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Clinical predictors of driving status in Huntington disease

L.J. Beglinger, PhD¹, L. Prest, J.A. Mills, MS¹, J.S. Paulsen, PhD^{1,2}, M.M. Smith, PhD¹, P. Gonzalez-Alegre, MD², K.C. Rowe, PhD¹, P. Nopoulos, MD¹, and E.Y. Uc, MD^{2,3}

¹Department of Psychiatry, University of Iowa Carver College of Medicine, Iowa City, IA, USA

²Department of Neurology, University of Iowa Carver College of Medicine, Iowa City, IA, USA

³Neurology Service, Veterans Affairs Medical Center, Iowa City, IA, USA

Abstract

Objective—To identify the motor, cognitive, and behavioral determinants of driving status and risk factors for driving cessation in HD.

Methods—Seventy-four patients with HD were evaluated for cognitive, motor, psychiatric, and functional status using a standardized battery (Unified Huntington Disease Rating Scale and supplemental neuropsychological testing) during a research clinic visit. Chart review was used to categorize patients into four driving status categories: currently driving, driving but with clinician recommendation to restrict (with previous, grouped together as “currently driving”), clinician recommendation to cease driving, and not currently driving due to HD (“not driving”). Multivariate and univariate logistic regression was used to identify significant clinical predictors of those driving vs. not driving.

Results—Global cognitive performance and UHDRS Total Functional Capacity scores provided the best predictive model of driving cessation (Nagelkerke $R^2 = 0.65$; $p < 0.0001$). Measures of learning ($p = 0.006$) and psychomotor speed/attention ($p = 0.003$) accounted for the overall cognitive finding. In univariate analyses, numerous cognitive, motor, and daily functioning items were significantly associated with driving.

Address correspondence to: Leigh Beglinger, Ph.D., University of Iowa, Department of Psychiatry, MEB 1-321, Iowa City, IA 52242-1000. Tel.: 319-335-8765. FAX: 319-353-3003. leigh-beglinger@uiowa.edu.

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Author contributions:

L.J. Beglinger (leigh-beglinger@uiowa.edu): Drafting/revising the manuscript for content, including medical writing for content; Study concept or design; Analysis or interpretation of data; Acquisition of data; Study supervision or coordination

L. Prest (luke-prest@uiowa.edu): Drafting/revising the manuscript for content; Study concept or design; Analysis or interpretation of data; Acquisition of data

J.A. Mills (jamills@healthcare.uiowa.edu): Analysis or interpretation of data; Statistical analysis

J.S. Paulsen (jane-paulsen@uiowa.edu): Study concept or design; Study supervision or coordination; Obtaining funding

M.M. Smith (megan-m-smith@uiowa.edu): Drafting/revising the manuscript for content, including medical writing for content; Analysis or interpretation of data; Acquisition of data

P. Gonzalez-Alegre (pedro-gonzalez-alegre@uiowa.edu): Drafting/revising the manuscript for content, including medical writing for content; Analysis or interpretation of data

K.C. Rowe (rowek@healthcare.uiowa.edu): study concept and design; literature review

P. Nopoulos (peggy-nopoulos@uiowa.edu): Drafting/revising the manuscript for content, including medical writing for content

E.Y. Uc (ergun-uc@uiowa.edu): Drafting/revising the manuscript for content, including medical writing for content; Study concept or design; Analysis or interpretation of data

Conclusion—Although driving status is associated with many aspects of the disease, results suggest that the strongest association is with cognitive performance. A detailed cognitive evaluation is an important component of multi-disciplinary clinical assessment in patients with HD who are driving.

INTRODUCTION

Huntington disease (HD) leads to abnormal movements (e.g., chorea, dystonia, and incoordination), psychiatric illness, and cognitive impairment.¹ The average age of diagnosis is in the mid 40s² during the peak period of productivity and independence for most people. Thus, instrumental activities of daily living such as driving are affected at an earlier point in the lives of HD patients compared to those with other neurodegenerative diseases like Parkinson (PD)³ and Alzheimer diseases (AD).⁴ We recently found driving to be one of the earliest reported areas of functional decline on the Unified Huntington's Disease Rating Scale (UHDRS) in patients who were not yet diagnosed with HD, underscoring the importance of early monitoring of this area.^{5, 6} Yet, we could only identify one research article on driving in HD.⁷ The purpose of the current study is to examine the association of different aspects (e.g., motor, cognitive) of HD with driving status and determine risk factors for driving cessation. Motor and cognitive impairment were hypothesized to be related to driving status.

