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case report

Saccadic Intrusions Contributing to Reading Disability: A Case Report

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ABSTRACT

Horizontal eye movements were recorded during tracking and reading in a patient with probable neurological involvement who complained of periods of oscillopsia and severe asthenopia, especially during reading. Saccadic intrusions occurred during all tracking tasks. Single and multiple saccadic intrusions found while reading, frequently accompanied periods of visual disturbance, and we attribute part of the reading disability to the presence of such abnormal eye movements. Various therapeutic measures were attempted and achieved some degree of success.

Key Words: saccadic intrusions, reading, oscillopsia, eye movements, neurological disease, strabismus, multiple sclerosis

Saccadic intrusions refer to a pair of conjugate saccades executed in opposite directions and having an average intersaccadic interval of 200 msec; the first saccade of an intrusion moves the eyes away from the intended position of fixation, while the second saccade of an intrusion returns the eye to the original fixation position, resulting in little net change in eye position.[1,2] Saccadic intrusions occur in a variety of pathological[2-6] and nonpathological[1,7-8] conditions. This report presents eye movement recordings during nonreading and reading tasks. Saccadic intrusions were frequently present and appeared to be responsible, in part, for the patient's chief complaint of "extreme difficulty during reading."

CLINICAL FINDINGS

Case History. The patient, a 27-year-old white female, was initially examined in the general optometric clinic in 1971 and has subsequently been examined in our specialty clinics over the past 5 years. The patient complained that letters and words appeared to "jump" (i.e., oscillopsia) and that her eyes "tripped over each other" as she read. Moreover, frontal headaches followed brief periods of reading. Because of these problems over the past several years, the patient has not been able to read for more than a few minutes without experiencing discomfort, confusion, and frustration. More recently, the problem has become so severe that the patient has decided to take a leave of absence from graduate school to reduce her reading requirement and has considered using materials from "Talking Books for the Blind" as a substitute for reading. The patient also complained that objects appeared larger, more saturated, and brighter in the right eye. At times, oscillopsia was noted during fixation of small, distant objects. Health history included hay fever, sinus problems, and emotional stress. She had not taken any drugs or medications on a regular basis for the past several months. Family history was noncontributory.

Optometric Test Results. Visual acuity was 6/6 (20/20) in each eye with full spectacle correction (RE, +3.75/−0.75 × 128; LE, +2.00/ −0.50 × 60/1.5Δ BD). Cover test revealed an intermittent right exotropia at distance (10Δ) and at near (6Δ); at times, a left hyperphoria (1.5Δ) was measured in primary position and in downgaze. Intermittent suppression of the right eye at distance and near was indicated by the Worth four dot test. Ocular motility testing in-

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dicated no gaze restrictions; however, slight jerkiness of the eyes was noted during fixation and pursuit tracking tasks. The nearpoint of convergence was normal (5 cm), but could only be accomplished with effort. Similarly, the accommodative amplitude (7 D) was normal in each eye, but could only be attained with effort. Dynamics of accommodation were abnormally slow, taking several seconds to attain clear focus through alternating ± 1 D flipper lenses monocularly and binocularly. There was no fixation disparity at distance or near. Stereoacuity was at least 40 sec arc. Aniseikonic testing (AO Office Eikonometer) with spectacle correction revealed +0.50 ± 0.37% (axis 90), +0.25 ± 0.50% (axis 180), and −0.10 ± 0.30° (declination), indicating absence of significant differences in ocular image size. Results of the biomicroscopic examination, intraocular pressure measurements, and color vision testing (Ishihara plates) were all within normal limits. Over the past 5 years, periods of orthoptic therapy (vergence, accommodation, and antisuppression exercises) have provided little relief of symptoms.

