Driving Abilities in Frontotemporal Dementia Patients

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Key Words

Dementia · Dementia, frontotemporal · Driving · Frontal lobe

Abstract

Objective: To evaluate driving competency and the relationship between neuropsychiatric symptoms and driving behavior in frontotemporal dementia (FTD) patients. **Methods:** Fifteen patients with a diagnosis of FTD and 15 healthy controls were administered a driving simulation task. Measures of driving performance and neuropsychiatric symptoms were assessed. **Results:** The FTD patients received more speeding tickets, ran more stop signs and were involved in more off-road crashes and collisions than the controls. The patients' overall average speed was significantly higher. Driving performance was correlated with agitated behavior. **Conclusions:** Behavioral changes characteristic of FTD patients have an impact on their driving skills leading to inappropriate driving behavior.

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Introduction

The driving competency of patients with dementia has become a major public safety concern [1–3]. As a complex task, driving requires a range of cognitive functions. Visual attention, visuospatial skills and executive functions

appear to be strongly related to driving ability [4–7]. Unsafe driving in dementia patients has been related to cognitive decline. To date no cognitive function or neuropsychological battery has proved to accurately predict driving fitness [8–10]. Dementia patients, in addition to a progressive decline in cognitive functions, may also demonstrate personality and social-cognitive impairment, but we know little about their impact on driving abilities [11, 12].

Frontotemporal dementia (FTD) is the second most common cause of primary dementia in the presenium [13, 14]. Its clinical expression is determined by the particular distribution of pathology affecting the frontal and/or temporal lobes. Two major FTD syndromes are recognized: a frontal variant (fvFTD) and semantic dementia or temporal variant (tvFTD) [15–18]. Typically, patients with predominant involvement of the frontal lobes (fvFTD) are characterized by profound changes in personality and executive dysfunction [18–20]. Semantic dementia patients are characterized by a progressive fluent aphasia and loss of semantic knowledge secondary to degeneration of the temporal neocortex [21–23].

Neuropsychiatric symptoms appear to differentiate FTD from other dementia syndromes [24–26]. Prominent changes in behavior and personality may appear even without changes in cognitive functioning in fvFTD [27, 28]. Compared to Alzheimer's disease, fvFTD patients are more likely to be depressed, agitated, irritable and disinhibited and to socially withdraw [29]. Using be-

Table 1. FTD demographic data and average scores on test battery

	Mean $\pm$ SD	Range
Age, years	56 $\pm$ 7.5	39–67
Education, years	16 $\pm$ 2	16–20
Disease duration, years	4.2 $\pm$ 1.6	2–8
WAIS-III full scale IQ	84 $\pm$ 14	67–121
Mattis Dementia Rating Scale total score	118 $\pm$ 17	90–142
Semantic Fluency	39 $\pm$ 29	5–107
Phonemic Fluency	23 $\pm$ 16	5–55
Boston Naming Test	41 $\pm$ 22	5–60
WMS-III general memory index	73 $\pm$ 17	49–103
Token test	87 $\pm$ 11	68–99

havioral scales such as the Frontal Behavioral Inventory, Kertesz et al. [30] found that lack of insight, inflexibility, personal neglect and disinhibition were the most common neuropsychiatric symptoms seen in FTD. Recently it has been reported that behavioral changes are prominent in the frontal and temporal variants of the disease [31–33]. Ritualistic behaviors, increased appetite, changes in food preference, disinhibition, social withdrawal and poor self-care were found to be equally prevalent in both [32, 34].

Most studies have related driving difficulties to cognitive dysfunction in dementia patients [35–37]. However, the impact of neuropsychiatric symptoms has been relatively ignored. Although antisocial behavior in FTD has been related to illegal driving acts, driving difficulties have not been systematically studied in this dementia group [38]. The objective of this study is to examine the driving behavior of FTD patients under common simulated driving conditions. We hypothesized that FTD patients would show poor driving performance. Moreover, personality and social cognition deficits in this population would have an impact on their driving abilities.

Methods

Subjects

Fifteen FTD patients (10 men and 5 women) with a diagnosis according to accepted clinical criteria were included in the study [39]. All patients were referred to the cognitive neuroscience section. The average disease duration was 4.2 $\pm$ 1.6 years (range 2–8). At evaluation, 10 patients (67%) were still driving, and 5 had recently stopped.

