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Behavioral Measures of Saccade Latency and Inhibition in Manifest and Premanifest Huntington's Disease

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Abstract

Initiation and inhibition of saccadic eye movements has been shown to be impaired in patients with Huntington's disease (HD) and premanifest gene carriers (PMGC), and may provide biomarkers useful in tracking phenotypic change. Computerized behavioral tests of prosaccade latency and disinhibition presented to 31 non-gene carriers (NGC), 25 PMGC, and 12 HD patients. These tests provided quantitative performance measures without use of eye-tracking equipment. Significant differences on saccade tests were found, with PMGC intermediate between NGC and HD patients. Saccade latency discriminated PMGC from NGC, whereas saccade disinhibition discriminated PMGC from HD patients. Results suggest utility of behavioral saccade measures as premanifest indicators of phenoconversion in HD.

Keywords

behavioral test; eye-tracking; Huntington's disease; oculomotor functioning; predictive testing; presymptomatic; saccade; saccadic eye movements

Huntington's disease (HD) is an autosomal dominant neurodegenerative disorder characterized by motor, cognitive, and psychiatric disturbances. Genetic testing for cytosine adenine guanine (CAG) trinucleotide expansion on the Huntingtin gene can reveal those at risk for developing the disease (Huntington's Disease Collaborative Research Group, 1993). The time at which a given individual begins to show symptoms is variable, but typically occurs between the 4th and 5th decades of life (Myers, 2004), with clinical diagnosis dependent on motor symptoms. Thus, an individual at risk for developing HD can be asymptomatic for years before receiving formal diagnosis, and controversy exists regarding the established diagnostic criteria (Paulsen et al., 2008). Quantitative measures that would identify premanifest gene carriers (PMGC) at the threshold of clinical diagnosis would be extremely valuable in guiding administration of neuroprotective interventions. Such measures would also have utility in tracking disease progression and measuring change with treatment.

A number of investigations suggest disturbed saccadic eye movements may precede clinical diagnosis. Across studies in clinically diagnosed HD, increased latency and variability for saccades, and difficulty inhibiting reflexive saccades to distracting stimuli, are common findings (Lasker & Zee, 1997). Subtle disturbances have also been identified in PMGC, and correlated with diminished striatal volume (Biglan et al., 2009). Blekher et al. (2004; 2006) identified these disturbances in PMGC relative to their non-gene carrier (NGC) siblings, with the strongest discriminating measure being saccade disinhibition and errors during a memory-guided saccade task. Golding, Danchaivijitr, Hodgson, Tabrizi, and Kennard (2006) found prolonged latency for initiating voluntary saccades, but not for reflexive prosaccades in PMGC relative to age-matched healthy controls. Hicks, Robert, Golding, Tabrizi, and Kennard (2008) found a small increase in latency for reflexive prosaccades relative to PMGC and recently diagnosed HD patients. More importantly, additional discriminatory power was found by including a task that required participants to switch between making reflexive saccades to a visual cue and inhibiting saccades to a visual cue. The importance of task complexity (i.e., conditional response switching) in discriminating premanifest from manifest HD was also observed in a study by Robert et al. (2009). Ali, Mitchell, Barker, and Carpenter (2006) created a composite measure based on reflexive prosaccade saccade latency that demonstrated diagnostic utility and a relationship to disease severity, as measured by the Unified Huntington's Disease Rating Scale (UHDRS; Huntington's Study Group, 1996). Findings from the previous cross-sectional studies have been supported by two recent longitudinal studies showing progressive worsening of saccade slowing, dysmetria, and disinhibition in premanifest HD (Antoniades, Xu, Mason, Carpenter, & Barker, 2010; Rupp et al., 2010). Taken together, these findings support the use of saccade measures, particularly saccade inhibition and perhaps saccade latency, for the purposes of early identification and tracking disease progression.

Recent technological developments, such as the saccadometer system (Ober Consulting Inc., Framingham, MA), have made evaluating saccadic eye movements less challenging. Additionally, new eye-tracking systems can compensate for head movement effects, which is a particularly relevant in evaluation of movement disorders. However, there remains a vast disparity between the tremendous apparent clinical utility of measuring eye movements and the limited de facto practice in clinical assessments and multicenter clinical trials. Possible reasons for this include technical complexities associated with collecting and interpreting data, obtaining the specialized equipment, and training staff to use it.

