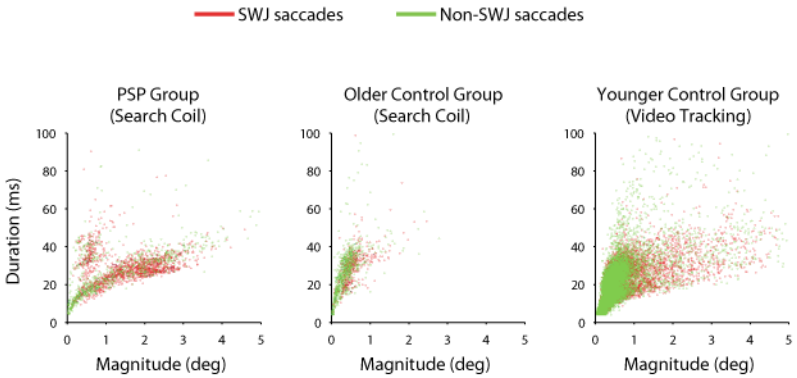
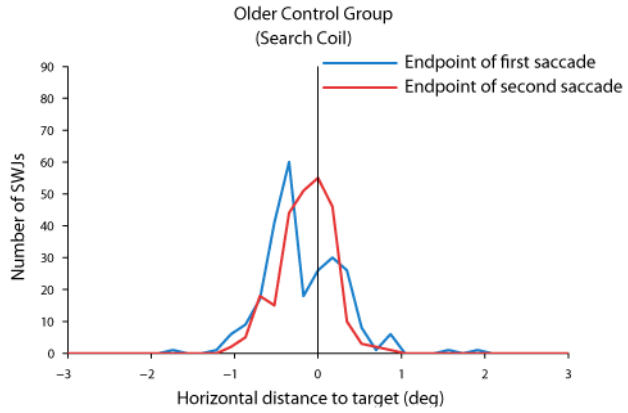
Title: Distinctive Features of Saccadic Intrusions and Microsaccades in Progressive Supranuclear Palsy

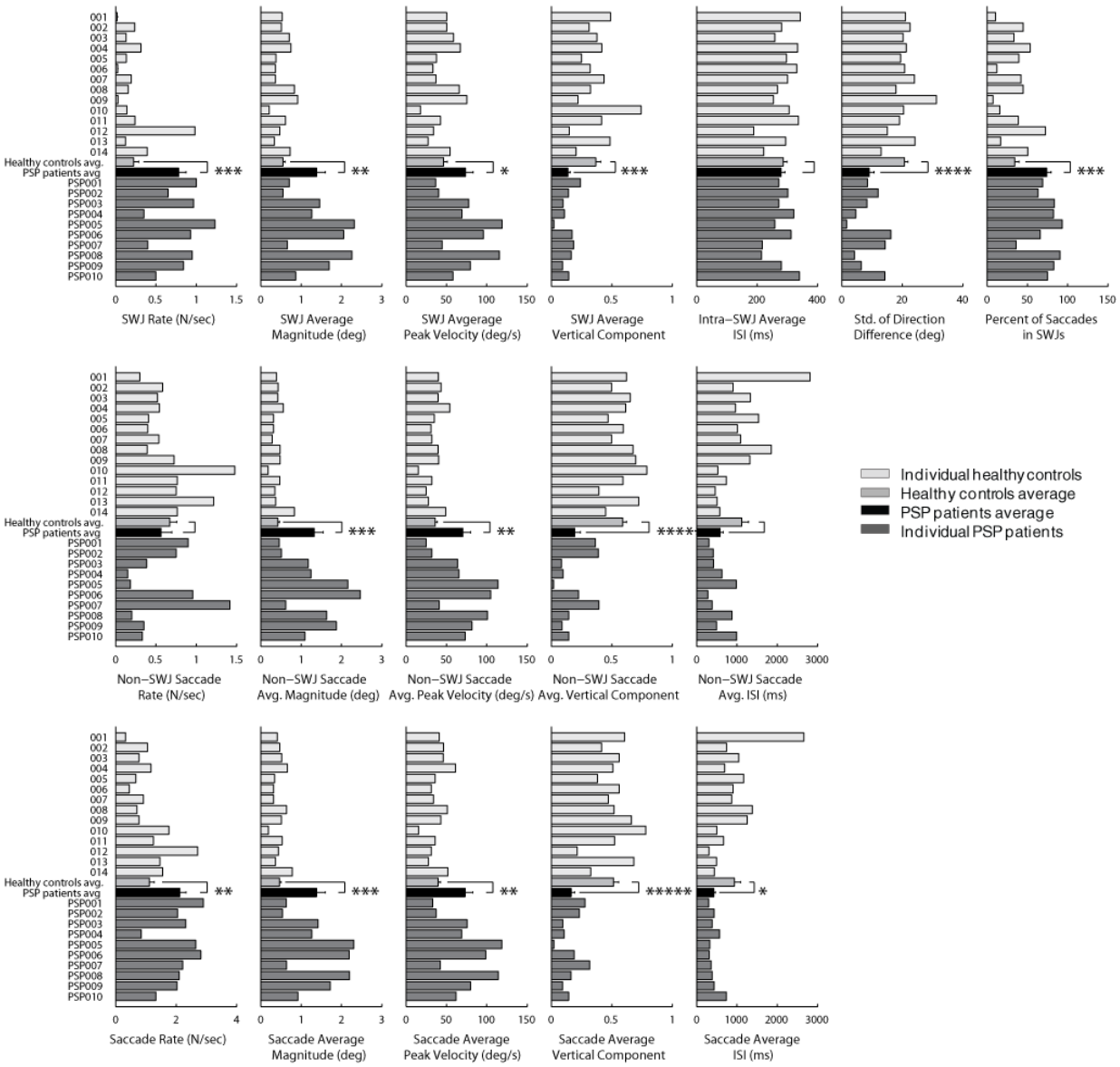
Supplemental material: 4 Supplementary Figures, 2 Supplementary Movies and 2 Supplementary Tables