Neurological Test Results. Red-free ophthalmoscopy revealed small, bilateral patchiness in the retinal nerve fiber layer. Optic disc margins were well defined and had normal coloration. Central visual field testing revealed small, bilateral arcuate scotomas inferiorly. Pupils were equal, round, regular, and reacted normally to light and accommodative stimuli. Saccades were normometric. Intermittent jerk nystagmus was observed during monocular and binocular fixation. Pursuit movements were jerky. Optokinetic nystagmus appeared irregular in upgaze. Flash electroretinographic waveforms (a and b) had normal latencies and amplitudes. Flash visual-evoked responses revealed significant asymmetry between left and right hemispheric responses to monocular stimulation of either eye. With monocular stimulation to the left eye, the initial negative latency peaked at 40 msec over the left hemisphere, but at 50 msec over the right hemisphere. In contrast, with monocular stimulation to the right eye, the initial negative latencies over each hemisphere peaked at 70 msec. These findings were repeated on a subsequent visit and suggest possible conduction defects involving the primary visual pathways. The electroencephalogram was within normal limits. A tentative diagnosis of subclinical multiple sclerosis was made by the neurologist.

METHODS

Eye Movement Recording

Horizontal eye position of both eyes was monitored using a photoelectric technique[9] with spectacle correction in place. The system had a linear range of at least ±5° with 10 min arc resolution. System bandwidth was 70 Hz. The patient's head was stabilized by a headrest/chinrest assembly. To test fixational, saccadic, and pursuit eye movements over the central field (±5°), the patient was instructed to track a small (4 min arc), bright spot of light under computer control (PDP-8/I) which was viewed on a display monitor placed 57 cm away along the midline. Details of the apparatus and test stimuli have been described elsewhere.[10] To test symmetric vergence movements, the patient was instructed to follow two targets, located 25 and 50 cm away along the midline, that were alternately illuminated with temporal randomization to minimize prediction effects. To test reading eye movements, the patient was instructed to read several 100-word paragraphs of college level material that were placed 57 cm away along the midline. All version and vergence eye movement testing was repeated on several occasions over a 6-month period. At one test session, vertical eye position of one eye was also monitored using electro-oculography; bandwidth was 15 Hz.

EYE MOVEMENT RESULTS

Fixation. Saccadic intrusions were always present. In the light (Fig. 1A), saccadic intrusion amplitude averaged 0.6 ± 0.3° with a frequency of 2 per second. The initial saccade, which is error-producing in nature, was generally (90% of the time) directed to the right. Intrusion intersaccadic intervals were generally between 100 and 500 msec; however, this interval was less than 100 msec 20% of the time, suggesting preprogramming rather than use of visual feedback in the generation of the subsequent error-correcting saccadic component. Saccadic intrusion durations were within normal limits.[11] At times, intrusion frequency increased to 4 per second with an amplitude of about 0.5°. Intermittent (<5% of the time) left jerk nystagmus with an amplitude of 0.4° and having slightly slowed[11] (by 20%) corrective saccades was also found. Vertical saccadic intrusions were never present. In total darkness (Fig. 1B), average saccadic intrusion amplitude increased to 1.4 ± 0.8° with a frequency of 2 per second. Also evident was more variability in the overall saccadic intrusion pattern.

Saccadic Tracking. Random horizontal step and pulse target displacements were accurately followed with normal latencies.[10] During fixation periods, saccadic intrusions were present and averaged 0.9 ± 0.6° with intersaccadic intervals of 150 to 500 msec. Direction of the initial saccade was to the right 70% of the time. Saccadic durations were increased[11] by up to