METHODS

Participants and procedures

Individuals seen for a clinical visit at The University of Iowa Huntington's Disease Society of America Center of Excellence served as participants for this study (2002 to 2010). All participants were seen by a multi-disciplinary team of specialists including a board-certified neurologist, psychiatrist, and clinical neuropsychologist. The final sample (N = 74) includes those patients for whom driving status could be ascertained by chart review and for whom neuropsychological assessment was completed within ($\pm$) three months of the driving status coded for each patient. Driving status was coded into four categories: 0 = participant is currently driving with no known contraindications, 1 = participant is currently driving but a clinician has recommended they restrict driving (e.g., low speeds, rural routes, non-inclement weather), 2 = participant has received a clinician recommendation to cease driving immediately, or 3 = participant has already stopped driving due to HD. The driving decisions were typically reached by clinical consensus of the neuropsychologist, neurologist, and social worker, and documented in the patients' medical records.

Measures

Participants were evaluated using a standardized HD assessment tool, the UHDRS battery,⁸ which is used for both clinical and research purposes. This battery includes a brief cognitive exam (detailed below), neurological exam, assessment of behavioral/psychiatric symptoms, and assessment of functional skills (i.e., activities of daily living). A neurologist examined the participant's individual motor signs (e.g., finger tapping, chorea, dysarthria). The sum of these individual signs was the Total Motor Score (TMS), which ranges from 0 to 124, with higher scores indicating more impaired motor functioning. The Total Functional Capacity (TFC) score,⁹ which is derived from reports of the participant and his/her companion, quantifies a participant's ability to perform both basic and instrumental activities of daily living. This scale ranges from 0 to 13, with higher scores indicating more intact functioning. A categorical classification of disease severity is based on these total scores, grouped into 5 stages, with lower stage indicating more intact functioning (e.g., TFC scores between 13 and 11 = stage 1 HD, 10–7 = stage 2, etc.). Psychiatric symptoms are assessed in 11 domains

(e.g., anxiety, hallucinations, depression), and the score is the sum of the product of frequency and severity for 11 symptoms.¹⁰ The total ranges from 0–176, with higher scores indicating increased psychiatric symptoms.

In addition to the other measures, three cognitive tests are part of the UHDRS: phonemic verbal fluency (The Controlled Oral Word Association Test),¹¹ Symbol Digit Modalities,¹² and Stroop Color and Word Test.¹³ The Symbol Digit Modalities Test (written version) reflects the number of correct items produced in 90 seconds and is a measure of psychomotor speed and attention. Phonemic fluency reflects verbal generativity and is typically considered a measure of executive function. The score is the number of correct words produced across three 1-minute trials. Three scores are generated on the Stroop – total number of correct words read, colors identified, and items on the interference trial in 45 seconds. The first two conditions reflect processing speed and the interference condition is an executive measure of inhibitory ability.

Participants also completed supplemental neuropsychological testing, including the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS),¹⁴ the Trail Making Test (TMT) parts A and B,¹⁵ and three subtests from the Wechsler Adult Intelligence Scale – III: Information (fund of knowledge), Letter-Number Sequencing (complex attention/working memory), and Similarities (verbal abstract reasoning).¹⁶ The RBANS is a brief, individually administered neuropsychological battery consisting of twelve subtests, which yield five Index scores and a Total Scale. The following domains are assessed: attention, language, visuospatial/constructional abilities, and immediate and delayed memory. All subtests were administered and scored as defined in the test manual, with the exception of the Figure Copy and Figure Recall, which were scored according to revised criteria.¹⁷ The Index and Total scores are age-corrected standard scores ($M = 100$, $SD = 15$) and were calculated from the RBANS manual norms. Individual subtest scores are reported as raw scores. The TMT is a two part paper-and-pencil test that requires participants to either connect consecutively numbered circles (TMT-A, a measure of visual scanning and psychomotor speed) or alternate between connecting numbered and lettered circles in order (TMT-B, an executive measure with set shifting). Both are scored according to completion time in seconds. An estimate of premorbid intellect was calculated using a demographically-based equation (the Barona formula¹⁸) as cognitive measures may underestimate premorbid level in patients with HD.¹⁹ For all cognitive tests, higher scores reflect better cognitive functioning, excepting the TMT, for which lower scores reflect better performance. Due to time constraints, participant fatigue, lack of cooperation, and/or inability to complete the tasks presented, not all measures were administered to each participant.