Supplementary Figure 1. Relationship between saccadic duration and saccadic magnitude for the three subject groups. Saccades in SWJs are plotted in red and saccades not in SWJs are plotted in green.



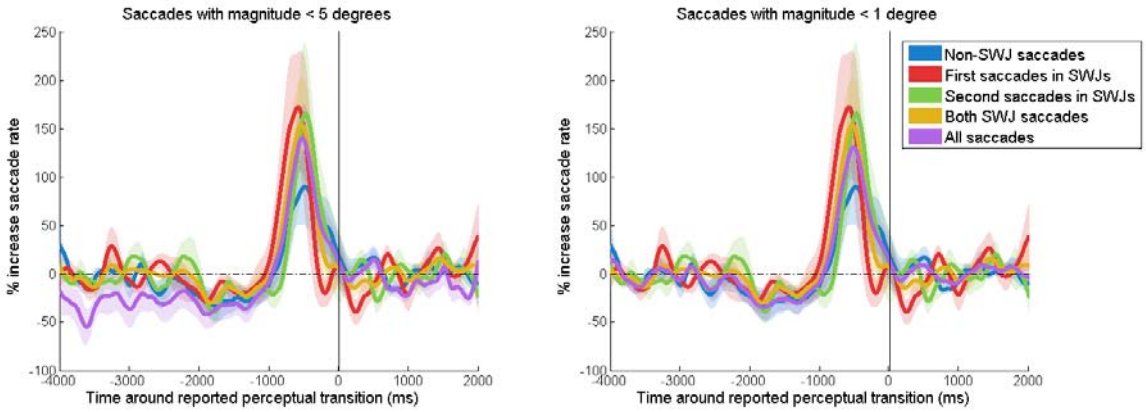
Supplementary Figure 2. Corrective function of the second saccade in SWJs. Eye position distributions at the end of the first saccade (blue) are compared to those at the end of the second saccade (red). The endpoints of the second saccades are centered on the central fixation target (i.e. the second saccade is corrective) whereas the endpoints of the first saccades tend to move the eye away from the target. Unlike the video-based data collected with the EyeLink system (Younger Control Group), the spatial resolution of the magnetic field/search-coil data (Older Control Group and PSP Group) was high enough to determine the absolute eye position in space. However, eye position measurements that depend on visually driven eye movements for calibration are inherently unreliable in PSP patients, as they cannot reliably point their foveal line of sight due to their defect in voluntary gaze. Thus, we conducted this analysis in the Older Control Group only.



