SACCADIC INTRUSIONS MADE SIMPLE

Janet C. Rucker, MD
New York University School of Medicine
New York, NY

INTRODUCTION

Saccadic Intrusions: simple definition

There are two main categories of abnormal spontaneous eye movements that can intrude upon our ability to visually fixate and hold our eyes steady. The first and most familiar of these is nystagmus. The second type is saccadic intrusions. Though there are several differences between these two types of eye movements, the most important difference is whether the very first movement consists of a slow drift of the eyes or of a fast eye movement (a saccade). The first movement in nystagmus is a slow drift of the eyes away from a desired position. This slow drift may then be followed by a fast corrective movement in the opposite direction (jerk nystagmus) or by another slow drift (pendular nystagmus). *The first movement (and all subsequent movements) of saccadic intrusions is a saccade that intrudes upon visual fixation.* The differences between nystagmus and saccades are further delineated in the table below.

Table: Differences between the two types of abnormal spontaneous eye movements: nystagmus and saccadic intrusions

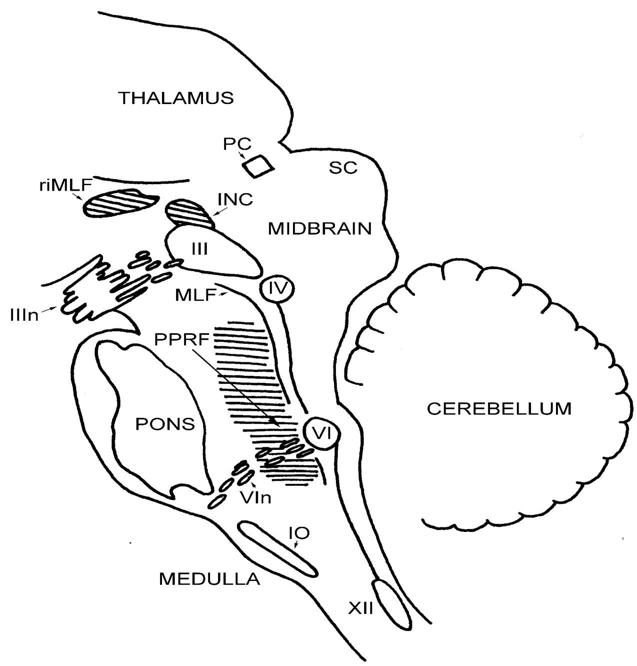
	Initial Movement	Rhythmicity	Timing	Constancy
NYSTAGMUS	Slow drift	Rhythmic	Regular, continuous, slower than saccadic intrusions	For types that occur in central fixation, sustained
SACCADIC INTRUSIONS	Saccade	Non-rhythmic and erratically appearing	Most types occur in irregular bursts	Unsustained

Saccades: what are they and what parts of the brain control them?

We have five different types of eye movements: saccades, smooth pursuit, vestibular ocular reflexes, optokinetic nystagmus, and vergence. All of these eye movements exist for two main reasons: 1) to hold images steady on the retina and 2) to point the fovea of our retina at features of visual interest. With regard to the first, if images are not steady on our retina, vision is degraded and oscillopsia, or a subjective sense of visual motion, will occur. With regard to the second, our fovea is the retinal location with the highest density of photoreceptors and, thus, the best visual acuity. If images are displaced from the fovea, visual clarity deteriorates. Our most rapid eye movements, saccades, exist to serve several visual needs such as allowing visual search, voluntary gaze towards an object of interest, and "reflexive" saccades in response to the sudden appearance of new visual, auditory, or tactile cues. Our brains have special circuitry dedicated to all of these functions. In addition, our brains have special circuitry to eliminate unwanted saccades. When this circuitry fails, unwanted saccades intrude upon our visual fixation – thus creating saccadic intrusions.

Several cortical regions, such as the parietal and frontal eye fields and others, initially generate the saccades we make. However, the localization of saccadic intrusions is not typically cortical and tends to be in structures in the brainstem and cerebellum. Parallel, descending pathways via intermediate structures such as the superior colliculus and basal ganglia connect the cortical regions with brainstem and cerebellar structures concerned with the generation of saccades. Execution of any type of saccade requires a sudden, intense neural discharge provided by excitatory burst neurons in the brainstem to the cranial nerve nucleus and motoneuron (Fig. 1). *For horizontal saccades, the burst neurons are located in the pontine paramedian reticular formation (PPRF) in the* *caudal, dorsal pons* – just rostral to the abducens nucleus. *For vertical saccades, most of the burst neurons are located in the rostral interstitial medial longitudinal fasciculus (riMLF) in the midbrain* rostral to the oculomotor nucleus. Some are located in the interstitial nucleus of Cajal (INC), just caudal to the riMLF. Inhibition of burst neurons is required at all times other than when a saccade is occurring. This is provided by *omnipause neurons located in the nucleus raphe interpositus (RIP)* in the caudal pons. Connections between the brainstem saccade structures and the cerebellum, especially the cerebellar vermis, are also important in normal saccade function and accuracy.