To provide a more readily available means of evaluating saccades, a behavioral methodology, entirely independent of eye-tracking equipment, was developed. The behavioral methodology (subsequently described in detail) requires fast and accurate eye movements to make fine perceptual discriminations. Stimulus presentation time decreases over the course of the test. Discrimination threshold serves as a proxy for saccade latency. Tests are administered on a standard PC computer with a 75 Hz screen refresh rate. Scoring is accomplished using an Excel template that identifies discrimination threshold based on statistical likelihood of correct responding by chance at each level of stimulus presentation time. To our knowledge, such behavioral tasks have not been used in studies of patients with HD, other neuropsychiatric disorders, or healthy persons.

The purpose of the present study was to examine whether the behavioral saccade measures could identify premanifest and disease manifest changes associated with HD. Our first aim was to replicate findings based on traditional eye-tracking of increased latency and saccade disinhibition in HD patients relative to PMGC, and PMGC relative to NGC. If group differences were found, we planned to examine sensitivity and specificity of the measures to premanifest changes, with scores from the UHDRS motor scale serving as standard of comparison. Additionally, we sought to determine whether PMGC and HD patients would

show additional impairment on the test of saccade inhibition after controlling for saccade latency.

Method

Participants

Patients with HD and their family members were recruited through the University of California, San Diego, Huntington's Disease Center of Excellence. Genetic testing was performed via blood draw or cheek swab. CAG expansion of 37 or greater identified individuals as gene positive for HD. A senior neurologist determined UHDRS motor scores and clinical status (i.e., presymptomatic or manifest disease). The study was approved by the University of California Human Research Protection Program and all participants provided written informed consent before participation. No volunteers were excluded from participation. All participants had normal or corrected vision, and no participant wore bifocal glasses during administration of the test. The final sample consisted of 12 patients with HD, 25 PMGC, and 31 NGC. Descriptive data are provided in Table 1. The average duration of illness for HD patients was 7.2 years ($SD = 3.2$); average CAG repeat length was 42.3 ($SD = 3.0$) for the PMGC and 46.9 ($SD = 5.1$) for HD patients. Differences between groups on age, education, and gender were not statistically significant.

Test Battery

The tests were designed to minimize visuospatial demands, and control for basic visuoperceptual processing. There were three subtests: a baseline test that did not require eye movement (fixation), a test for latency of reflexive saccades (prosaccade), and a test for ability to inhibit reflexive saccades to a distracting stimulus and make volitional anti-saccades to a target (saccade inhibition). Simulated screen captures are provided in Figure 1. The primary visual stimulus used in the saccade tests was the Landolt C optotype. This is a small, black, circular target with a white *c* subtending 0.4° of visual angle inscribed in the center. The gap in the circle subtends 0.10° of visual angle. As demonstrated by Haarmeier and Theier (1999), foveal acuity is required to identify orientation (e.g., forward or backward) of the target. In all of the tests, the subject was asked to focus on a central fixation point for 1,500 ms. Following this period, a target stimulus with either a forward or backward facing *c* appeared for a brief period of time. After presentation, the subject indicated whether the *c* was facing forward (i.e., gap facing right) or flipped to face backwards (gap facing left) by telling the administrator, who pressed a button on the computer keyboard. A masking stimulus was displayed for 25 ms immediately following target presentation so as to prevent subjects from responding based on retinal afterimages.

Fixation Test—In the baseline fixation test, the target stimulus appeared in the same position as the fixation point; thus, no oculomotor movement was required (see Figure 1A). The amount of time that the target was presented decreased in a stepwise fashion in increments of 50 ms, from 40 s to 50 ms, with four stimuli presented per step (i.e., odds of perfect performance of a step by chance = 1:16, $p = .0625$). Orientation of the *c* was evenly split within blocks. In a pilot study with a sample of five participants (aged 25-53 years), all subjects demonstrated perfect performance on even the most difficult level of the fixation test. The purpose of the fixation test was to rule out potential confounds of bradyphrenia, attention deficit, perseverative responding, and general visual dysfunction (e.g., acuity, contrast sensitivity) to ensure that test results were specific to the assessment of saccadic eye movements. In this study, successful completion of the fixation test was defined as combined accuracy across the 150-, 100-, and 50-ms levels (well below expected performance on tests requiring saccadic eye movements) of 83% or better (i.e., 10 correct out of 12).

