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Square wave oscillation

The relationship of saccadic intrusions and oscillations

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ABSTRACT. A patient with progressive supranuclear palsy exhibited an extremely high number of square wave jerks. These usually sporadic saccadic intrusions were so frequent as to form a continuous oscillation. Such a phenomenon suggests an underlying commonality between sporadic saccadic intrusions (square wave jerks, saccadic pulses and double saccadic pulses) and saccadic oscillations (macro square wave jerks, MSO and flutter).

Key words: square wave jerks; saccadic intrusions; saccadic oscillations

INTRODUCTION

Visual fixation may be interrupted by either sporadic eye movements or by sustained oscillations. The latter include the various forms of nystagmus, which are all initiated by slow drifts off fixation, and saccadic oscillations (macro saccadic oscillations, flutter, voluntary 'nystagmus', etc.) (Dell'-Osso, 1982). Sporadic disturbances, including square wave jerks, saccadic pulses, and double saccadic pulses (Doslak *et al.*, 1983), are always saccadic and are termed saccadic intrusions (Daroff, 1977). The patient we will report had a unique eye movement disturbance which, at times, was virtually continuous and at other times more sporadic, thus serving to illustrate the relationship between saccadic oscillations and intrusions which may be related along a continuum.

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CASE REPORT

This 63-year-old gentleman was admitted to hospital in June 1982 with a history of progressive slowness in ambulation over the past two years. On examination he was found to demonstrate ridigity of all extremities, masked facies, bradykinesia, and slowness on making turns. He had finger-to-nose ataxia and was noted to be dysarthric. There was no distinct abnormality on mental status testing.

Clinical examination of extraocular movements revealed inability to make vertical saccadic or pursuit eye movements but normal vertical oculo-cephalic movements

were present. There was full excursion of horizontal saccadic and pursuit movements.

CT scan revealed no abnormalities. The clinical diagnosis was progressive supranuclear palsy.

METHODS

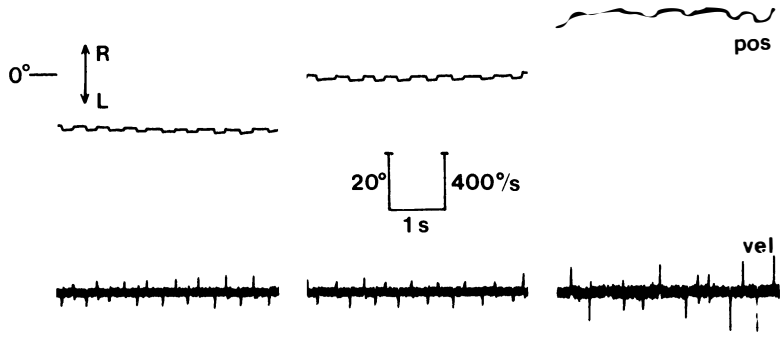
The patient was seated in a dimly-illuminated room in a chair with a head rest and chin brace, placed at the center of an arc of radius 1.5 m on which were mounted red light-emitting diodes for use as targets. His eye movements were recorded using infrared oculography (Narco Bio-Systems Model 200). A vertical EOG lead was used to detect blinks. Eye movements were electronically differentiated and both position and velocity traces were recorded on a modified Beckman Type R Dynograph. The bandwidth of the entire system (position and velocity) was DC-100 Hz. Eye movements were recorded as the patient fixated targets at 0 and ± 10 and ± 20 deg. Smooth pursuit and convergence were evaluated by having the patient follow a hand light.

Fig. 1. Square wave oscillations (SWO) seen in primary position and at ±20°. Note the great regularity of the eye movements seen at 0° and -20°.

RESULTS

An extraordinary number of square wave jerks (SWJ) were present in both primary position and lateral gaze (Fig. 1.) They ranged in amplitude from 2 to 5 deg and were so frequent that it was often difficult to determine on examination which saccades took the eyes off target and which returned them. Their duty cycle (the ratio of time off target to time on target) was ≤ 0.5; a duty cycle of 0.5 indicates a perfectly symmetrical oscillation with equal amounts of time on and off target. The time spent off target was roughly equal to the normal saccadic reaction time (200-300 msec). Assuming that the eyes were on target during the longer half of the cycle, the initial saccade of each SWJ was usually to the left of fixation, with only occasional SWJ's to the right (Fig. 2). At times the SWJ occurred irregularly and sporadically but with no SWJ-free intervals longer than 1 sec (Fig. 2, particularly the left portion). At other times, however, they took on the unique form of a regular, periodic oscillation, each half-cycle of which was an otherwise ordinary SWJ (Fig. 1 and Fig. 2, right portion).