Supplementary Figure 3. Comparison of SWJ and saccade properties in PSP patients vs. control subjects –Individual subjects' data and population averages. The light gray bars in each panel (labeled "001" through "014") represent individual healthy subjects (Younger Control Group represented in the first 7 bars and Older Control Group in the following 7). The dark gray bars (labeled "PSP001" through "PSP010") represent individual PSP patients. The medium gray and black bars indicate the respective averages for the control and the PSP population. The standard error of the mean is indicated, along

with the p-values for each comparison (* (p≤0.01), ** (p. ≤0.001), *** (p≤0.0001), **** (p≤0.00001); two-tailed t-tests). The SWJ and saccade properties represented in each panel (from left to right and top to bottom) are:

a. SWJ rate (number of SWJs per second).
b. Average magnitude of saccades that are part of SWJs.
c. Average peak velocity of saccades that are part of SWJs.
d. Average vertical component of saccades in SWJs.
e. Average ISI between first and second saccade in a SWJ (intra-SJW ISI).
f. Standard deviation of the direction difference between first and second saccade in a SWJ.
g. Percentage of small saccades (up to 5 deg) that are part of SWJs.
h. Non-SWJ saccade rate (rate of saccades that are not part of SWJs).
i. Average magnitude of saccades that are not part of SWJs.
j. Average peak velocity of saccades that are not part of SWJs.
k. Average vertical component of saccades outside SWJs.
l. Average ISI between saccades outside SWJs.
m. Total saccadic rate (including both saccades (up to 5 degrees) inside and outside SWJs).
n. Average magnitude of all saccades (both inside and outside SWJs).
o. Average peak velocity of all saccades (both inside and outside SWJs).
p. Average ISI for all saccades (both inside and outside SWJs).
q. Average vertical component of all saccades (both inside and outside SWJs).



Supplementary Figure 4.

SWJs counteract visual fading and filling-in during fixation. SWJ dynamics are shown in correlation to stimulus visibility in a visual fading paradigm. The original data was collected as part of a previous study (Troncoso et al., 2008a). Subjects (n = 6) reported the perceptual filling-in of an artificial scotoma embedded in dynamic noise (see (Troncoso et al., 2008a) for details). The plots illustrate the % increase in instantaneous saccade rates before the perceptual transitions towards “unfilled” (i.e. visible) scotomas, for the subject average. Reported perceptual transitions towards visible scotomas are aligned at time = 0. The different colored lines correspond to saccades outside SWJs (brown), saccades constituting SWJs (blue), and the first (green) and second (i.e. return) (red) saccades of SWJs. In each case, the percent increase in saccade rate was calculated over the average saccade rate (of that type of saccade) during the recording session. Shaded areas indicate SEM between subjects. The results suggest that all saccades contributed to maintaining visibility and counteracting fading and filling-in during visual fixation, and that the strongest contributions were those of saccades forming part of SWJs. The results were equivalent for saccades up to 5 degrees (left) and up to 1 degree (right).

Supplementary Movie 1.

Eye position traces of two consecutive SWJs from a patient with PSP. Left panel: horizontal eye position from one eye. Right panel: horizontal versus vertical eye position for the same eye.

Supplementary Movie 2.

This video clip shows the typical appearance of square-wave jerks in a patient with PSP. Note how these small saccades occur in pairs, the first movement taking the eye away from the fixation position and the second returning it. The initial movement may be to the left or right. Courtesy of Dr. Janet Rucker.