Prosaccade Test—The prosaccade test followed the same general design as the fixation test, with the addition of 10° of visual angle difference between target location (i.e., where the forward- or backward-facing *c* is presented) and central fixation point, thereby necessitating oculomotor movement (see Figure 1B). For each trial, the target location was randomly assigned to one of eight cardinal positions. The first three blocks consisted of 6 items with presentation times of 1,200, 1,150, and 1,100 ms, respectively. These blocks were primarily intended to serve as practice. The remaining 36 blocks contained eight stimuli, with presentation time decreasing in 25-ms increments, from 1,000 to 100 ms. Within each block, targets were presented randomly without replacement in one of eight cardinal positions from the central fixation point. Discrimination threshold was the level at which the subject was able to identify at targets well above chance levels, and operationally defined as at least seven of the eight targets within a block ($p = .031$), or six out of the eight targets in two consecutive blocks ($p = .002$). In the event that two consecutive blocks of six out of the eight accuracy are achieved, the discrimination threshold was estimated between the two blocks (e.g., six out of the eight at 300 and 325 ms would be scored as 313 ms). The discrimination threshold was hypothesized to reflect latency of the fovea to reach the target.

Saccade Inhibition Test—The saccade inhibition test was similar to the prosaccade test in that the target appeared in one of eight cardinal positions 10° of visual angle away from the center. However, before presentation of the target, a black circle appeared in the cardinal position opposite to the location where the target was to be presented (see Figure 1C). As with typical antisaccade task designs, presentation time for the distractor and target were equivalent, and the distractor disappeared when the target was presented. On presentation of the distractor in the periphery, the subject was instructed to move his or her eyes to the opposite area of the screen. For the saccade inhibition test, threshold measurement was based on the presentation time of the distractor, rather than the target, as this is the first cue to initiate saccadic movement. Failure to inhibit movement to the distractor necessitates a change in eye position twice as far in distance (as from the central fixation point) to match foveal position with location of the target for accurate responding, and is therefore expected to impair performance. The first 3 blocks consisted of six items with presentation times of 1,400, 1,350, and 1,300 ms, respectively. These blocks were primarily intended to serve as practice. The remaining 44 blocks contained eight stimuli with presentation time decreasing in 25-ms increments, from 1,200 to 100 ms. We expected the discrimination threshold on the saccade inhibition test to thus coincide with latency of eyes to reach the target, and reflect the composite of saccade latency and ability to inhibit saccades toward the distractor.

Protocol

The computerized battery was administered in a private testing room by one of the authors. Participants were seated at a standard distance of 57 cm from the computer monitor, and all subjects were able to maintain this distance throughout examination. All participants completed all tests in a well-lit room. The administrator entered responses on the keyboard (i.e., *s* for “same” and *f* for “flipped”) and was blind to diagnostic status for all PMGC and NGC participants at time of testing.

Statistical Analysis

SPSS software was used to perform statistical analyses. Group comparisons on the UHDRS, prosaccade, and saccade inhibition measures (NGC vs. PMGC and PMGC vs. HD) were made using 95% confidence intervals around differences in mean scores to better illustrate magnitude of group differences (Tryon, 2001). Given previous findings of increased variability in HD, separate estimates of variability were used. Linear discriminant function analyses with prior probabilities computed by group sample size and separate covariance matrices were performed to identify cut scores to discriminate PMGC from NGC and

PMGC from HD patients. Stepwise linear regression analysis was performed to examine the relationship between prosaccade and saccade inhibition performances between groups.

Results

Group Differences

Descriptive statistics for group performances on the saccade test and UHDRS are provided in Table 2. All participants were able to perform the baseline fixation test with an accuracy level above 90%, and group differences in accuracy were not significant. As expected, the HD patients had significantly higher UHDRS motor scores than PMGC (M difference = 32.1, 95% CI = [6.4, 57.8]). In turn, PMGC had slightly higher UHDRS motor scores than NGC (M difference = 2.3, 95% CI = [0.2, 4.5]). Number of participants, by group, with scores for each level of the prosaccade tests are illustrated in Figure 2, and for the saccade inhibition test in Figure 3. Statistically significant group differences were found on the prosaccade and saccade inhibition tests, with lower values (i.e., better performance) for NGC versus PMGC, and for PMGC versus HD. On the prosaccade test, the mean difference between NGC and PMGC was 53 ms (95% CI = [28, 78]) and between PMGC and HD it was 139 ms (95% CI = [120, 160]). For the saccade inhibition test, the mean difference between NGC and PMGC was 101 ms (95% CI = [36, 165]) and between PMGC and HD it was 244 ms (95% CI = [122, 367]).