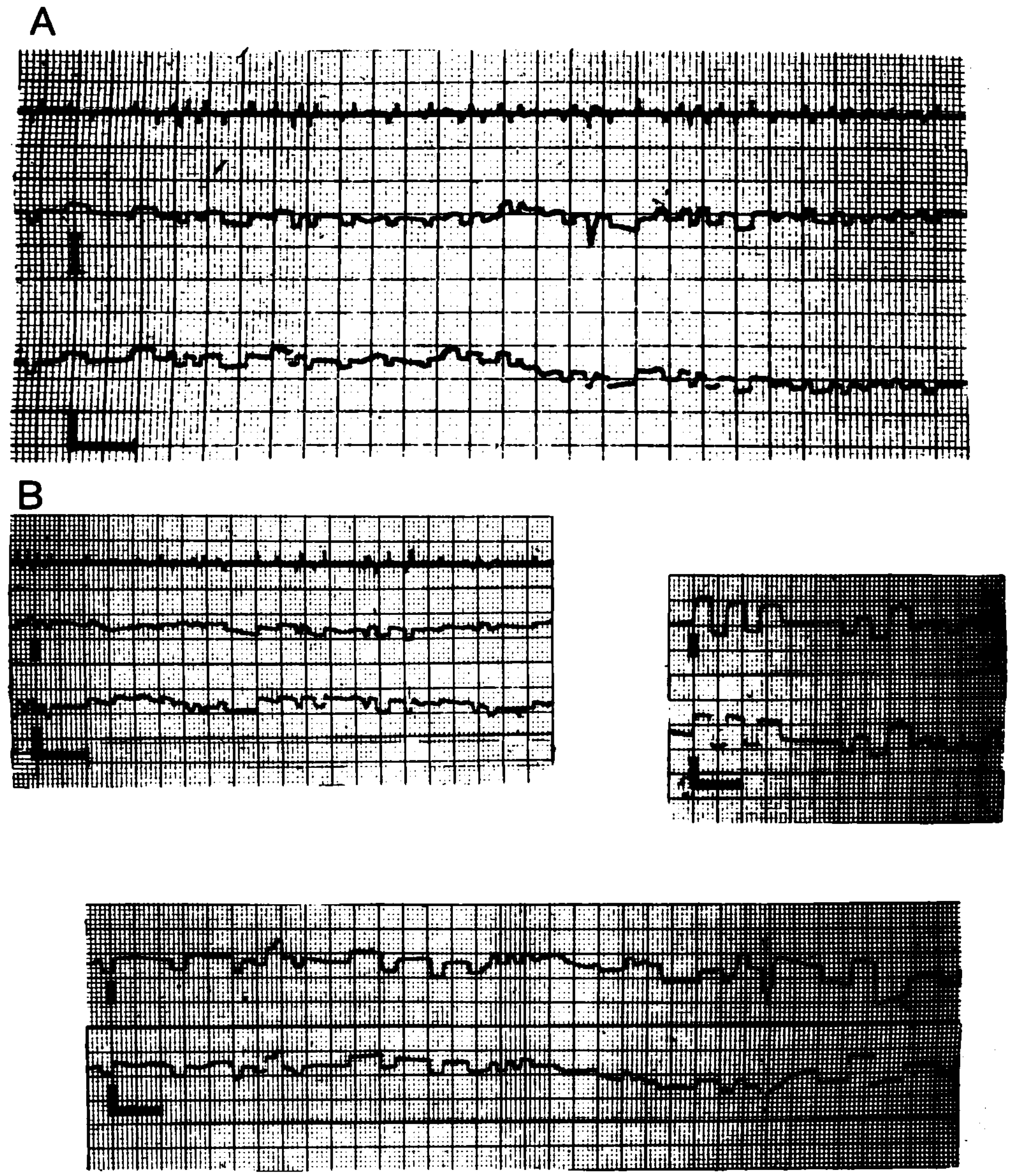

FIG. 1. Midline fixation. A: lights on; right eye occluded. Small-amplitude saccadic intrusions are present throughout record. From top to bottom: right eye velocity, left eye position, and right eye position. B: Upper left: binocular fixation with lights on. From top to bottom: right eye velocity, left eye position, and right eye position (upper left); and left eye position and right eye position (upper right and bottom). Upper right and bottom: fixation in darkness. Saccadic intrusion amplitude and variability increased in dark. For this and all other figures, upward deflections denote leftward movements, and calibration bars represent 2° and 1 sec.

50% for a few (5%) of the saccades. Vertical saccades (10 and 20° amplitudes) had normal dynamic characteristics.[11]

Optokinetic Nystagmus. Normal (gain >0.8) optokinetic nystagmus was elicited to a moving (5° per second, left or right) field (20°) of vertical black-and-white stripes. During this 20-sec test segment, only three distinct saccadic intrusions were found having amplitudes ranging from 0.5 to 2.5° and intersaccadic intervals ranging from 150 to 250 msec.