The SWJ persisted during an unsuccessful attempt at convergence. Pursuit was



present but at greatly reduced gain and the incidence of SWJ was less.

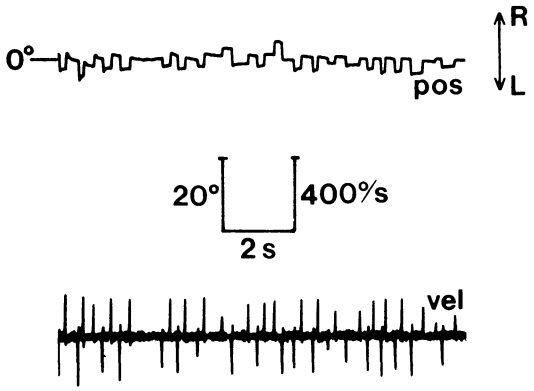


Fig. 2. Transition between irregular square wave jerks (left portion of figure) and SWO (right portion).

DISCUSSION

Square wave jerks have been described in both normal subjects and in patients with a wide range of disorders (Ciuffreda *et al.*, 1979; Herishanu & Sharpe, 1981; Hotson, 1982; Jung & Kornhuber, 1964; Sharpe *et al.*, 1982). SWJ are one of the class of saccadic intrusions along with saccadic pulses (SP) (stepless saccades) and double saccadic pulses (DSP) (Dell'Osso, 1982; Doslak *et al.*, 1983; Schmidt *et al.*, 1980). These eye movements are all initiated by a fast eye movement away from the desired position of gaze. Unlike SP or DSP, each SWJ consists of two completely normal saccades. They may occur singly or in small groups and have been classified only as an intrusion, as distinct from saccadic oscillations such as flutter, macro square wave jerks (MSWJ) and macro saccadic oscillations (MSO) (Dell'Osso *et al.*, 1977). Our case suggests that this separation is artificial; SWJ usually occur sporadically as an intrusion but may occur continuously as an oscillation. Our patient illustrates this continuum. Two basic patterns were seen. In one ('square wave oscillation') the eyes made saccades off target to the left, returned after a latency of approximately 250 msec, and repeated the process continuously for extended periods of time. The SWJ frequency at times exceeded 100/min. Since the time off-target was the visual reaction time, this oscillation differs from MSWJ, where the off-target time is always less than this (Dell'Osso *et al.*, 1977); MSWJ always have a duty cycle $\ll 0.5$. In the second pattern (SWJ intrusions), the SWJ were less periodic but still frequent, with more intersaccadic variability; during these periods a few SWJ to the right also appeared. Individual SWJ's seen in either pattern were indistinguishable. Thus, separate generators for them are unlikely. Mechanistically, then, frequent SWJ intrusions and SWO may be either the desynchronization of a single underlying oscillatory process, or more likely, may represent variation in the mechanism responsible for the restraint of intrusions during fixation.

The same reasoning is applicable to other forms of saccadic intrusions. For example, a SP is produced by a single inappropriate burst of firing; a DSP arises from two such pulses occurring back-to-back, equal in amplitude but opposite in direction. Depending on how long such a sequence continues, a prolonged chain of these movements can be produced; if they go on for several cycles they become ocular flutter, a well-known cerebellar eye sign (Daroff, 1982; Zee & Robinson, 1979). The boundary between one or two isolated pulses and flutter appears to be arbitrary,

TABLE 1

Saccadic intrusions	*Saccadic oscillations*
Bobbing (sporadic)	Bobbing
Double saccadic pulses	Opsoclonus, flutter, flutter dysmetria, voluntary 'nystagmus'
Macro square wave jerks (sporadic)	Macro square wave jerks
Saccadic pulses	Convergence-retraction 'nystagmus', superior oblique myokymia
Square wave jerks	Square wave oscillations
	Macro saccadic oscillations
	Myoclonus

but they are often discussed as separate phenomena (Toupet *et al.*, 1982). This approach obscures the underlying unity of mechanism of both the sporadic and oscillatory saccadic disturbances of fixation. Similarly, MSWJ were not originally included as saccadic intrusions since they were first observed only in bursts (Dell'-Osso, *et al.*, 1975). We have since seen rare single MSWJ in occasional patients. The various saccadic intrusions and their corresponding oscillations are listed in the table. Thus, saccadic intrusion and saccadic oscillations may represent manifestations of common underlying instabilities, different only in frequency and persistence.

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