Discrimination

The ability of the measures to classify PMGC from NGC was assessed using linear discriminant function analysis separately for each measure. Optimized cut scores were derived, and, for all measures, specificity was favored over sensitivity. A cut score of 5.5 for UHDRS motor accurately classified 64.3% of the sample, $\chi^2(1, N = 56) = 5.489, p = .019$, with specificity of 97% and sensitivity of 24%. On the prosaccade test, a cut score of 238 ms accurately classified 79% of the sample, $\chi^2(1, N = 56) = 20.826, p < .0001$, with 94% specificity and 60% sensitivity (see Figure 1). With a cut score of 525 ms, the saccade inhibition test accurately classified 75% of the sample, $\chi^2(1, N = 56) = 15.430, p < .001$, with 94% specificity and 52% sensitivity (see Figure 2). The saccade measures were significantly better at classifying these groups than UHDRS motor scores: prosaccade, $\Delta\chi^2(1, N = 56) = 15.337, p < .001$; saccade inhibition, $\Delta\chi^2(1, N = 56) = 11.150, p = .002$. was Classification statistically better with the prosaccade relative to the saccade inhibition measure, $\Delta\chi^2(1, N = 56) = 5.390, p = .020$, but this corresponded to correct classification of only two more PMGC. Follow-up analyses indicated that combinations of the variables did not yield improved classification.

To determine whether PMGC was correctly classified by the prosaccade and saccade inhibition tests differed with respect to estimated time before phenoconversion, the prophecy formula based on age and CAG repeat length developed by Langbehn et al. (2004) was employed to generate predictions. Although lacking a prospective validity study, this formula was derived in analysis based on an international sample of nearly 3,000 individuals, and has been cited in at least 20 studies of premanifest changes in HD. Independent sample t tests (using equal variances with statistical criterion $\alpha = .05$) compared age and estimated time before phenoconversion between the correctly and incorrectly classified PMGC. Age differences in classification accuracy were not statistically significant for the prosaccade or saccade inhibition tests. For the prosaccade test, the correctly classified group was found to be closer to the estimated time of phenoconversion by 7.86 years (95% CI [2.22, 13.50]), with a mean time before phenoconversion of 11.43 years ($n = 15, SD = 4.97$) for the correctly classified PMGC and 19.29 years ($n = 10, SD =$

8.01) for the incorrectly classified participants. The estimated time before phenoconversion did not differ between PMGC classified by the saccade inhibition test.

Linear discriminant function analysis using the saccade measures was repeated for classifying PMGC and HD patients. On the prosaccade test, a cut score of 338 ms accurately classified 81% of the sample, $\chi^2(1, N = 37) = 8.250, p = .004$, with 96% specificity and 50% sensitivity (see Figure 2). With a cut score of 625 ms, the saccade inhibition test accurately classified 89% of the sample, $\chi^2(1, N = 37) = 19.400, p < .0001$, showing 92% specificity and 83% sensitivity (see Figure 3). The difference in classification power favoring the saccade inhibition performance was statistically significant, $\Delta\chi^2(1, N = 37) = 11.150, p < .001$. This finding suggests that saccade disinhibition becomes prominent after phenoconversion. Follow-up analyses indicated that combinations of the variables did not yield improved classification.

Relationship Between Prosaccade and Saccade Inhibition

Stepwise linear regression was used to determine if group status explained variability in saccade inhibition performance after controlling for prosaccade performance. For PMGC versus NGC, group status did not was not associated with a significant change. For PMGC versus HD patients, prosaccade performance explained 49.2% of the variability in saccade inhibition performance (across both groups); the addition of group status in the second step explained an additional 5.7% of the variability, $\Delta F(1, 34) = 4.327, p = .045$. A graph illustrating the different relationships between performances on these two tests for PMGC and HD patients is shown in Figure 4. This suggests that the saccade latency is disturbed first in progression of disease, followed by difficulty inhibiting saccades. Although removal of an outlier PMGC case rendered the interaction no longer statistically significant (primarily due to limited HD patient sample size), clustering of PMGC cases around the trend line contraindicated a spurious finding.