Table 2. NBRS factor scores

NBRS factor scores	FTD (n = 15) mean $\pm$ SD
Cognitive impairment	15 $\pm$ 6
Agitation	8 $\pm$ 3
Retardation	5 $\pm$ 3
Depression	5 $\pm$ 3
Apathy	6 $\pm$ 3
Psychosis	3 $\pm$ 2
Lability	3 $\pm$ 2
Total score	56 $\pm$ 14

As part of the FTD protocol, all patients received a neurological and neuropsychological evaluation. No significant motor abnormalities that could interfere with the driving task were found. The neuropsychological evaluation included the Mattis Dementia Rating Scale [40], Phonemic Fluency, Semantic Fluency, Boston Naming Test, Token Test, Wechsler Adult Intelligence Scale-III (WAIS-III) [41] and Wechsler Memory Scale-III (WMS-III) [42]. For the purpose of this study only the dementia severity as assessed by the Mattis Dementia Rating Scale was considered. The FTD patients' data are presented in table 1.

Neuropsychiatric symptoms were assessed using the Neurobehavioral Rating Scale (NBRS), a 28-item clinician-rated instrument used for the assessment of severity of neuropsychiatric features on a scale from 0 (not present) to 7 (extremely severe) [43]. Confirmatory factor analysis has revealed 7 NBRS factors in patients with dementia: cognitive impairment, psychosis, agitation, retardation, depression, apathy and lability [44]. The agitation factor includes 4 items: disinhibition/aggression, agitation, hostility and excitement. The apathy factor includes expressive deficit and emotional withdrawal. The FTD patient scores on the different factors of the NBRS are presented in table 2.

Brain MR images were obtained for all the patients. Distribution and severity of atrophy was assessed in order to correlate this measure to driving variables. A neuroradiologist (N.P.), who was blind to the patients' data, rated the MRI scans based on visual inspection. Atrophy severity was assessed on a 4-point scale: 0 = no atrophy, 1 = mild, 2 = moderate and 3 = severe atrophy. Frontal and/or temporal atrophy was present in 11 patients. In 4 patients the MRI was read as normal. The distribution of atrophy was predominantly frontotemporal in 6 patients, bifrontal in 3 and bilateral anterior temporal in 2.

The patients were matched for age, education and gender with 15 healthy volunteers who were recruited and compensated following the guidelines of the Clinical Research Volunteer Program of the Clinical Research Center, National Institutes of Health. The volunteers were screened for neurological disorders, psychiatric problems and other serious medical conditions.

The 2 groups did not differ significantly by age ($p = 0.86$) or education ($p = 0.80$).

Fig. 1. Driving simulator: road view as seen by the participant.

Driving Simulation Task

Driving was assessed in all participants using version 8 of the Low-Cost Driving Simulator from Systems Technology, Inc. [45]. The simulator consists of a computer screen showing an image of the road as seen by the driver, a steering wheel with a horn in the center, a turn signal to the left of the wheel and 2 pedals at the feet, the accelerator on the right and brake on the left, as they would appear in a normal automatic transmission car. In the top right corner of the computer screen there is a simulated rear view mirror. Along the bottom of the screen, the driver can see the front part of the car and the current speed in miles per hour (fig. 1).

The simulation depicts a 2-lane road in 1 rural and 2 urban driving settings and exposes the driver to various real-life driving situations. There are 12 stoplights, 8 with pedestrians crossing, and 10 stop signs. Five pedestrians enter the roadway from the left, 5 from the right, and another 10 remain on the sides of the road. Twelve billboards displaying boldfaced words are strategically placed throughout the simulation and appear equally on the left and right sides of the road. The speed limit is posted at 7 points in the simulation. Speed is monitored continuously. A ticket is issued if the driver exceeds the speed limit by ≥ 10 m/h (16.09 km/h). Traffic situations include 8 slow-moving or stationary vehicles ahead of the driver, moving in the same direction, and 25 vehicles approaching in the opposite lane. The road curves 12 times to each side. The total distance of the simulation is approximately 13.25 miles (21.32 km).

At the end of the task, the program provides a summary of the driver's errors such as the total number of collisions, off-road accidents, and traffic light and speeding tickets. A detailed profile of the driving performance was generated with information sampled every 2 s. These raw data were analyzed for abnormal behavior such as haphazard stopping, running stop signs and unusual variations in speed that would not be included in the summary report.

Following completion of the task, the examiner recorded the total number of billboards the subject could recall with and without cues. This score reflects the memory component of the driving simulation task.