Pursuit. Pursuit ability varied with stimulus characteristics, although in all cases saccadic intrusions (0.8 ± 0.4°) were present. For slowly moving targets of relatively large excursions (Fig. 2A), pursuit gain was generally within normal limits (>0.8). However, saccadic intrusions having amplitudes of 0.4 to 2.5°, frequencies of 1.5 to 2.0/sec, and intersaccadic intervals generally ranging from 100 to 500 msec were superimposed on the smooth movements. One-second bursts of saccadic intrusions having amplitudes and frequencies ranging from 0.5 to 1.0° and 3.5 to 4 per second, respectively, were sometimes present. For slowly moving targets of relatively small excursions (Fig. 2B), low-gain (~0.2), saccadic-pursuit with small-amplitude (0.5 to 1.0°) saccadic intrusions superimposed was found. For slightly higher target velocities at relatively larger excursions (Fig. 2C), high gain (>0.8) pursuit prevailed with corrective saccades and saccadic intrusions (0.5 to 2.0°) present.

Symmetric Vergence. Vergence latencies were within normal limits (~200 msec). Other dynamic characteristics of convergence were also normal[12] (Fig. 3). However, during divergence, a large-amplitude (4.2 ± 0.8°), saccadic intrusion was always present with intersaccadic intervals frequently (50% of the time) less than 100 msec, suggesting they were preprogrammed and not dependent on visual feedback, as such short intersaccadic intervals are too brief for generation of a visually guided corrective movement. During periods of fixation, small-amplitude

