Elimination of climbing fiber instructive signals during motor learning

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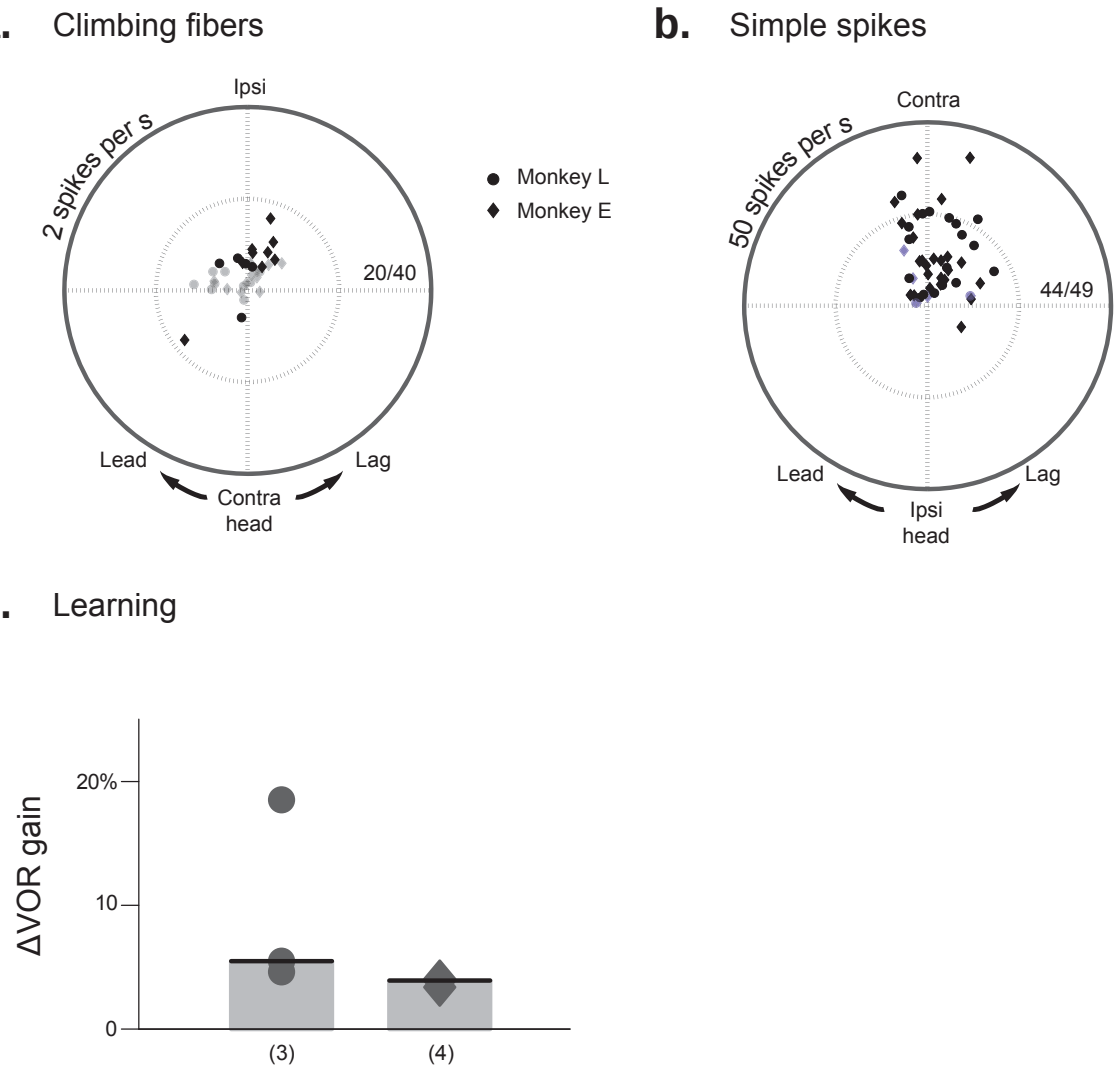
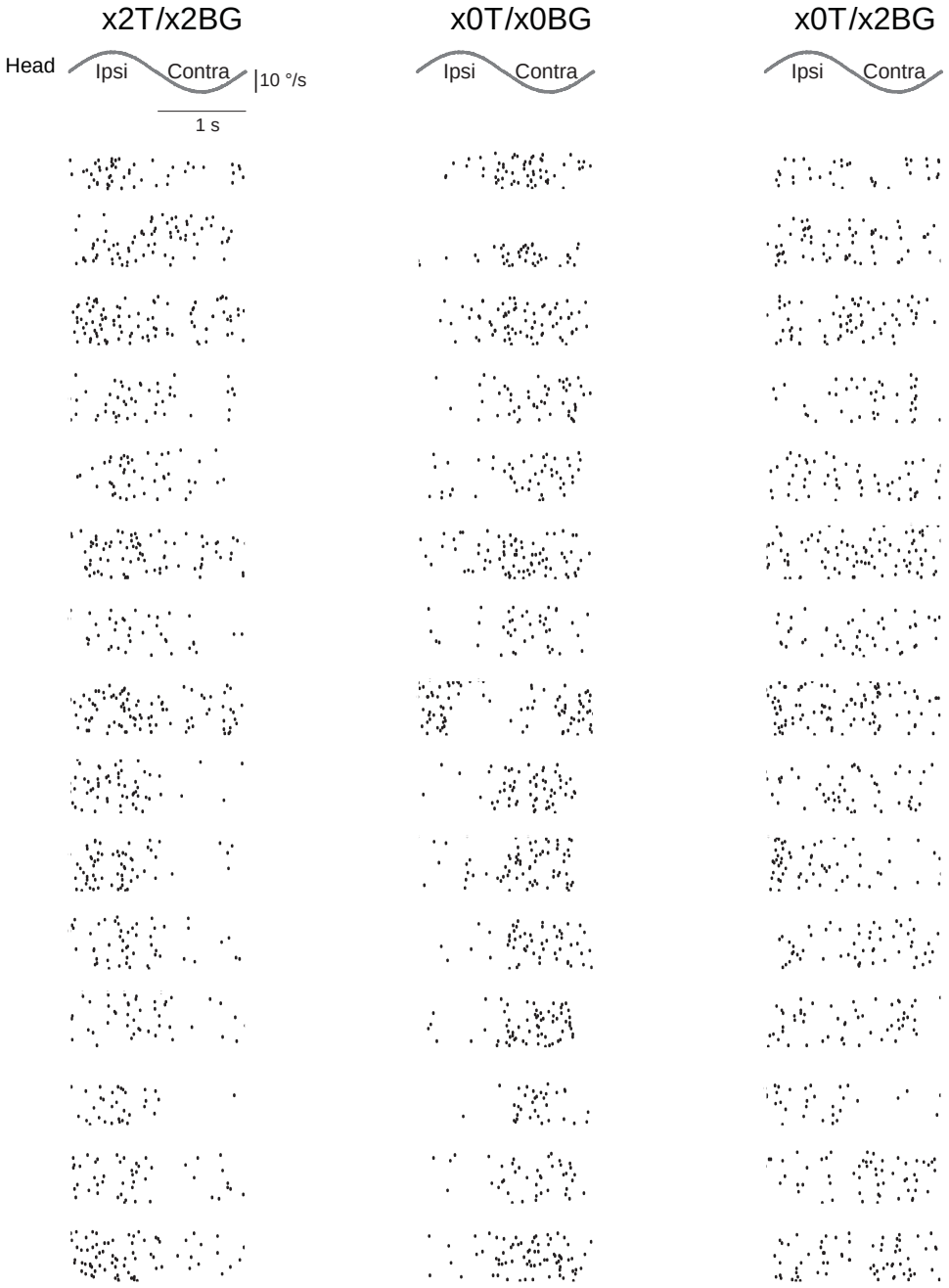
Supplementary Figure 1



Neural responses and changes in VOR gain elicited by the ×2T/×0BG training stimulus. Climbing fiber responses (a), Purkinje cell simple spike responses (b), and behavioral changes (c) associated with the ×2T/×0BG training stimulus. Neural responses significantly different from zero are indicated by black symbols, and the number of significant neurons out of the total recorded is noted on each polar plot.