Figure 1. Drawing of a sagittal brainstem view showing the localization of ocular motor-related nuclei.



Within the midbrain, premotor burst neurons for vertical saccades are located within the riMLF. The INC likely also contains vertical premotor burst neurons. The shaded region in the pons is the PPRF, containing premotor burst neurons for horizontal saccades, with an arrow showing the approximate location of these neurons in the caudal PPRF.

Abbreviations: PC = posterior commisure; riMLF = rostral interstitial medial longitudinal fasciculus; INC = interstitial nucleus of Cajal; SC = superior colliculus; IIIn = oculomotor nerve fascicle; III = oculomotor nucleus; IV = trochlear nucleus; MLF = medial longitudinal fasciculus; PPRF= paramedian pontine reticular formation; VI = abducens nucleus; VIn = abducens nerve rootlets; IO = inferior olive; XII = hypoglossal nerve. Drawing based on Buttner U, Buttner-Ennever JA. Prog Brain Res 2005;151:1-42.

SACCADIC INTRUSIONS

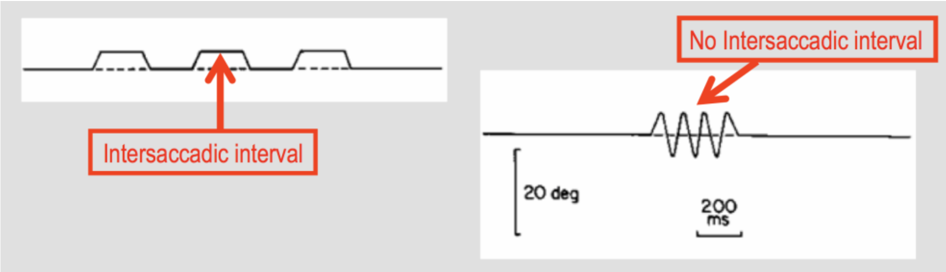
Classification and the importance of intersaccadic intervals

As above, saccadic intrusions are unwanted saccades that intrude upon visual fixation and, thus, disrupt vision. Sustained saccadic intrusions (e.g. saccadic oscillations) may cause the patient to experience oscillopsia. Saccadic intrusions are often recognizable at the 'bedside' on the clinical examination, but they have been defined based on their characteristics as seen on quantitative eye movement recordings and sometimes such eye movement recordings may be needed for the physician to be absolutely certain of the type of intrusion being seen. It is very important to characterize them accurately, as they have widely different causes and neurological prognoses.

To examine a patient for the presence of saccadic intrusions, the patient just stares straight ahead at a fixation target and the examiner watches the eyes. It is important to watch closely, as most of the movements can be quite small. They are often provoked by gaze-shifts, so eliciting them during the examination may occur by asking the patient to look quickly to one side and then back to the center. They may also be seen superimposed on other types of eye movements, such as during smooth pursuit attempts.

Saccadic intrusions are mainly categorized into two types – those with an intersaccadic interval and those without one. In the first case, each abnormal unwanted saccade of the intrusion is separated by a brief interval called the intersaccadic interval (Fig. 2 left). In the second case, back to back saccades occur without any pause or interval in between movements (Fig. 2 right). In addition to whether or not they have an intersaccadic interval, saccadic intrusions are also defined by the duration of their intersaccadic interval is one is present, by how large they are (e.g., their amplitude), by whether they remove and return the eye to central fixation or whether they oscillate about central fixation, and by the direction in which they move (i.e., horizontal, vertical, torsional). The most common types of saccadic intrusions will be addressed below.

Figure 2. Saccadic intrusions with (left) and without (right) and intersaccadic interval.



The horizontal line in the figure represents a stationary eye maintaining visual fixation. In the left image, the upward deflection of the line represents a sudden fast saccade, followed by a pause, and then a saccade is made back to the fixation point. Three of these pairs of saccades away from and back to fixation are seen. In the right image, the upward deflection of the line also represents a saccade but note that it is immediately followed by a series of saccades with no interval in between.