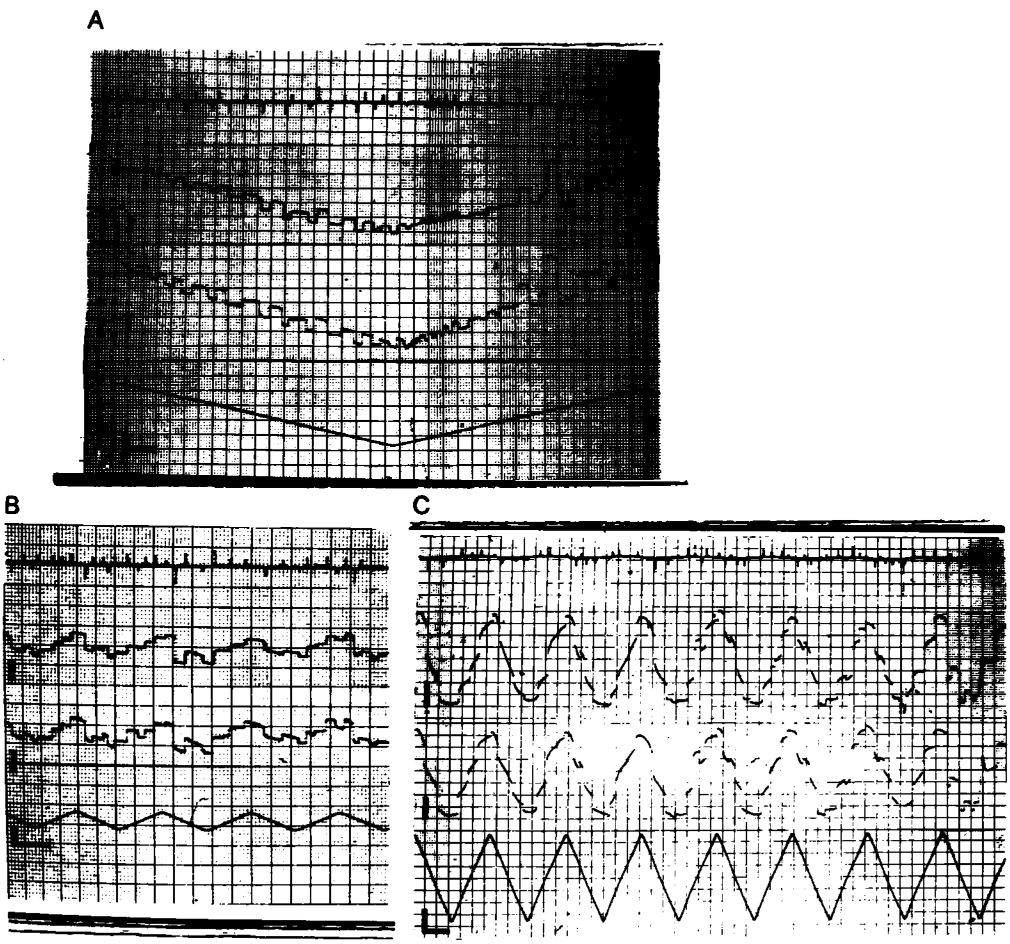

FIG. 2. Pursuit. Binocular viewing. A: tracking of target having large amplitude (8°) and very low velocity (0.8° per sec). Saccadic intrusions are evident throughout, including high frequency (7 to 8 saccades/sec) bursts at turnaround point. B: tracking of target having small amplitude (2°) and low velocity (1.75° per sec). Low-gain, asymmetric tracking with presence of saccadic intrusions evident. C: tracking of target having large amplitude (10°) and moderate velocity (6.75° per sec). Pursuit gain is generally within normal limits. Corrective saccades and saccadic intrusions are present. From top to bottom: right eye velocity, left eye position, right eye position, and stimulus, for all three records.

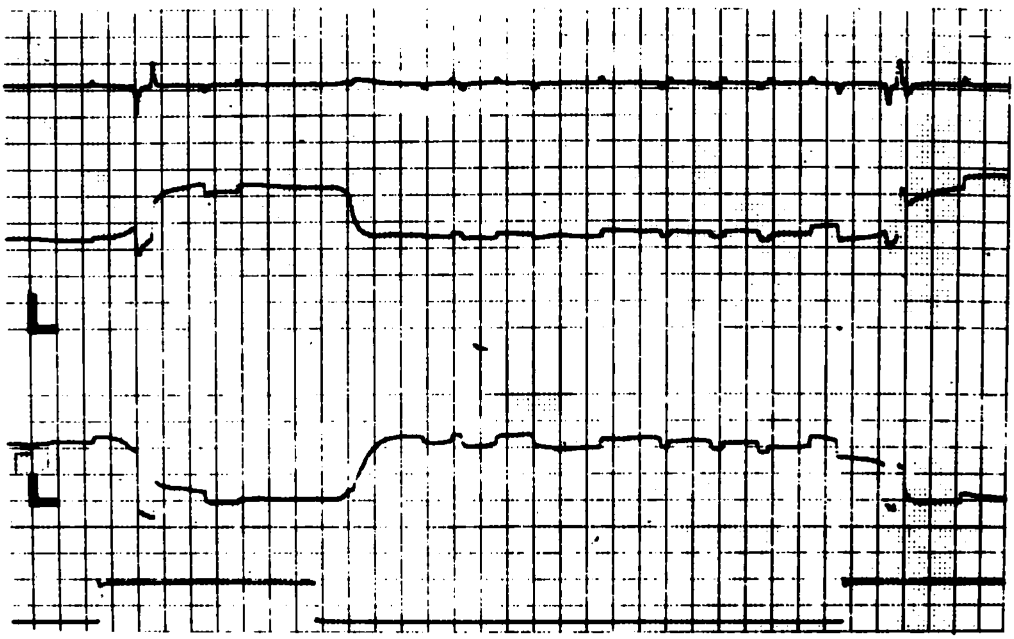

FIG. 3. Symmetric vergence. Convergence movements within normal limits. Large-amplitude saccadic intrusions are present during divergence movements. Small-amplitude saccadic intrusions are present during bifixation periods. Conventions are the same as in Fig. 2.

(~0.5°) saccadic intrusions having longer intersaccadic intervals of 150 to 500 msec were present, which suggested dependence on visual feedback for their generation.

Reading Eye Movements. Eye movements were recorded on several occasions over a six-month period. At the initial test session (Fig. 4A), there occurred brief (1 to 6 sec) bursts of saccadic intrusions having amplitudes ranging from 2.0 to 8.5° and averaging 5.0 ± 2.2°. Intersaccadic intervals ranged from 150 to 600 msec. Thus, the small-amplitude saccadic intrusions found during nonreading tasks were replaced by intermittently occurring, larger-amplitude intrusive saccades. Also present were single, 2 to 3° saccadic intrusions which were initially difficult to differentiate from regressive movements; however, these saccades were of larger amplitude than typical regressive movements[13] and had a common baseline before and after the movement, which strongly suggested they were saccadic intrusions rather than typical regressive movements.