In Monkey L (circles), the climbing fiber response to the ×2T/×0BG stimulus was not statistically different from the response to the ×0T/×2BG stimulus ($P > 0.05$, paired t-test; Table 1). Nevertheless, ×2T/×0BG training induced a learned increase in VOR gain in Monkey L, in contrast to the decrease in VOR gain induced by ×0T/×2BG training (Fig. 4b). Thus, stimuli that induced similar climbing fiber responses could induce opposite changes in VOR gain.

Supplementary Figure 2a



Spike trains in individual climbing fibers during training.
Rasters showing the responses in 15 climbing fibers in Monkey L (a) and 24 climbing fibers in Monkey E (b) during 35-40 cycles of the ×2T/×2BG, ×0T/×0BG, and ×0T/×2BG training stimuli, aligned on the onset of ipsiversive head movement. Each tick represents the occurrence of a spike in the climbing fiber, measured as a complex spike in its Purkinje cell target. All recordings were from horizontal gaze velocity Purkinje cells (HGVPs).

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Supplementary Figure 2b

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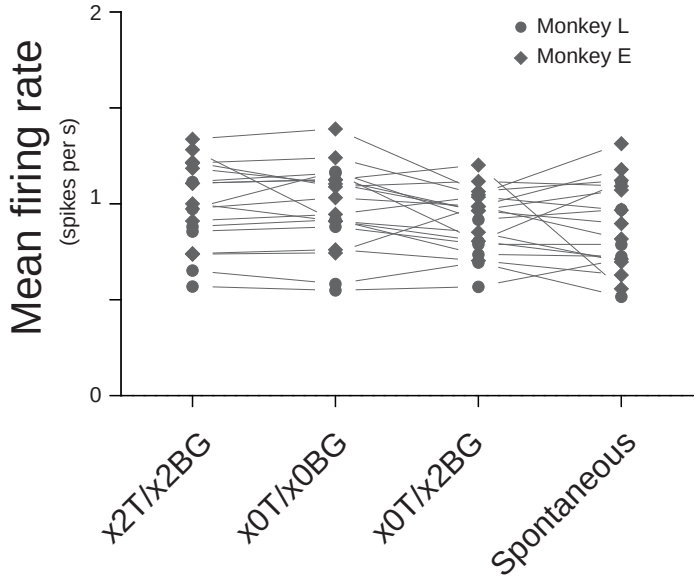
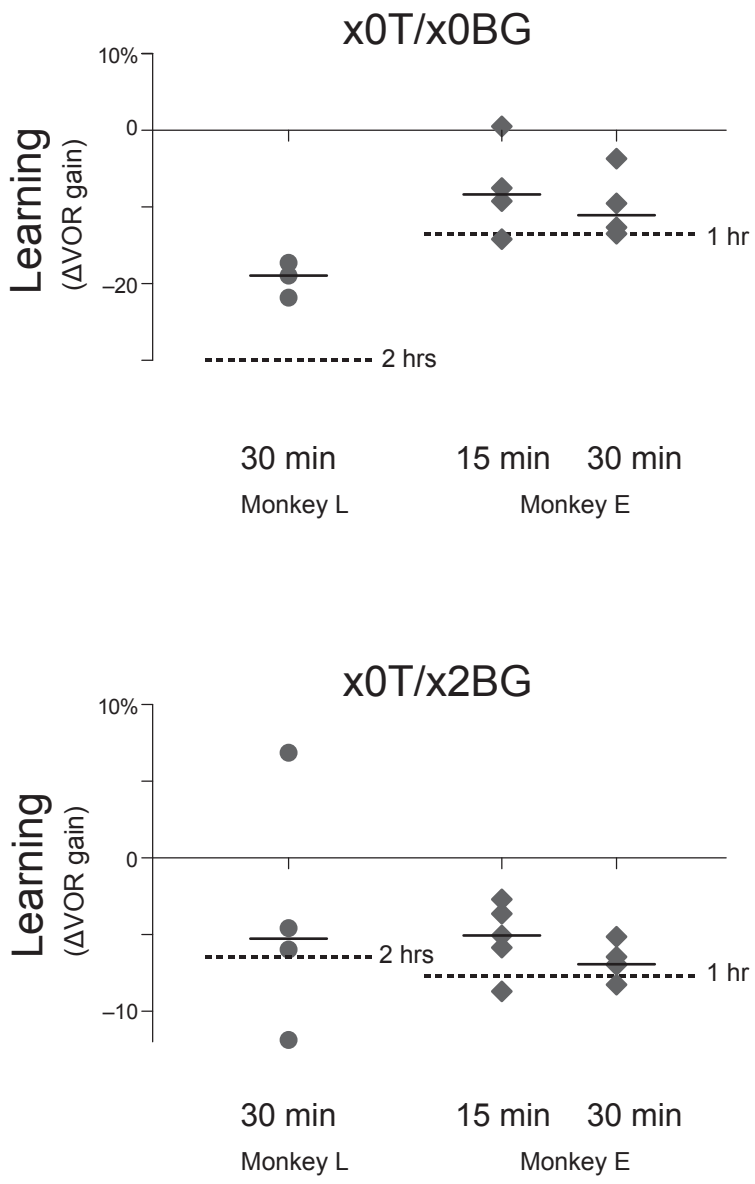
Supplementary Figure 3



