by Driving Cessation and Self-Reported Crashes.

Characteristics, %		No driving cessation N=986	Driving cessation N=65	Non-crash involvement N=746	Crash involvement N=240
Age, mean ± SD		72.8 ± 4.5	77.0 ± 5.3 *	72.6 ± 4.5	73.4 ± 4.7 *
Female		41.5	53.8 ¥	44.5	32.1 *
Primary level [(1)]		25.3	20.0	22.4	34.6 *
Live alone		28.4	41.5 *	28.0	29.6
Driving frequency	≤ 1 day			11.9	10.0
(per week)	2-3 days			38.1	48.7 *
	every days			25.9	38.7
	no response			24.1	2.5
Crash in the past five years		24.3	20.0		
Sensorial deficits	near vision	0.4	4.6 **	1.7	2.9
	far vision	1.7	12.3 ***	1.7	2.9
	hearing	3.4	6.1	2.9	5.0
Motor deficits	walk 0.5-1 km	3.4	18.5 ***	3.5	3.3
	walk up/down two stairs	4.6	21.5 ***	4.7	4.2
CNS disease [(2)]	no	90.3	64.6	90.3	90.0
	Parkinson	0.6	4.6 **	5.1	4.6
	stroke	4.9	4.6	2.4	1.7
	prevalent dementia	2.0	9.2 **	0.8	1.2
	future dementia	0.8	12.3 ***	0.8	0.8
		1.4	4.6 *	0.9	2.9 *
Depressive symptomatology		4.9	10.8 *	5.4	3.3
Diabetes		7.3	10.8	7.1	7.9
Heart disease		17.3	30.8 **	17.7	16.2
Medication	anti-epileptics	1.6	12.3 ***	1.1	0.4
	benzodiazepine	19.7	21.5	19.7	19.6
	antidepressant	6.0	10.8	6.0	5.8
	relaxant/anti-inflammatory	9.4	6.1	8.4	12.5 ¥

Note: [(1)] **equivalent to 0-5 years schooling;** CNS=Central Nervous System; [(2)] every pathology was individually compared to the reference category (no CNS disease); t-test and chi-2 or Fisher test exact: ¥ p< 0.10, * p<0.05, ** p<.01, *** p<.001

Table 2. Cognitive Variables: Thresholds Significantly Associated with Driving Cessation and Percentage of Poor Performance Among the Two Groups

		No driving cessation	Driving cessation
Cognitive variables		%	%
MMSE < 27		18.3	39.1
BVRT < 11		23.3	48.4
IST	< 57	20.0	41.5
TMT-A	time ≥ 3.5	8.7	29.2
	correct < 23	2.5	9.2
	not done	3.4	10.8
TMT-B	time ≥ 7	12.5	33.8
	correct < 22	27.4	41.5
	perseverations ≥ 2	10.6	21.5
	not done	4.8	15.4

Note: MMSE=number of correct responses to Mini Mental State Examination (out of 30); IST =number of correct responses given in 60 seconds to Isaacs Set Test; BVRT=number of correct responses to Benton Visual Retention Test (out of 15); TMT-A time (TMT-B time)=total time divided by the total number of transitions at the Trail Making Test-part A (part B); TMT-A correct (TMT-B correct)=number of correct transitions at the TMT- A (B) (out of 24); TMT-B perseverations=number of perseveration errors at the TMT-B

Table 3. Factors associated with Driving Cessation: multivariate model, N=1051 Drivers in the Last 5 Years

		OR	(CI 95%)
Age (years) †		1.18	(1.11-1.25)***
Gender	female vs. male	3.1	(1.7-5.6)***
Far vision		7.0	(2.4-20.1)***
TMT-A	time ≥ 3.5 or correct ≤ 22	2.9	(1.5-5.6)**
CNS disease	Parkinson vs. no	17.0	(3.6-81.4)***
	head trauma vs. no	1.4	(0.4-5.0)
	stroke vs. no	4.2	(1.4-12.7)*
	prevalent dementia vs. no	13.9	(4.0-48.8)***
	future dementia vs. no	1.9	(0.5-7.7)
Epileptics		5.8	(1.4-23.5)*

Note: † odds ratios reflect a one-year increase; TMT-A time=total time divided by the total number of transitions at the Trail Making Test-part A; TMT-A correct=number of correct transitions at the TMT-A (out of 24); CNS=Central Nervous System; * p<.05, ** p<.01, *** p<.001

Table 4. Factors associated with Self-Reported Crashes: multivariate model, N=986 Current Drivers

		OR	(CI 95%)
Age (years) †		1.04	(1.01-1.08)*
Gender	female vs. male	0.7	(0.5-1.0[*
Education	≤ primary vs. ≥ secondary	1.6	(1.1-2.2)**
Driving frequency	2-3 days vs. ≤ 1 day	1.6	(1.0-2.8)
(per week)	every days vs. ≤ 1 day	2.0	(1.2-3.4)*
	no response vs. ≤ 1 day	0.1	(0.1-0.3)***
TMT-B	correct < 6 or perseverations ≥ 5	7.7	(2.5-24.0)***
CNS disease	Parkinson vs. no	1.0	(0.2-6.3)
	head trauma vs. no	1.0	(0.5-2.1)
	stroke vs. no	0.5	(0.1-2.1)
	prevalent dementia vs. no	0.4	(0.1-3.0)
	future dementia vs. no	3.4	(1.0-11.4)*

Note: † odds ratios reflect a one-year increase, a difference of 10 years in age increased the risk of crash involvement by a factor of 1.5; TMT-B correct=number of correct transitions at the Trail Making Test-part B (out of 24); TMT-B perseverations=number of perseveration errors at the TMT-B; CNS=Central Nervous System; * p<.05, ** p<.01, *** p<.001