Statistical analysis

Descriptive statistics were calculated for demographic (i.e., sex, age, and education) and composite clinical variables (UHDRS TMS, Behavioral Total, TFC, and RBANS Total Scale) for all four driving status groups. ANOVAs, χ^2 , and post hoc tests were used to assess for group differences on demographic and clinical variables. Stepwise multiple logistic regression was used first to examine which of the four main domains of clinical symptoms (UHDRS TMS, Behavioral Total, TFC, and RBANS Total Scale) were associated with driving status. Given the modest sample size in each of the four groups, we collapsed the groups into two for regression analyses (driving = 0s and 1s vs. not driving = 2s and 3s). Follow-up stepwise multiple regression was also used to examine the individual item components of the RBANS, TMS, and TFC as predictors of driving status (driving vs. not driving). Age was defined a priori as a covariate and included in the multiple regression models. Finally, we conducted exploratory univariate logistic regression on all available

clinical predictors of driving status to see which disease-related variables were individually associated with driving.

Standard protocol approvals, registrations, and patient consents

All procedures were approved by The University of Iowa Institutional Review Board. All study participants signed informed consent documents prior to data collection informing them that the clinic data would be used for research purposes and authorizing review of their medical records for data collection.

RESULTS

Participants

Descriptive statistics for demographic and clinical characteristics are provided in Table 1 for all 74 participants. The sample was 55% female and participants had an average age of 48.2 years ($SD = 12.3$) and an average education of 13.6 years ($SD = 2.31$). UHDRS and cognitive scores indicated the sample overall demonstrated abnormalities in motor functions, psychiatric ratings, cognition, and functional capacity consistent with mild to moderate HD (Table 1). Specifically, 38% of the sample fell within stage 1 (early), 35% in stage 2, 21% in stage 3 (moderate), and 6% in stage 4. Consistent with the study inclusion criterion of being able to complete neuropsychological assessment, no participants were classified with stage 5 HD (severe). When the sample was categorized into the four groups based on driving status, the mean clinical features in the four major domains (motor, cognition, TFC, behavioral) generally reflected worsening disease characteristics with more restricted driving status, excepting behavioral scores (see Table 1). The four groups did not differ on age, education, gender, or behavioral scores (all $p > 0.05$). TMS, RBANS Total, TFC, and HD stage all showed significant group differences (by driving category) at $p < 0.0001$.

Clinical predictors of driving cessation

Multivariate logistic regression results are presented in Table 2. We first examined a model with all four major clinical domains: TMS, TFC, and behavioral signs of HD were not significantly related to driving cessation when entered into the stepwise regression analysis with the cognitive score. Only RBANS Total was significant ($\chi^2 = 40.8$; $df = 5$; Nagelkerke $R^2 = 0.65$; $p < 0.0001$). However, the best fit model retained both the RBANS Total and TFC ($\chi^2 = 41.8$; $df = 3$; Nagelkerke $R^2 = 0.65$; $p < 0.0001$). Both models adjusted for age. For both measures, having a lower score increased the odds of receiving a recommendation to stop driving. For a 5-point decrease in RBANS total score, the odds ratio increased by a factor of 1.76 (95% CI = 1.24, 2.49). In other words, those who scored 75 have 76% higher odds of receiving a recommendation to stop driving as those who scored 80 (at the same age and functional level). This was true for any 5-point decrease on the RBANS. Figure 1 shows predicted probabilities of receiving the recommendation to stop driving for RBANS scores of 40–115. Because the TMS is highly correlated with TFC, we also ran a model with only RBANS and TMS. Although TMS was close, it was not a significant predictor of driving status ($\chi^2 = 2.96$; $df = 1$; $p = 0.09$). Next all individual cognitive subtest items were entered into a stepwise regression (Trails A, Trails B, RBANS: List Learning, Story Memory, Figure Copy, Line Orientation, Picture Naming, Semantic Fluency, Digit Span, Coding, List Recall, List Recognition, Story Recall, Figure Recall, and the five UHDRS cognitive test variables: SDMT, Verbal Fluency, Stroop Color, Word, and Interference), motor individual items (Ocular, Saccade Initiation, Saccade Velocity, Dysarthria, Tongue Protrusion, Finger Taps, Pronate-supinate hands, Luria motor sequencing task, Rigidity, Bradykinesia, Dystonia, Chorea, Gait, Tandem Walking, Retropulsion), and TFC items (Occupation, Finances, Chores, ADL, Care Level). The only variables retained were RBANS Coding (psychomotor speed) ($\chi^2 = 8.65$; $df = 1$; $p = 0.003$) and List Learning (immediate verbal memory) ($\chi^2 =$