Supplementary Table 1: Summary of Clinical Features of PSP Patients

Subject/Sex/Age	Disease duration	Clinical Presentation and ocular motor findings	CNS Medications	Date of record
PSP01/M/61	4	Falls; difficulty with vertical gaze Slow downward saccades; impaired vergence	None	4/10/07
PSP02 /M/74	6	Slow speech; loss of balance Slow vertical saccades; impaired convergence	None	4/11/07
PSP03 /F/61	4	Loss of balance and falls Slow vertical saccades, impaired vertical pursuit and vergence	Levodopa	4/3/07
PSP04 /F/65	3	Dysarthia; fixed stare; falls Vertical saccades difficult to initiate and slow; absent vergence	None	2/13/07
PSP05 /M/58	5	Falls; difficulty looking up or down Vertical saccades slow; vertical pursuit and vergence impaired	Paroxetine	2/27/07
PSP06 /F/66	4	Dizziness and falls; dysphagia Vertical saccades slow and difficult to initiate; impaired	None	5/30/07

		vergence		
PSP07 /F/67	5	Falls; dysphagia; difficulty focusing on things Slow and small vertical saccades; absent vergence	Donepezil, memantine, levodopa	7/10/07
PSP08 /M/67	3	Falls; dysphagia Slow vertical saccades; impaired vergence	Fluoxetine, levodopa, donepezil	7/17/07
PSP09 /M/70	7	Falls; dysphagia; cannot look down Slow vertical saccades, especially downward	Levodopa	6/12/07
PSP10 /F/72	2	Falls; Cannot look up or down Slow vertical saccades; mild slowing of horizontal saccades; impaired vertical pursuit and vergence	Levodopa	5/22/07

Supplementary Table 2. Characteristics of SWJs –Individual subjects' values and population averages.

		SWJ Rate (N/s)	Number of SWJs*	SWJ Magnitude (deg)	SWJ Peak Velocity (deg/s)	SWJ Vertical comp	Intra SWJ ISI (ms)	Inter-SWJ ISI (ms)	SWJ Std of Direction difference
Older Control Group (Search coil)	14	0.39	47	0.7	50	0.2	220	500	13
	13	0.13	15	0.34	27	0.49	290	500	24
	12	1	120	0.47	34	0.15	190	380	15
	11	0.24	29	0.6	42	0.42	340	800	19
	10	0.14	17	0.21	18	0.7	310	500	20
	9	0.029	7	0.9	80	0.22	250	1300	31
	8	0.16	19	0.8	70	0.32	270	1700	18
Average of Older Control Group			0.3 ± 0.1	40 ± 10	0.6 ± 0.1	50 ± 10	0.4 ± 0.1	270 ± 20	800 ± 200
Younger Control Group (Video tracking)	7	0.19	1100	0.36	37	0.44	300	1000	24
	6	0.027	150	0.36	33	0.32	330	1000	21
	5	0.13	700	0.38	38	0.25	300	1400	19
	4	0.31	1700	0.7	70	0.42	330	800	21
	3	0.13	700	0.7	60	0.38	260	1200	20
	2	0.24	1300	0.5	50	0.31	280	900	23
	1	0.017	90	0.5	50	0.49	340	2800	21
Average of Younger Control Group			0.15 ± 0.04	800 ± 200	0.5 ± 0.1	48 ± 5	0.37 ± 0.03	310 ± 10	1300 ± 300
Average of all controls			0.2 ± 0.1	400 ± 200	0.6 ± 0.1	47 ± 4	0.37 ± 0.04	290 ± 10	1100 ± 200
PSP patients	PSP10	0.5	60	0.9	60	0.14	340	1000	14
	PSP09	0.8	100	1.7	80	0.09	280	600	6
	PSP08	0.9	19	2.3	120	0.16	210	600	4.2
	PSP07	0.4	100	0.7	45	0.18	220	400	14
	PSP06	0.9	220	2.1	100	0.17	310	310	16
	PSP05	1.2	150	2.3	120	0.021	260	400	1.6
	PSP04	0.35	21	1.3	70	0.11	320	900	4.7
	PSP03	1	60	1.5	80	0.1	270	470	8
	PSP02	0.7	80	0.6	40	0.14	300	500	12

	PSP01	1	60	0.7	37	0.24	270	320	8
Average of PSP patients			0.8 ± 0.1	90 ± 20	1.4 ± 0.2	70 ± 10	0.14 ± 0.02	280 ± 10	500 ± 100