Procedure

The examiner fully explained the location and use of each part of the simulator and instructed the subjects to abide by all traffic laws and to act as if they were driving an actual car. The subjects were warned that speed limits would be strictly enforced during the simulation, such that a siren would sound and a ticket would be issued should they exceed the posted speed by >10 m/h (16.09 km/h). No a priori information was provided regarding the billboards. Upon inquiry the examiner informed the subjects that the signs were just for scenery. The subjects practiced during a warm-up section of 500 ft (152.4 m) to get used to the handling of the simulated car. When the subjects felt comfortable operating the vehicle, they began the full-length simulation.

Upon completion the subjects were reminded of the billboards scattered throughout the simulation and were asked to recall any words from the billboards that they could remember. A recognition test was then administered. The subjects were shown 12 cards, each containing a word that appeared in the simulation along with 3 other choices, and instructed to choose the word that appeared during the simulation.

Results

Between-group comparisons on speed, speeding tickets, pedestrian hits, traffic light tickets and number of billboards recalled after the simulation were performed with multivariate analysis of variance (table 3). Age was entered in the model as a covariate. Multivariate Pillai's trace statistic yielded an overall significant difference in performance between groups ($F_{1,28}$, $p = 0.001$).

Because the raw data indicated that several FTD patients randomly stopped driving for variable lengths of time throughout the simulation, the average velocity while moving was calculated. Univariate analysis demonstrated that the average velocity while moving was significantly higher for the patient group ($F = 4.5$, $p < 0.05$). Further demonstrating the abnormal stop-and-go behavior observed in the patient group, there was a significant difference in speed variability, as reflected by the standard deviations of velocity ($F = 17.6$, $p < 0.001$) calculated for both groups. Accordingly the patients received more speeding tickets ($F = 10.7$, $p = 0.003$). No difference was found for the number of pedestrian hits or traffic light tickets issued between the groups. The FTD patients remembered fewer words on both the free recall ($F = 18.4$, $p < 0.001$) and cued ($F = 4.5$, $p < 0.05$) recognition tests.

Forward stepwise logistic regression was performed in order to determine which of these highly correlated variables best predicted group membership and to limit the number of comparisons used in the Spearman correlations. The results suggested that speed variability and the

Table 3. FTD and NC driving performance

	FTD	NC	p value
Average speed	31 ± 9 (16–47.2)	25.6 ± 3 (19–30)	<0.05
SD of average speed	14.2 ± 2 (8.4–14.2)	8 ± 1 (6–10)	<0.001
Off-road accidents	1.6 ± 2.5 (0–8)	(0–1)	NA
Total collisions	1.3 ± 1.7 (0–5)	0	NA
Stop signs ignored	2 ± 3.6 (0–10)	0	NA
Pedestrian hits	1 ± 2 (0–6)	(0–2)	NS
Traffic light tickets	1 ± 1 (0–3)	1 ± 1 (0–3)	NS
Speeding tickets	11 ± 11 (0–33)	1 ± 2 (0–5)	0.003
Free recall	1 ± 1 (0–3)	4 ± 2 (1–8)	<0.001
Cued recall	7.2 ± 2.7 (3–12)	9 ± 2 (4–11)	<0.05

NC = Normal controls; NA = nonapplicable; NS = nonsignificant. Results are means ± SD with figures in parentheses representing the range.

number of billboards recalled after the simulation correctly classified 90% of the subjects.

Three variables, number of off-road accidents, collisions and stop signs ignored, were not included in the analysis, as the data for the control group were not normally distributed. None of the control subjects ran a stop sign or had a collision, and only 1 of them had 1 off-road accident. In contrast, 60% (9 of 15) of the FTD patients had collisions, 47% (7 of 15) off-road accidents, and 33% (5 of 15) ran stop signs with a between-group χ^2 analysis reaching significance ($p = 0.003$).

Correlations were investigated using Spearman's rank statistics with the total NBRS score, agitation and apathy factors. Speeding was correlated with the total score obtained on the NBRS ($r = 0.61$, $p < 0.05$) and with the number of stop signs ignored ($r = 0.52$, $p = 0.05$). The agitation factor of the NBRS was positively correlated with the number of collisions ($r = 0.75$, $p < 0.01$) and the score obtained on the free recall task ($r = 0.60$, $p < 0.05$). Dementia severity, as assessed with the Mattis Dementia Rating Scale, was not correlated with any driving measure. We further investigated if driving performance in FTD patients could be related to the degree of atrophy observed on structural images. No correlations with any driving measure were observed when severity of frontotemporal or temporal atrophy alone were considered. However, severity of frontal atrophy was positively correlated with the total score obtained on the NBRS ($r = 0.53$, $p < 0.05$).