7.48; $df = 1$; $p = 0.006$). Finally, we re-ran the stepwise regression with the above predictor variables but leaving out the RBANS Coding subtest. In this model the SDMT is significant (with List Learning), albeit less so ($\chi^2 = 5.27$; $df = 1$; $p = 0.02$) than Coding suggesting that Coding and SDMT may be interchangeable.

Univariate regression results are presented in Table 3 for all clinical variables at the composite and individual item levels. Twelve out of 17 motor variables were significantly associated with driving status, as were 12 out of 13 RBANS scores, all 5 UHDRS cognitive scores, 3 out of 6 other cognitive scores, and 5 out of 5 functional capacity scores (in addition to stage of HD, which is based on TFC total). In contrast, none of the 9 behavioral scores examined were significant predictors of driving status.

DISCUSSION

Driving cessation is a key turning point in the progressive functional decline seen in dementing illnesses and is one of the first reported areas to decline in patients with HD.⁵ Our results show that although motor and functional declines are associated with driving in patients with HD, cognitive impairment is a stronger risk factor affecting the decision for driving cessation. HD has an average age of onset during the time when most adults rely on driving for work and family responsibilities. Public safety concerns versus loss of independence and quality of life for patients must be considered when examining driving. Driving safety is a frequent question asked of health care providers for individuals with degenerative diseases; caregivers and patients do not tend to make these decisions without clinician input.²⁰ Previous research has demonstrated that most often the decision to stop driving is at the recommendation of a physician and driving cessation is usually an abrupt event.²¹ Thus clinicians have a responsibility to consider carefully the decision about whether to recommend restriction or driving cessation. In patients with HD, there is little past research to guide this decision. Understanding what clinical variables that most influence decision-making regarding driving safety may assist in informing clinicians about how to monitor risk and educating patients and their families about why decisions are made.

Clinician ratings have better sensitivity and specificity on driving risk than caregiver and patient self-reports.²⁰ A study in PD showed that driving abilities of PD patients were estimated best by a neuropsychologist guided by cognitive testing and interview against the gold standard of driving performance scoring on a road test by a driving instructor; the neurologist and the patient overestimated the driving ability of the patient.²² Accuracy of assessment is improved with cognitive assessment, and specifically with cognitive cutoff score supplementation by the clinician.^{23, 24} The scant past research on driving in patients with HD has been based on patient or caregiver report. Rebok and collaborators⁷ surveyed a cohort of 73 clinic patients (average disease duration 6 years) and found that 72% were still driving after disease onset. Those still driving differed from those no longer driving (based on self report) with shorter disease duration, lower neurological impairment, and less functional and cognitive impairment. A subsample of 29 patients completed an additional neuropsychological assessment, a driving questionnaire with crash history, and a driving simulator task. Fifty-eight percent of the subsample of HD patients had had a collision in the past two years compared to 11% of controls. The only variable which separated the patients who had informant-reported collisions from those who did not was a measure of simple reaction time. Self-rated driving ability, motor abnormalities, cognitive impairment, and driving simulator measures failed to separate the groups. Despite poorer performance on nearly all tests compared to controls and some appreciation of declining driving skills, HD patients continued to drive as many miles per year as controls and to drive in all weather and traffic conditions at or above the speed limit indicating a lack of insight (or willingness to cease driving) about driving safety. A strength of the current study is that clinician-based

recommendations for driving restriction or cessation were included. Our results add to the existing literature by characterizing levels of motor, cognitive, functional, and behavioral impairments associated with differing levels of driving performance (see Table 1 and Figure). The average scores for cognitive and motor functioning for each level of driving may be useful guidelines to help clinicians gauge when to increase monitoring for driving safety. For example, clinicians did not recommend driving cessation until patients had significant motor impairment (TMS mean of 37). Additionally, the figure provides probabilities about the likelihood of not driving for a wide range of cognitive scores (as measured by the RBANS). From information presented here, tentative cutoff scores could be proposed to be validated in future research with independent samples. Such work is needed to establish practice guidelines for driving assessment in HD.