Discussion

Summary of Findings

In this study, we investigated changes associated with premanifest and manifest HD using behavioral measures of saccade latency and inhibition. First, we found that all participants were able to complete the battery of tests, which included a baseline measure to ensure understanding of test instructions and rule out confounds of perseverative responding and general visual dysfunction. Our findings on the tests of saccade latency and inhibition generally corresponded to previous findings from other investigators who used traditional eye-tracking. Specifically, patients with HD performed worse than PMGC, who in turn performed worse than NGC siblings. Linear discriminant function analysis showed superiority of the saccade measures relative to the UHDRS in classifying PMGC from NGC. Optimized cut scores based on the saccade measures favored sensitivity over specificity, and slightly better classification of PMGC and NGC was found using saccade latency over inhibition. Additionally, classification based on saccade latency, but not disinhibition, produced PMGC groups that differed in the expected direction with respect to estimated time before phenoconversion.

Classification of PMGC from HD patients was also accomplished by both saccade measures, but saccade disinhibition proved to be more predictive of manifest disease. Finally, stepwise linear regression suggested that differences between PMGC and NGC on the saccade inhibition performances were primarily driven by group differences in saccade latency. However, saccade inhibition differences between PMGC and HD patients were explained by saccade latency and group status, suggesting saccade disinhibition affected performance.

Implications

Results from this study indicate utility of the behavioral saccade measures, obtained independently of eye-tracking equipment, for studying changes associated with premanifest and manifest HD. All participants were able to produce meaningful data on the tests, and findings generally corresponded to previous investigations using traditional eye-tracking. Classification rates for behavioral tests were grossly similar to those observed using traditional eye-tracking (e.g., see Antoniadou et al., 2010; Blekher et al., 2006). Given the ease of administration and scoring associated with the behavioral measures, this approach may be advantageous relative to traditional eye-tracking methodologies, particularly for clinical evaluations of individuals, or in studies where a number of different behaviors or traits are being assessed. However, it is emphasized that the discrimination threshold from the prosaccade behavioral test serves only as a proxy for saccade latency; the discrimination thresholds should not be interpreted as substitutes for direct quantitative measurement of saccades. Furthermore, discrimination threshold on the saccade inhibition test reflects latency for a reflexive prosaccade and ability to inhibit saccades to a distracting stimulus.

In the present study, the prosaccade test was more sensitive to premanifest changes and more closely related to estimated time before phenocconversion than was the saccade inhibition test. This finding is in keeping with results from a recent longitudinal study by Antoniadou et al. (2010) showing the importance of increasing latencies for reflexive saccades over a 3-year test–retest interval in premanifest HD. However, it stands in contrast to results based on eye-tracking measures from Golding et al. (2006), who found no differences for latency of reflexive prosaccades in PMGC versus healthy controls. It is also somewhat discrepant with Blekher et al. (2006), who found that errors on tests for inhibition of saccades and memory-guided saccades were the most prominent features in PMGC, and Hicks et al. (2008), who found only a small difference for reflexive prosaccade latency. One possible reason for this discrepancy is that traditional eye-tracking studies are capable of generating separate measures for percentage accuracy for inhibiting saccades, latency for antisaccades, and variability in latency; the behavioral test provides a single composite measure of all three. It is also possible that saccade disinhibition to other stimuli present in the room may have affected the prosaccade latency measure; however, if this were the case, difficulty performing the fixation test should also have been observed in PMGC and HD. Another possibility is that in PMGC, reduced prosaccade latency, however minimal it may be, drives performance on the prosaccade and saccade inhibition tests, whereas the increasingly pronounced problem of saccade disinhibition begins to contribute in later disease stages.

Interestingly, Lang, Reischies, Majer, and Daum (1999) used a pencil-and-paper behavioral test of saccade speed, the Guided Visual Exploration test (Reischies, Gaebel, Mielewczyk, & Frick, 1988) in a study comparing HD patient performance to age-matched healthy controls. Here, subjects are presented with a paper showing arrows and numbers and must visually follow a path of directional arrows that lead to a final numerical target. Although the timed test confounds saccade speed with visuospatial abilities and visual scanning, Lang et al. found excellent sensitivity (96%) and specificity (100%). These findings would be comparable with differences observed between groups on the prosaccade test, and provide further support for the utility of behavioral measures of oculomotor functioning in contexts where traditional eye-tracking is not available.