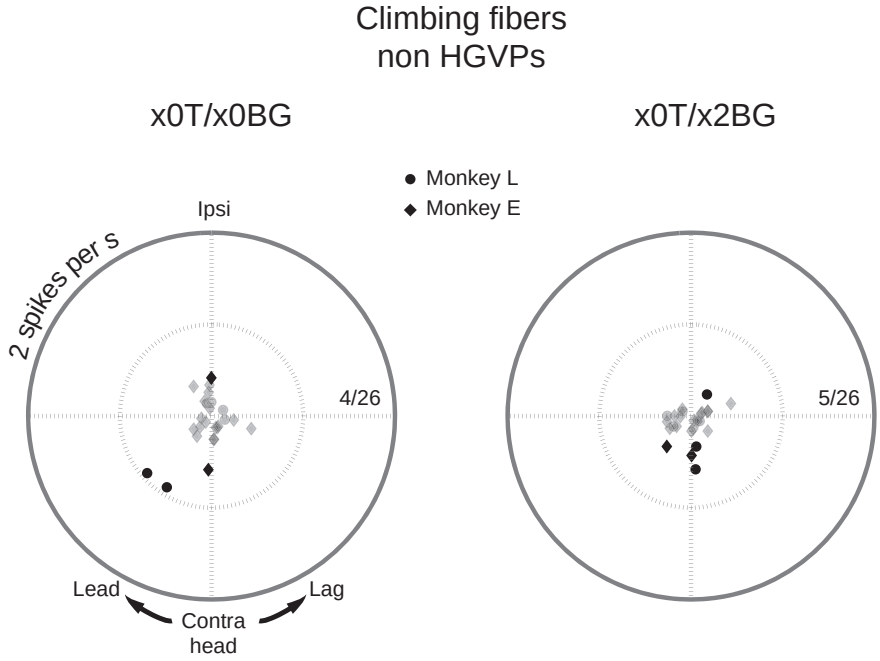
Average firing rate of climbing fibers did not vary across training stimuli.
Each set of connected points represents the average firing rate of a single climbing fiber during ×2T/×2BG, ×0T/×0BG, and ×0T/×2BG training stimuli, plus spontaneous activity. The training stimuli did not affect the average firing rate ($P > 0.05$, ANOVA).