The results of the univariate regression indicate that nearly all aspects of HD are associated with driving status (except psychiatric symptoms), with many motor, cognitive, and functional signs being significant predictors. However, the multivariate results supported cognition and functional status as the strongest clinical variables in driving prediction. These findings are similar to those of Cubo and colleagues²⁵ in patients with PD, which showed several predictors of driving status, but functional measures were among the strongest predictors. Our follow-up analyses provide guidance about a focused battery for driving assessment that includes specific cognitive items. The cognitive tasks that accounted for this finding were measures of verbal learning, attention, and psychomotor speed (i.e., RBANS List Learning and Coding). These areas of cognitive dysfunction are typical features of the frontal-subcortical profile of HD²⁶ and these specific RBANS subtests have previously been shown to be abnormal in HD.²⁷ Additionally, attention, working memory, and executive functions are key cognitive processes in driver performance²⁸ and are affected by neurodegenerative disease.²⁹ These cognitive tests, or variants that tap similar processes, should be considered for inclusion in cognitive batteries when driving is being monitored. While there is a similar task to Coding (Symbol Digit Modalities Test) in the current UHDRS battery, there is no list learning task so this would be a meaningful (minimum) addition if only the UHDRS is used for clinical visits.

Although this study adds important information to the limited literature addressing driving in patients with HD, some weaknesses should be noted. First, the main outcome of driving status was obtained from medical records, and no formal assessment of driving skill or past driving records were obtained. Second, the data presented here are cross sectional and do not allow for examination of specific cognitive change over time that may signal the need for increased monitoring. Future studies should include longitudinal clinical assessments, more detailed information about driving history including collisions and exact dates of driving cessation or restriction, and objective measures of driving performance (i.e., on-road driving assessment).

By comparing patients not driving to those driving based on a combination of clinician-determined recommendation and patient and family report, our results show that although most disease-related signs worsen with more restricted driving status, cognition showed the strongest association with driving. We conclude that cognitive assessment should be a routine aspect of clinical monitoring for patients with HD who are still driving.