Saccadic intrusions *with an intersaccadic interval*

Square wave jerks

Square wave jerks are pairs of small (0.5 degree) involuntary saccades that take the eyes off the target and are followed, after an intersaccadic interval (130 to 200 msec), by a corrective saccade that brings the eyes back to the target (Fig. 2 left) (Abadi and Gowen, 2004). They may occur in normal individuals (especially the elderly), but also in a variety of neurological disorders, most prominently cerebellar disorders and progressive supranuclear palsy (Herishanu and Sharpe, 1981; Otero-Millan et al., 2011; Shallo-Hoffman et al., 1989). In disease states, they tend to occur very frequently. Square wave jerks seldom cause visual symptoms, unless large and frequent. They are generally thought to be due to disruption of control centers that maintain visual fixation, such as the superior colliculus or its inputs.

Macrosaccadic oscillations

Macrosaccadic oscillations are large-amplitude (5-15 degrees) square-wave intrusions that oscillate the eye around the desired fixation point with an intersaccadic interval in between each saccadic movement. They are often small at first and then get larger and then smaller again. They generally occur with cerebellar disease, especially with disease affecting the cerebellar fastigial nucleus (Selhorst et al., 1976).

Saccadic intrusions *without an intersaccadic interval*

Ocular flutter and opsoclonus

Ocular flutter is a burst of back-to-back horizontal saccades without an intersaccadic interval (Fig. 2 right). These movements typically look much faster than square wave jerks, which also tend to mainly occur in the horizontal direction. When back-to-back saccades without an intersaccadic interval occur in multiple directions (i.e., horizontal, vertical, torsional), this is opsoclonus, which is also sometimes called ‘saccadomania’. Ocular flutter and opsoclonus are usually encountered in the context of brainstem encephalitis or paraneoplastic syndromes. They have been reported in association with the following antibodies: Hu, Yo, Ma, amphiphysin, P/Q calcium channel, and NMDAR (Bataller and Dalmau, 2004; Gordon, 2015; Smith et al., 2011). In the setting of brainstem encephalitis, patients typically also exhibit myoclonus, ataxia, and emotional lability. In children, opsoclonus is most associated with neuroblastoma as part of the ‘dancing eyes and dancing feet’ syndrome (Shawkat et al., 1993). Patients with flutter and opsoclonus frequently complain of oscillopsia, even if the oscillations are of small amplitude; this is due to their high frequency that causes a large degree of retinal motion. Although there is no animal model for flutter and opsoclonus, current hypotheses explain these oscillations in terms of the connectivity between the brainstem neurons that generate and regulate saccades - the "burst" and "omnipause" cells (Shaikh et al., 2008).

A special situation – voluntary ‘nystagmus’ or flutter

Some normal individuals can generate flutter-like movements (“voluntary nystagmus”), usually using voluntary convergence of the eyes to induce these oscillations. These tend to be very fast horizontal back-to-back saccades that, in most cases, cannot be maintained for too long.

References:

Abadi RV, Gowen E. Characteristics of saccadic intrusions. Vision Res 2004;44:2675-2690.

Bataller L, Dalmau J. Neuro-ophthalmology and paraneoplastic syndromes. Curr Opin Neurol 2004;17:3-8.

Gordon LK. Paraneoplastic syndromes in neuro-ophthalmology. J Neuroophthalmol 2015;35:306-314.

Herishanu YO, Sharpe JA. Normal square wave jerks. Invest Ophthalmol Vis Sci 1981;20:268-272.

Otero-Millan J, Serra A, Leigh RJ, et al. Distinctive features of saccadic intrusions and microsaccades in progressive supranuclear palsy. J Neurosci 2011;31:4379-4387.

Selhorst JB, Stark L, Ochs AL, et al. Disorders in cerebellar ocular motor control. II. Macrosaccadic oscillation. An oculographic, control system and clinico-anatomical analysis. Brain 1976;99:509-522.

Shaikh AG, Ramat S, Optican LM, et al. Saccadic burst cell membrane dysfunction is responsible for saccadic oscillations. J Neuroophthalmol 2008;28:329-336.

Shallo-Hoffman J, Petersen J, Muhlendyck H. How normal are ‘normal’ square wave jerks? Invest Ophthalmol Vis Sci 1989;30:1009-1011.

Shawkat FS, Harris CW, Wilson J, et al. Eye movements in children with opsoclonus-polymyoclonus. Neuropediatrics 1993;24:218-223.

Smith JH, Dhamija R, Moseley BD, et al. N-methyl-D-aspartate receptor autoimmune encephalitis presenting with opsoclonus-myoclonus: treatment response to plasmapheresis. Arch Neurol 2011;68:1069-1072.