Supplementary Figure 4



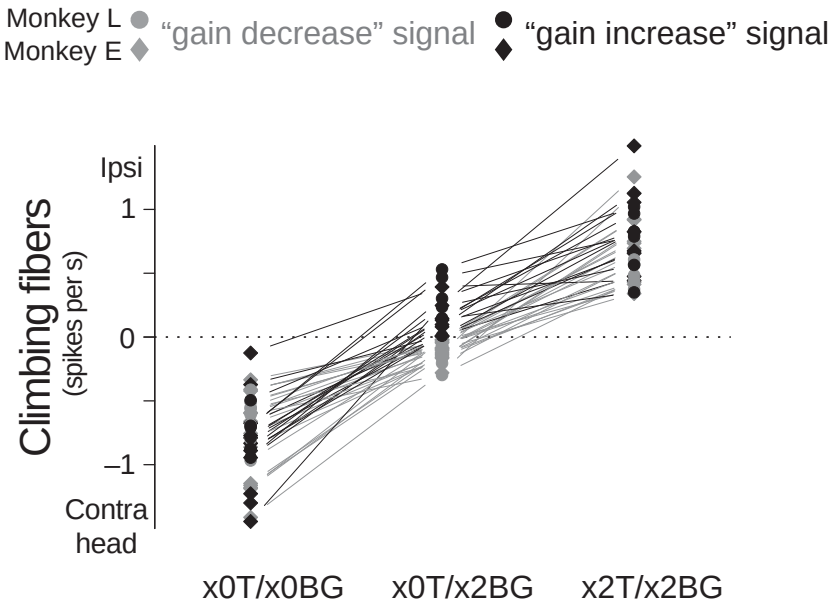
Most of the learning occurs early in the training session.
Changes in VOR gain after 30 minutes of training in Monkey L, and 15 and 30 minutes in Monkey E. Each point represents the change in VOR gain at the indicated time points during a single replication of a behavioral training session. Solid bars represent the median change in VOR gain at the indicated time points, and dotted lines represent median changes in VOR gain during the entire training session (2 hrs for Monkey L and 1 hr for Monkey E; as shown in Figure 4). Most of the changes in VOR gain occurred early in the training session.