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References

1. Paulsen JS, Ready RE, Hamilton JM, Mega MS, Cummings JL. Neuropsychiatric aspects of Huntington's disease. *J Neurol Neurosurg Psychiatry*. 2001; 71:310–314. [PubMed: 11511702]
2. Walker FO. Huntington's disease. *Lancet*. 2007; 369:218–228. [PubMed: 17240289]
3. Uc EY, Rizzo M, Johnson AM, Dastrup E, Anderson SW, Dawson JD. Road safety in drivers with Parkinson disease. *Neurology*. 2009; 73:2112–2119. [PubMed: 20018639]
4. Dawson JD, Anderson SW, Uc EY, Dastrup E, Rizzo M. Predictors of driving safety in early Alzheimer disease. *Neurology*. 2009; 72:521–527. [PubMed: 19204261]
5. Beglinger LJ, O'Rourke JJ, Wang C, Langbehn DR, Duff K, Paulsen JS. Earliest functional declines in Huntington disease. *Psychiatry Res*. 2010; 178:414–418. [PubMed: 20471695]
6. Paulsen JS, Wang C, Duff K, et al. Challenges assessing clinical endpoints in early Huntington disease. *Mov Disord*. 2010; 25:2595–2603. [PubMed: 20623772]
7. Rebok GW, Bylsma FW, Keyl PM, Brandt J, Folstein SE. Automobile driving in Huntington's disease. *Mov Disord*. 1995; 10:778–787. [PubMed: 8749997]
8. Huntington Study Group. Unified Huntington's Disease Rating Scale: reliability and consistency. *Mov Disord*. 1996; 11:136–142. [PubMed: 8684382]
9. Shoulson I, Fahn S. Huntington disease: clinical care and evaluation. *Neurology*. 1979; 29:1–3. [PubMed: 154626]
10. Beglinger LJ, Langbehn DR, Duff K, et al. Probability of obsessive and compulsive symptoms in Huntington's disease. *Biol Psychiatry*. 2007; 61:415–418. [PubMed: 16839521]
11. Benton, AL.; Hamsher, K.; Varney, N.; Spreen, O. Contributions to Neuropsychological Assessment: A Clinical Manual. New York: Oxford University Press; 1983.
12. A, Smith. Symbol Digit Modalities Test (SDMT) Manual. Los Angeles: Western Psychological Services; 1982. (Revised)
13. Stroop JR. Studies of interference in serial verbal reactions. *J Exp Psychol*. 1935; 18:643–662.
14. Randolph C, Tierney MC, Mohr E, Chase TN. The Repeatable Battery for the Assessment of Neuropsychological Status (RBANS): Preliminary Clinical Validity. *J Clin Exp Neuropsychol*. 1998; 20:310–319. [PubMed: 9845158]
15. Reitan RM. Validity of the trail making test as an indicator of organic brain damage. *Percept Mot Skills*. 1958; 8:271–276.
16. Wechsler, D. Wechsler Adult Intelligence Scale. 3. San Antonio, TX: Psych Corp; 1997.
17. Duff K, Leber WR, Patton DE, et al. Modified scoring criteria for the RBANS figures. *Appl Neuropsychol*. 2007; 14:73–83. [PubMed: 17523881]
18. Barona A, Reynolds CR, Chastain R. A demographically based index of premorbid intelligence test for the WAIS-R. *J Consult Clin Psychol*. 1984; 52:885–887.
19. O'Rourke JJ, Adams WH, Duff K, et al. Estimating premorbid functioning in Huntington's disease: The relationship between disease progression and the wide range achievement test reading subtest. *Arch Clin Neuropsychol*. 2011; 26:59–66. [PubMed: 21147861]
20. Brown LB, Ott BR, Papandonatos GD, Sui Y, Ready RE, Morris JC. Prediction of on-road driving performance in patients with early Alzheimer's disease. *J Am Geriatr Soc*. 2005; 53:94–98. [PubMed: 15667383]
21. Adler G, Kuskowski M. Driving cessation in older men with dementia. *Alzheimer Dis Assoc Disord*. 2003; 17:68–71. [PubMed: 12794382]
22. Heikkila VM, Turkka J, Korpelainen J, Kallanranta T, Summala H. Decreased driving ability in people with Parkinson's disease. *J Neurol Neurosurg Psychiatry*. 1998; 64:325–330. [PubMed: 9527142]
23. Adler G, Rottunda S, Dysken M. The older driver with dementia: an updated literature review. *J Safety Res*. 2005; 36:399–407. [PubMed: 16226768]

24. Grace J, Amick MM, D'Abreu A, Festa EK, Heindel WC, Ott BR. Neuropsychological deficits associated with driving performance in Parkinson's and Alzheimer's disease. *J Int Neuropsychol Soc.* 2005; 11:766–775. [PubMed: 16248912]
25. Cubo E, Martinez Martin P, Gonzalez M, et al. What contributes to driving ability in Parkinson's disease. *Disabil Rehabil.* 2010; 32:374–378. [PubMed: 19958153]
26. Zakzanis KK. The subcortical dementia of Huntington's disease. *J Clin Exp Neuropsychol.* 1998; 20:565–578. [PubMed: 9892059]
27. Duff K, Beglinger LJ, Theriault D, Allison J, Paulsen JS. Cognitive deficits in Huntington's disease on the Repeatable Battery for the Assessment of Neuropsychological Status. *J Clin Exp Neuropsychol.* 2010; 32:231–238. [PubMed: 19484645]
28. Rizzo, M.; Kellison, IL. The Brain on the Road. In: Marcotte, TD.; Grant, I., editors. *Neuropsychology of Everyday Functioning.* New York: Guilford Press; 2010. p. 168-208.
29. Uc EY, Rizzo M. Driving and neurodegenerative diseases. *Curr Neurol Neurosci Rep.* 2008; 8:377–383. [PubMed: 18713573]

Figure 1. Predicted probabilities of receiving the recommendation to stop driving for a range of RBANS scores by HD stage

RBANS Total Scale scores from 40–115 are presented on the x -axis. Probability to stop driving is on the y -axis. Age is constant at 48.2 (average age of sample). The blue line corresponds to HD stage 1 (mild), the red line to HD stage 2 (mild to moderate), and the green line to those in HD stages 3 and 4 (moderate to severe). So for example, a participant with RBANS = 80 has an estimated probability of receiving a recommendation to stop driving of 0.10 if s/he has TFC~12, 0.25 if s/he has TFC~8, and 0.60 if s/he has TFC~4.