Measures of saccadic eye movements are not unique in their ability to differentiate among HD groups. Motor, psychiatric, cognitive, and sensory tests have also proven useful in this regard (for a review, see Paulsen et al., 2008). However, the addition of behavioral measures of saccades to a comprehensive evaluation could prove useful in improving detection of early phenotype changes and monitoring change associated with progression and treatment.

Moreover, a recent study by Blekher et al. (2009) showed that poor performance on a test of information processing speed in premanifest and manifest HD appeared to be driven by inefficient eye movements, further highlighting the importance of eye movement assessment in this population.

Limitations and Future Directions

Results suggest that the tests are sensitive to premanifest and manifest changes associated with HD. Because our results were somewhat different to previous eye-tracking investigation, traditional eye-tracking should be performed while participants complete the test battery to resolve issues regarding what specific component of saccade latency (e.g., latency to initiate movement, predictive errors, inhibition errors, distance and location errors) is being measured by each test in each group. Thus, the behavioral measures do not offer a substitute for traditional eye-tracking for quantitative, physiological units of specific aspects of saccadic eye movements. For example, the prosaccade test almost entirely reflects latency and does not measure velocity, whose absolute units with respect to time are relatively miniscule. Biglan et al. (2009) showed that although reflexive saccade latency was useful in classifying premanifest (HD), it was not correlated with striatal volume; however, saccade velocity, which is not measured in the behavioral tests, was inversely correlated to striatal volume. One additional limitation is that participants must not be wearing bifocal glasses during administration of the test, as this would necessitate head movements to discriminate targets presented in the upper quadrants of the screen. Furthermore, test-retest reliability of the behavioral tests has not yet been assessed.

The present tests could also be improved using computerized adaptive testing, wherein all participants would start at a medium difficulty level, and performance would dictate advancement to a more challenging level or stepping back to an easier level. This process was estimated to increase efficiency by at least 50% through reduction of required test items (Schmidt & Embretson, 2003). Variability in saccade latency, known to be increased in PMGC and HD patients, could also be measured by the number of trials required to ascertain measurement. A study by Finke, Bublak, Dose, Müller, and Schneider (2006) showed a left-lateralized spatial attention bias in HD patients that was positively correlated with earlier age-at-onset and CAG repeat length. Although not possible given data collection procedures in the present study, it would be useful to determine whether error rates were higher in PMGC and HD patients when targets were presented in the right visual hemifield. Finally, application of the tasks in studies of other populations widely known to have abnormal saccadic eye movements (e.g., PD, traumatic brain injury, schizophrenia) would further inform validity and utility.

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FIGURE 1.

(A) Sequence of screen images and duration from the Fixation test, (B) prosaccade saccade test, and (C) saccade inhibition test. A distractor stimuli is presented in the opposite corner of the screen from where the target will appear before presentation of the target. Subjects are instructed to look for the target in the region opposite the distractor. Response screen not shown in figure.

FIGURE 2.

Prosaccade task performance. The dashed line (238 ms) indicates optimized cut score for discriminating nongene carrier from premanifest gene carrier (PMGC); the solid line (338ms) indicates optimized cutscore for discriminating PMGC from Huntington's Disease (HD).

FIGURE 3.

Saccade inhibition performance, by group. The dashed line (525ms) indicates optimized cutscore for discriminating nongene carrier from premanifest gene carrier (PMGC); the solid line (625ms) indicates optimized cutscore for discriminating PMGC from Huntington's Disease (HD).

FIGURE 4.
Relationship between prosaccade and saccade inhibition performances in premanifest and manifest Huntington's disease patients.

TABLE 1

Sample Characteristics

Group	n	Gender		Age (years)			Education (years)		
		M	F	M	SD	M	M	SD	SD
Nongene carriers	31	20	11	39	12	14.7	14.7	2.3	
Prenanifest gene carriers	25	14	11	43	11	15.7	15.7	3.4	
Huntington's disease patients	12	8	4	46	14	14.5	14.5	3.3	

TABLE 2

Performance, by Group

Group	UHDRS motor		Fixation (% correct)	Prosaccade (ms)		Antisaccade (ms)	
	<i>M</i>	<i>SD</i>		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Nongene carriers	1.3	2.4	99.6	210	21	444	52
Prenanifest gene carriers	3.6	4.8	98.1	263	66	545	172
Huntington's disease patients	35.7	12.1	98.3	402	172	790	172

Note. UHDRS = United Huntington's Disease Rating Scale.