Because the patient reported increased difficulty after 10 to 15 min of reading, we recorded her reading eye movements after 12 min of intensive reading in our laboratory during which time she reported considerable visual fatigue, discomfort, and jumping of letters; we also asked the patient to depress a switch, which activated the event marker on the strip chart recorder, during periods in which the words or letters seemed to jump and she became confused. A typical record is shown in Fig. 4B. Large-amplitude (5 to 10°) saccadic intrusions occurred concurrent with periods of visual disturbance. Also present were single, rightward directed saccadic intrusions, as found in Fig. 4A, and single leftward directed saccadic intrusions that occurred primarily during prolonged fixation (see beginning of record), with most of these single intrusive saccades occurring during or in close proximity to the designated periods of visual disturbance. These periods of visual disturbance increased twofold (6 vs. 12 sec out of a total of 40 sec) when the patient was fatigued. In this session, other eye movement abnormalities were found which could be related to the reading disability. These included: (1) reverse staircases,[13-19] (2) prolonged fixations[13,20] (500 to 4000 msec) during which time the patient indicated there was fixity of gaze ("locked gaze"), thus demonstrating an ocular motor apraxia-like condition,[21] with difficulty moving the eyes to the new intended position, especially when at the end of a line, and (3) intermittent, brief (1 to 3 sec) periods of gross (1 to 3°) over- or underconvergence.

On another occasion, both horizontal and vertical eye position of one eye were recorded during

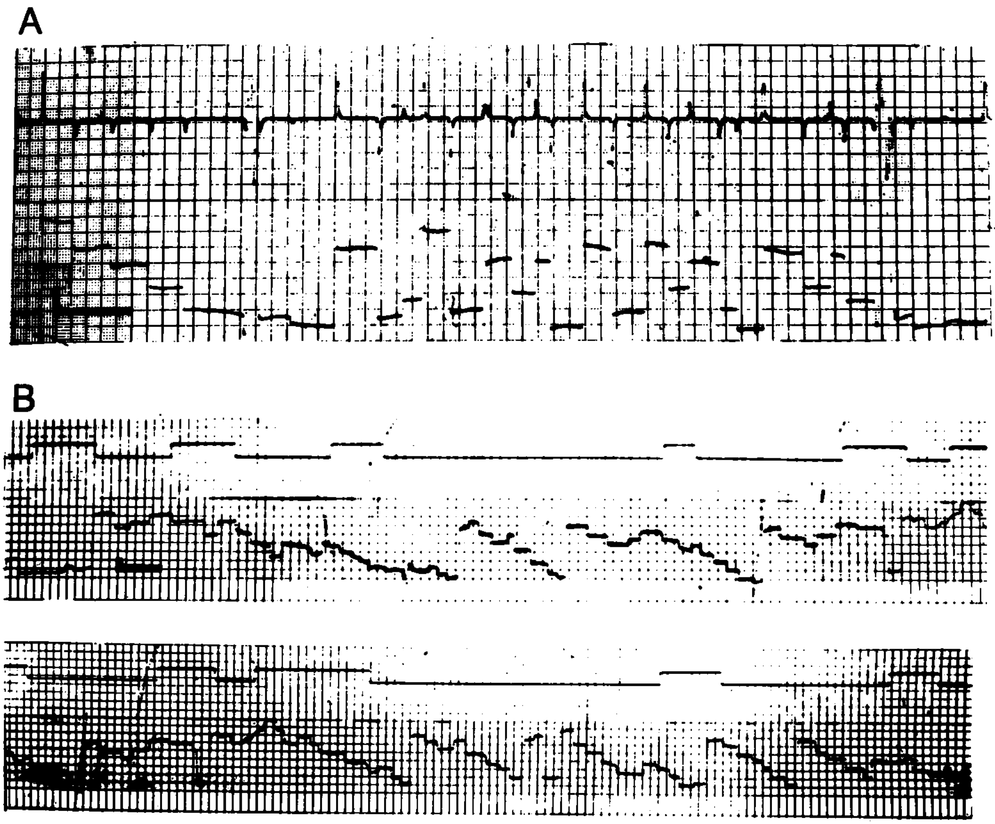

FIG. 4. Reading. Binocular viewing. A: normal reading followed by a 6-sec flurry of large-amplitude saccadic intrusions. Note the absence of small-amplitude saccadic intrusions. B: abnormal reading patterns for extended continuous reading period. The patient indicated that she was visually fatigued. The lower trace is left eye position. The upper trace is the event marker activated by the patient (upward deflections) to indicate periods of confusion and jumping of words and letters during reading. In most instances there was good agreement between subjective and objective measures with saccadic intrusions occurring within or in close proximity to patient-indicated periods of visual disturbance.