Table 1
Descriptive statistics of demographics and predictor variables by driving status groups

Clinical Variables	Total Sample	Groups by Driving Status ^a			p-value
		0	1	2	3
N	74	16	19	19	20
Gender (%female)	55%	63%	58%	47%	55%
Age (years)	48.19 (12.32) 18.0–72.0	44.25 (12.86) 21.0–68.0	47.53 (11.98) 24.0–72.0	49.58 (12.42) 18.0–69.0	50.65 (12.19) 20.0–70.0
Education (years)	13.64 (2.31) 8.0–20.0	13.63 (2.42) 8.0–19.0	13.71 (2.31) 9.0–18.0	13.43 (1.28) 12.0–16.0	13.74 (2.90) 9.0–20.0
HD stage					<0.0001
1	25 (38%)	12	8	5	0
2	23 (35%)	4	8	8	3
3	14 (21%)	0	1	3	10
4	4 (6%)	0	0	0	4
5	0 (0%)	0	0	0	0
UHDRS ^b Total Motor Score	32.35 (17.91) 0.0–72.0	13.00 (10.68) 0.0–32.0	32.67 (15.36) 10.0–57.0	37.39 (17.51) 8.0–72.0	43.58 (12.17) 17.0–61.0
RBANS Total Score	69.35 (15.89) 44.0–114.0	86.19 (13.16) 63.0–114.0	73.72 (10.57) 53.0–87.0	62.33 (11.24) 49.0–82.0	57.68 (12.21) 44.0–94.0
Total Functional Capacity	8.61 (3.63) 1.0–13.0	11.81 (1.64) 9.0–13.0	9.94 (2.30) 6.0–13.0	8.69 (2.80) 4.0–13.0	4.18 (2.30) 1.0–9.0
UHDRS Behavioral Total	20.85 (21.88) 0.0–101.0	22.88 (16.85) 0.0–58.0	12.41 (10.85) 0.0–33.0	24.27 (24.34) 0.0–90.0	24.17 (29.75) 0.0–101.0

^a0 = currently driving without restrictions, 1 = recommendation to restrict driving, 2 = recommendation to stop driving, 3 = no longer driving due to HD.

Descriptive statistics are presented as Means (SD) with ranges in italics.

UHDRS = Unified Huntington's Disease Rating Scale; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status.

Lower scores indicate better performance (i.e., less advanced disease) for Total Motor Score, Behavioral Total, and HD Stage. Higher scores indicate better performance on the RBANS and TFC.

Table 2
Summary of multiple regression analyses for variables predicting driving performance (driving versus not driving).

Model examining all global predictors					
<i>Outcome Variable</i>	<i>Predictors</i>	<i>B</i>	<i>SE B</i>	<i>β</i>	<i>p-value</i>
Driving Status (0/1 vs. 2/3)	Covariates Age	0.005	0.04	0.03	0.91
	RBANS Total^a	-0.11	0.04	-0.92	0.0032
	TFC ^b	-0.24	0.17	-0.48	0.17
	TMS ^c	0.02	0.03	0.18	0.59
	Behavioral Total ^d	0.02	0.02	0.21	0.44
Best Fit Model					
<i>Outcome Variable</i>	<i>Predictors</i>	<i>B</i>	<i>SE B</i>	<i>β</i>	<i>p-value</i>
Driving Status (0/1 vs. 2/3)	Covariates Age	0.01	0.04	0.06	0.79
	RBANS Total^a	-0.11	0.04	-0.98	0.0015
	TFC ^b	-0.31	0.16	-0.60	0.0470

^aRepeatable Battery for the Assessment of Neuropsychological Status Total

^bTotal Functional Capacity score from the UHDRS

^cUHDRS Total Motor Score

^dUHDRS Behavioral Total

Table 3

Univariate logistic regression: individual predictors of driving status (driving vs. not driving).