Supplementary Figure 5



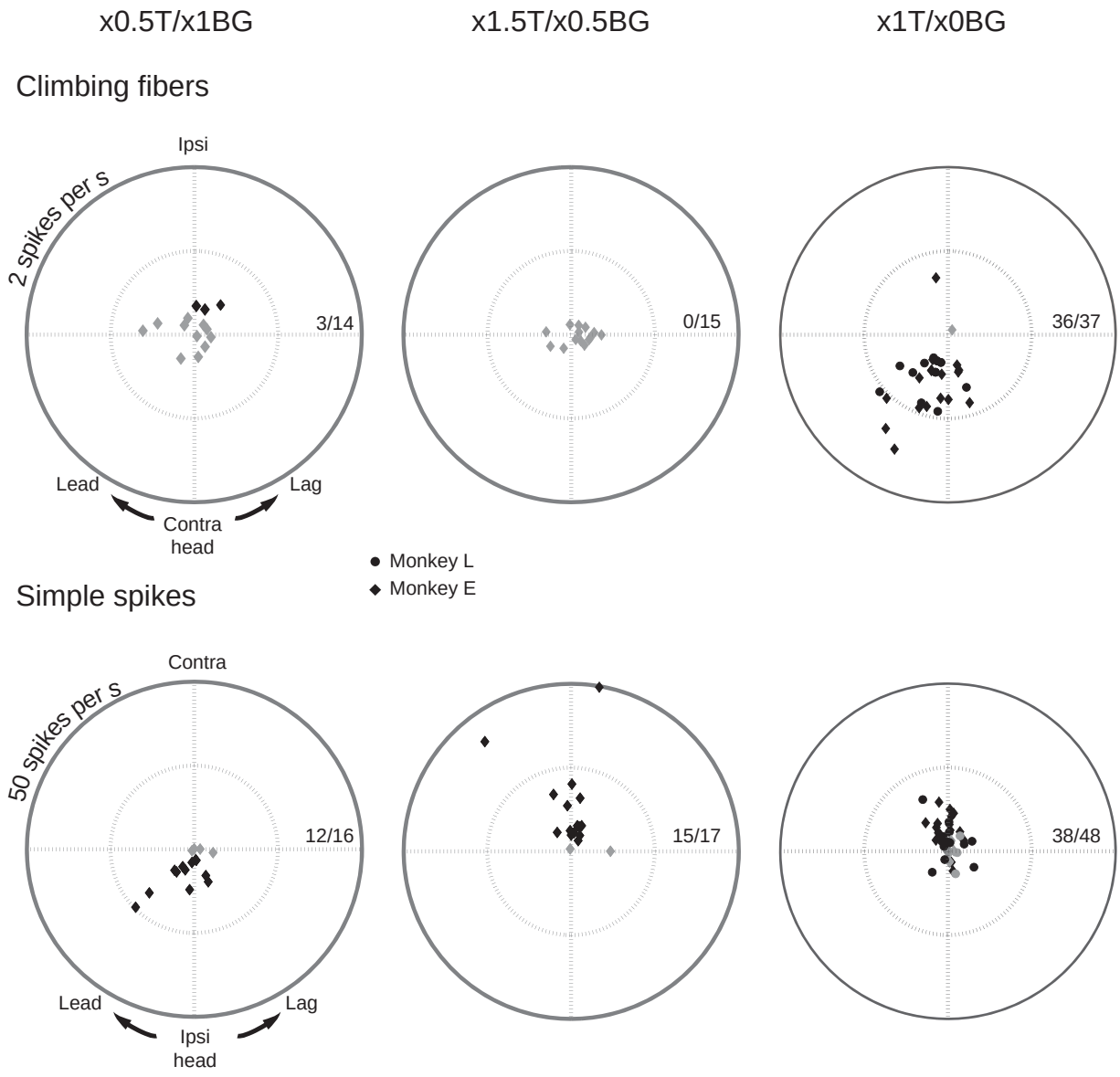
Climbing fiber responses in non-HGVPs during ×0T/×0BG and ×0T/×2BG training. Polar plots showing the climbing fiber responses recorded in Purkinje cells that were sensitive to head and/or eye velocity, but did not fulfill the criteria for classification as an HGVP. Individual climbing fibers with a response significantly different from zero are shown in black. Neither ×0T/×0BG nor ×0T/×2BG training elicited a significant response in this population of climbing fibers ($P > 0.05$, one sample t-test).

Supplementary Figure 6



Climbing fibers with "gain decrease" and "gain increase" responses during ×0T/×2BG training had similar responses during standard training stimuli.
The climbing fiber responses to ×0T/×0BG, ×0T/×2BG and ×2T/×2BG training stimuli are plotted, with positive values representing an increase in firing rate during ipsiversive head velocity, and negative values representing an increase in firing during contraversive head velocity. 39 of the 45 climbing fibers shown in **Fig. 2** were recorded for all three stimuli, and were included in this plot and the analysis in **Supplementary Table 1**. Each climbing fiber was categorized according to whether its response during ×0T/×2BG training was in the "gain decrease" (grey) direction or "gain increase" (black) direction. An increase in firing during contraversive head velocity was categorized as "gain decrease", since this is what is observed during standard ×0T/×0BG training, which decreases VOR gain. An increase in firing during ipsiversive head velocity was categorized as "gain increase", since this is what is observed during standard ×2T/×2BG training, which increases VOR gain. Climbing fibers with "gain decrease" and "gain increase" responses during ×0T/×2BG training had similar responses during the standard training stimuli.