Discussion

The results show that patients with FTD have substantial impairment in simulated driving. More than half of the patients had collisions and off-road accidents. The patients ran stop signs and received more speeding tickets than the control group. These findings corroborate previous reports of illegal driving acts, and hit and run accidents observed in FTD patients [38, 46].

One of the variables that best discriminated between patients and controls was the variability in speed while driving. Speeding was related to running stop signs and to a greater number of speeding tickets obtained by patients who, rather than slowing down to an appropriate speed after receiving a speeding violation, often disregarded the warning sirens and continued to accelerate. At other times they would drive very slowly or stop randomly throughout the simulation. Previous studies on driving in dementia patients did not report speed variability or traffic violations as common findings. In fact elderly drivers tend to compensate for reduced abilities by reducing their speed [47], and Alzheimer's disease patients drove more slowly than normal controls and were less able to finish a driving simulation due to confusion [48].

In our study both speeding and collisions were related to the patients' agitated and aggressive behavior as measured by the NBRS. Neuropsychiatric symptoms that are measured in the agitation factor include: disinhibition, aggression, hostility, excitement and of course agitation. Associations between disinhibition and risky driving have been reported previously [49]. However, this relationship has only been observed in younger drivers and,

to our knowledge, has never been reported in clinical populations [49, 50].

Driving errors, such as crashes, have been reported in previous studies and related to deficits in visuoconstructive abilities [10, 35]. It could be argued that off-road accidents or collisions displayed by FTD patients could be explained by visuospatial deficits. However, no such deficit was apparent on neuropsychological testing, and visuospatial skills are compromised late in the course of the disease. Furthermore no relationship was found between the patients' driving behavior and the total score obtained in the Mattis Dementia Rating Scale as a global measure of cognitive dysfunction. The patients' poor recall of billboards after the simulation and improvement on the recognition task is in accordance with the pattern of memory impairment reported previously in FTD patients [51, 52]. Memory is required to remember episode-specific rules, routes and laws. Its deficit in FTD patients could further contribute to their driving difficulties under certain circumstances (e.g. a new route to learn or remember).

Thus, the driving difficulties observed in FTD appear to be different from those reported in other types of dementia patients. The unpredictable driving behavior and disregard for social norms and laws within this population might be explained by the breakdown in social behavior that characterizes this disease [46, 53]. FTD research suggests that the ventromedial areas of the prefrontal cortex are affected early in the course of the disease [17, 28, 54]. This region is considered necessary for decision making, particularly in evaluating the consequence of decisions [55]. It has also been proposed that knowledge of social events and rules is stored in this area of the neocortex [56, 57]. Thus, the patients' improper behavior while driving might reflect the loss of functions mediated by this region. The observed relationship between severity of frontal atrophy and behavioral abnormalities supports this idea. Of significant concern is the fact that the majority of the FTD patients included in this study were driving at the time of the assessment. Those patients who stopped driving before being evaluated did so an average of 2 years after receiving their diagnosis. Someone other than the patient always made the decision that they stop driving. Anecdotal reports of our patients' driving histories reveal impaired driving ability as well as a lack of insight into their deficits. One of the patients chased another car in hot pursuit after he had been cut off, but his license was only revoked 3 years later. Another patient was forced to stop driving after several accidents and speeding violations. One woman drove off the side of the

road, ran into a utility pole and continued driving home on the rims of the tires with the air bags deployed. Despite their obvious impairments, these patients continued driving, and the FTD patients' spouses accepted their dangerous driving until their evaluation by our team.

The assessment of driving competence represents a challenge that is not easily met. Highly complex in nature, driving cannot simply be measured as a function of its independent cognitive components [10, 58]. Therefore driving would be best assessed by an off-road evaluation specific to driving, such as that required in a driving simulator [7, 59, 60]. We cannot verify the extent to which an individual patient's performance on a driving simulator reflects actual driving behavior, although many studies have found a significant association between simulated and real driving [61].

It could also be argued that the poor performance of FTD patients in this study might be related to cognitive dysfunction, but we did not find any relationship between a general measure of cognitive functioning, the Dementia Rating Scale, and driving performance. To our knowledge this is the first study to examine driving performance in patients with FTD and to investigate a relationship between a core feature in this disease, neuropsychiatric symptoms, and driving behavior.

Based on our findings, we can conclude that FTD patients have substantial impairment on a simulated task, which appears to reflect the breakdown in social behavior frequently observed in this population. We suggest that fitness to drive should always be questioned in FTD patients.

Acknowledgments

We thank Neal Jeffries, PhD, for his statistical advice and Sarah Wakamiya for helping collect the data.

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