Variable	N	OR ^a	CI ^b	p-value
Motor				
Total Motor	71	1.07	1.03, 1.10	0.0007
DCL ^c	67	1.62	1.00, 2.62	0.07
Gait	71	4.36	1.85, 10.30	0.0015
Dysarthria	71	6.22	2.31, 16.75	0.0008
Luria Sequence	71	2.37	1.46, 3.82	0.0010
Tandem Walk	71	2.38	1.37, 4.14	0.0036
Finger taps	71	1.64	1.17, 2.30	0.0071
Pronate-Supinate Hands	71	1.95	1.35, 2.81	0.0008
Tongue Protrusion	71	4.01	1.94, 8.30	0.0006
Pull	71	3.22	1.56, 6.66	0.0029
Rigidity	71	1.56	1.05, 2.32	0.040
Chorea	71	1.09	1.00, 1.19	0.06
Dystonia	71	1.10	0.95, 1.28	0.24
Occular	71	1.24	0.96, 1.60	0.14
Saccade Velocity	71	1.96	1.34, 2.87	0.0010
Saccade Initiation	71	1.67	1.23, 2.28	0.0021
Bradykinesia	71	1.55	0.94, 2.56	0.12
Cognitive				
RBANS^d				
Total Score	71	0.89	0.85, 0.94	0.0002
List Learning	74	0.70	0.60, 0.82	0.0002
Story Memory	73	0.76	0.66, 0.87	0.0004
Figure Copy	74	0.80	0.69, 0.92	0.0039
Line Orientation	72	0.83	0.73, 0.96	0.018
Picture Naming	73	0.80	0.43, 1.49	0.56

Variable	N	OR ^a	CI ^b	p-value
Semantic Fluency	72	0.72	0.62, 0.84	0.0002
Digit Span	72	0.69	0.55, 0.88	0.0043
Coding	72	0.82	0.75, 0.89	0.0002
List Recognition	73	0.57	0.42, 0.76	0.0005
List Recall	73	0.54	0.41, 0.72	0.0002
Story Recall	72	0.70	0.57, 0.85	0.0009
Figure Recall	73	0.80	0.71, 0.90	0.0008
Other Cognitive				
Trail Making A	62	1.05	1.02, 1.09	0.0008
Trail Making B	62	1.02	1.01, 1.03	0.0002
WAIS III – LNS ^e	33	0.57	0.37, 0.89	0.019
WAIS III – Info ^f	32	0.86	0.65, 1.12	0.30
WAIS III – Sim ^g	39	0.83	0.64, 1.07	0.19
Barona Estimated IQ	55	0.95	0.88, 1.02	0.19
UHDRS^h Cognitive	67	0.87	0.81, 0.93	0.0004
Verbal Fluency	67	0.90	0.84, 0.95	0.0008
Stroop Color	67	0.93	0.89, 0.96	0.0007
Stroop Word	67	0.95	0.93, 0.98	0.0014
Stroop Interference	67	0.92	0.87, 0.96	0.0008
TFCⁱ				
Total Score	66	0.60	0.48, 0.77	0.0002
Chores	65	0.07	0.02, 0.25	0.0002
Finances	65	0.30	0.16, 0.55	0.0005
ADL	65	0.20	0.09, 0.45	0.0005
Occupation	65	0.36	0.21, 0.61	0.0006
UHDRS Behavioral				
Total Score	66	1.02	0.99, 1.04	0.26
Anxiety Frequency	66	0.81	0.59, 1.11	0.24

Variable	N	OR ^a	CI ^b	p-value
Anxiety Severity	66	0.94	0.63, 1.41	0.80
Sadness Frequency	66	1.02	0.75, 1.39	0.91
Sadness Severity	66	1.10	0.78, 1.54	0.68
Aggression Frequency	66	1.11	0.74, 1.65	0.69
Aggression Severity	66	1.04	0.60, 1.79	0.91
Irritability Frequency	66	0.92	0.65, 1.31	0.72
Irritability Severity	66	1.08	0.73, 1.60	0.74
Other				
Stage of HD	66	6.08	2.53, 14.66	0.0004

^aOdds Ratio;

^b95% Confidence Interval (lower confidence level, upper confidence level);

^cDiagnostic Confidence Level;

^dRepeatable Battery for the Assessment of Neuropsychological Status;

^eWechsler Adult Intelligence Score – Letter Number Sequencing;

^fWechsler Adult Intelligence Score – Information;

^gWechsler Adult Intelligence Score – Similarities;

^hUnified Huntington’s Disease Rating Scale;

ⁱTotal Functional Capacity..

Significant *p* values (using false discovery rate) are bolded.