reading. Saccadic intrusions of approximately 5° in amplitude occurred intermittently. A few (20%) of these intrusive saccades had a small (1 to 2°) vertical component. Return-sweep saccades were within normal limits.

Saccadic intrusions were found with equal frequency during monocular and binocular viewing during all versional testing (reading and nonreading). Furthermore, saccadic intrusion frequency was not dependent on the patient's effort to track the target. The intrusive saccade intensity was much greater than that found in a typical strabismic patient[8] and did not change with application of plus lenses or prisms.

DISCUSSION

While saccadic intrusions during tracking tasks have been reported in some patients with frank neurological involvement,[2–6] these intrusive saccades have also been found in persons who do not manifest clinical signs and symptoms of brain pathology.[1, 7–8] In our clinic, we have objectively documented the presence of saccadic intrusions of various intensities during tracking tasks in about 10% of our patients who appear to be free of ocular or neurological disease. This has included a young child without reading difficulty, a young woman with reading difficulty, strabismics, a middle-aged woman undergoing recent psychological stress, anxious individuals, and persons whose saccadic intrusions can be related to predictive strategies designed to enhance pursuit tracking performance. Thus, a diagnosis must be based on more than simply the presence of saccadic intrusions, and recent efforts[2, 7–8] using detailed quantitative analysis of the frequency, amplitude, and intersaccadic interval of these intrusive saccades have assisted in the differential diagnosis in patients exhibiting such eye movements.

To the best of our knowledge, this is the first report in which reading eye movements were objectively recorded in a patient with presence of saccadic intrusions implicated in the reading difficulty. With our patient, presence of saccadic intrusions usually occurred concurrent with, or in proximity to, periods of visual disturbance (i.e., oscillopsia). Further, visual fatigue exacerbated the condition. Although oscillopsia was reported at times during fixation of the test spot and small objects in the room, saccadic intrusions were not always present during these episodes. The patient's signs (saccadic intrusions, asymmetric visually-evoked response waveforms, ophthalmoscopically determined nerve fiber defect, and visual field defect) and symptoms (oscillopsia, interocular differences in size, brightness, and color of objects) are strongly suggestive of neurological involvement, such as early multiple sclerosis. The presence of oscillopsia in conjunction with abnormal fixational eye movements is consistent with such a diagnosis.[22] However, additional periodic testing of sensory and motor functions is required before a definite diagnosis can be made.

Several therapeutic measures were attempted and met with varying degrees of success. Relief of symptoms after occlusion of one eye suggests the contribution of abnormal binocular vision, including oculomotor imbalance and/or aniseikonia, to the reading difficulty; however, only a slight reduction of symptoms was reported by the patient under such conditions. A typoscope was also tried. We felt this simple device might help to direct the patient's gaze and attention to the appropriate line of print and thus minimize distractions from the surrounding text. Some relief was noted. Enlarging the print by projecting paragraphs of text onto a screen was not beneficial; however, the patient was able to read longer and with more comfort using a small, low-powered magnifier. Lastly, simply taking more frequent rest periods allowed the patient to read for up to 1 hr before the onset of severe asthenopia.

We have considered developing a reading aid for patients with saccadic intrusions and other eye movement abnormalities that interfere with reading. The patient would wear a simple eye movement monitoring device while reading text reflected off a lightweight, rotatable mirror. Whenever either a threshold number and/or amplitude of saccadic intrusions occurred, the eye movement signal would be electronically transmitted to an external feedback system which controlled mirror rotation. This system would rapidly shift the image of the text precisely in the same direction and by the same amount as the eyes had moved, thereby maintaining the text effectively stabilized with respect to the lines of sight during a flurry of saccadic intrusions.

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