Supplementary Figure 7



Climbing fiber and Purkinje cell simple spike responses to ×0.5T/×1BG, ×1.5T/×0.5BG and ×1T/×0BG training stimuli.
Polar plots showing the climbing fiber (a) and Purkinje cell simple spike responses (b) of individual neurons to the ×0.5T/×1BG and ×1.5T/×0.5BG training stimuli (Monkey E) and the ×1T/×0BG training stimulus (Monkeys L and E, see Methods for detailed description of stimuli). Neural responses significantly different from zero are indicated in black symbols, and the number of significant neurons out of the total recorded is noted on each polar plot.

Supplementary Table 1

Monkey L	"gain decrease" (8) Mean	SEM	"gain increase" (7) Mean	SEM	*P*-value
Climbing fiber response (spikes per s)					
x0T/x0BG	-0.64	0.07	-0.77	0.06	0.15
x2T/x2BG	0.58	0.05	0.76	0.10	0.08
x2T/x0BG	0.14	0.06	0.10	0.09	0.70
x1T/x0BG	-0.54	0.09	-0.50	0.11	0.79
Climbing fiber mean firing rate (spikes per s)					
x0T/x0BG	0.86	0.10	0.96	0.12	0.51
x2T/x2BG	0.92	0.10	0.87	0.11	0.76
x0T/x2BG	0.82	0.07	0.85	0.09	0.80
x2T/x0BG	0.90	0.10	0.81	0.13	0.55
x1T/x0BG	0.76	0.06	0.89	0.08	0.20
Purkinje cell simple spike sensitivity (spikes per s per °/s)					
Eye velocity	1.30	0.18	0.71	0.25	0.05
Head velocity	0.97	0.16	0.66	0.19	0.19
Cell location (cm)					
A/P	-0.25	0.43	-0.14	0.32	0.84
M/L	0.07	0.46	-0.43	0.26	0.35

Monkey E	"gain decrease" (13) Mean	SEM	"gain increase" (11) Mean	SEM	*P*-value
Climbing fiber response (spikes per s)					
×0T/×0BG	-0.82	0.10	-0.76	0.13	0.69
×2T/×2BG	0.76	0.08	1.01	0.16	0.14
×2T/×0BG	0.16	0.10	0.25	0.08	0.47
×1T/×0BG	-0.53	0.09	-0.57	0.24	0.82
Climbing fiber mean firing rate (spikes per s)					
×0T/×0BG	0.99	0.07	1.06	0.06	0.48
×2T/×2BG	1.02	0.06	1.19	0.10	0.14
×0T/×2BG	0.92	0.06	0.94	0.05	0.76
×2T/×0BG	0.90	0.06	1.02	0.08	0.21
×1T/×0BG	0.85	0.06	1.01	0.10	0.12
Purkinje cell simple spike sensitivity (spikes per s per °/s)					
Eye velocity	1.38	0.18	1.67	0.39	0.18
Head velocity	1.09	0.15	1.62	0.33	0.49
Cell location (cm)					
A/P	0.24	0.31	-0.22	0.30	0.27
M/L	0.13	0.37	-0.12	0.26	0.58

Climbing fibers carrying "gain decrease" versus "gain increase" climbing fiber signals during ×0T/×2BG training did not differ in any other property. Climbing fibers carrying "gain decrease" versus "gain increase" signals during ×0T/×2BG training were categorized as described in **Supplementary Figure 6**. Responses of the two groups of climbing fibers to other training stimuli, and their average firing rate, sensitivity to eye and head velocity, and anatomical location were compared using t-tests. Sensitivity to eye velocity was measured during smooth pursuit eye movements; sensitivity to head velocity was measured during VOR cancellation (see Methods). Anterior-posterior (A-P) and medial-lateral (M-L) locations were measured relative to the mean of the full population of neurons recorded. No significant differences were found.