Older Control Group (Search coil)		Non-SWJ Saccade Rate (N/s)	Number of Non-SWJ Saccades*	Non-SWJ Saccade Magnitude (deg)	Non-SWJ Saccade Peak Velocity (deg/s)	Non-SWJ Saccade Vertical comp	
	14	0.8	190	0.8	49	0.45	
	13	1.2	180	0.37	28	0.7	
	12	0.8	330	0.35	25	0.39	
	11	0.8	150	0.48	32	0.6	
	10	1.5	210	0.18	15	0.8	
	9	0.7	190	0.48	41	0.7	
		8	0.39	90	0.48	40	0.7
Average of Older Control Group		0.9 ± 0.1	190 ± 30	0.5 ± 0.1	33 ± 4	0.6 ± 0.1	
Younger Control Group (Video tracking)	7	0.5	5000	0.29	32	0.5	
	6	0.4	2400	0.31	31	0.6	
	5	0.41	3600	0.32	35	0.47	
	4	0.5	6000	0.6	50	0.6	
	3	0.5	4200	0.42	40	0.7	
	2	0.6	6000	0.43	43	0.5	
		1	0.3	1800	0.39	40	0.6
Average of Younger Control Group			0.47 ± 0.04	4000 ± 1000	0.39 ± 0.04	39 ± 3	0.56 ± 0.03
Average of all controls		0.7 ± 0.1	2000 ± 1000	0.42 ± 0.04	36 ± 3	0.59 ± 0.03	
PSP patients	PSP10	0.33	160	1.1	70	0.15	
	PSP09	0.35	240	1.9	80	0.09	
	PSP08	0.2	42	1.6	100	0.14	
	PSP07	1.4	500	0.6	41	0.39	
	PSP06	1	700	2.5	100	0.23	
	PSP05	0.18	320	2.2	110	0.02	
	PSP04	0.15	50	1.2	70	0.1	

	PSP03	0.38	140	1.2	60	0.08	
	PSP02	0.8	250	0.5	32	0.39	
		PSP01	0.9	170	0.46	25	0.36
Average of PSP patients		0.6 ± 0.1	300 ± 100	1.3 ± 0.2	70 ± 10	0.20 ± 0.04	
Older Control Group (Search coil)		Saccade Rate (N/s)	Number of Saccades*	Saccade Magnitude (deg)	Saccade Peak Velocity (deg/s)	Saccade Vertical Component	
	14	1.6	190	0.8	50	0.33	
	13	1.5	180	0.36	28	0.7	
	12	2.7	330	0.44	31	0.22	
	11	1.3	150	0.5	36	0.5	
	10	1.8	210	0.19	16	0.8	
		9	0.8	190	0.5	43	0.7
	8	0.7	90	0.6	50	0.5	
Average of Older Control Group		1.5 ± 0.3	190 ± 30	0.5 ± 0.1	37 ± 5	0.5 ± 0.1	
	7	0.9	5000	0.32	34	0.47	
Younger Control Group (Video tracking)	6	0.45	2400	0.32	31	0.6	
	5	0.7	3600	0.34	36	0.38	
	4	1.2	6000	0.7	60	0.5	
	3	0.8	4200	0.5	46	0.6	
		2	1.1	6000	0.47	47	0.42
		1	0.33	1800	0.41	41	0.6
Average of Younger Control Group		0.8 ± 0.1	4000 ± 1000	0.43 ± 0.05	42 ± 4	0.50 ± 0.03	
Average of all controls		1.1 ± 0.2	2000 ± 1000	0.46 ± 0.04	39 ± 3	0.52 ± 0.04	
PSP patients	PSP10	1.3	160	0.9	60	0.14	
	PSP09	2	240	1.7	80	0.09	
	PSP08	2.1	42	2.2	110	0.16	
	PSP07	2.2	500	0.6	42	0.32	
	PSP06	2.8	700	2.2	100	0.19	
	PSP05	2.7	320	2.3	120	0.021	

	PSP04	0.9	50	1.3	70	0.11	
	PSP03	2.3	140	1.4	80	0.1	
		PSP02	2.1	250	0.5	37	0.23

*Note that eye movement recordings had different durations in different subjects affecting the total number of saccades and SWJs.