Supplemental information

The nervous system tunes sensorimotor gains when reaching in variable mechanical environments

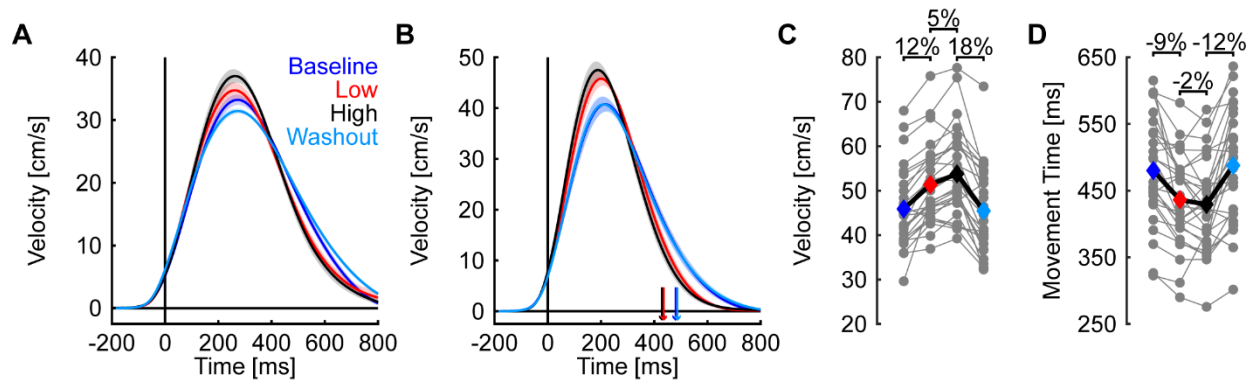Philipp Maurus, Kuira Jackson, Joshua G.A. Cashaback, and Tyler Cluff

Figure S1. Properties of voluntary reaching movements during unperturbed trials in *Experiment 2*.
(A) Mean and SE forward velocities of the same exemplar participant as in **Figure 5**. The data are aligned with movement onset (t=0 ms).
(B) Group mean and SE forward velocity. The data are plotted in the same format as **(A)**. Colored arrows indicate the mean movement time (i.e., the instant the hand entered the goal target).
(C) Grey dots represent the mean peak forward velocity of each participant. Colored diamonds are the group averages.
(D) Movement times are displayed following the same layout as **(C)**.
Statistically significant effects are highlighted with %-changes in the outcome variable.
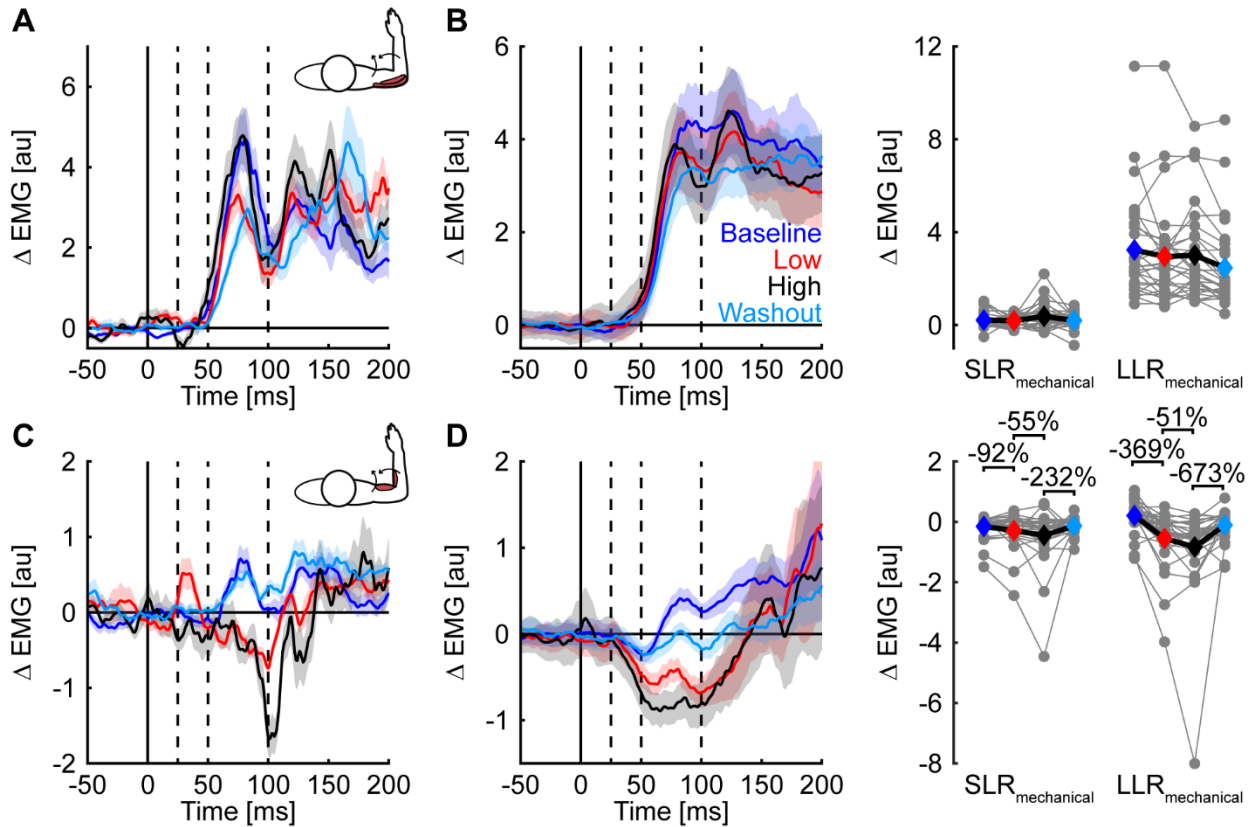Related to Figure 4.

Figure S2. Muscle stretch responses during mechanical probes that flexed the elbow.

(A) Mean and SE stretch response of the elbow extensor muscles (agonists) of the same exemplar participant as in **Figure 6**. The data are plotted as muscle stretch responses (ΔEMG) and correspond to the difference in muscle activity between mechanical probes and unperturbed trials in each phase of the experiment. The data are aligned with perturbation onset (t=0 ms). Dashed vertical lines separate short-latency (SLR$_{mechanical}$: 25 to 50 ms) and long-latency (LLR$_{mechanical}$: 50 to 100 ms) muscle stretch responses.

(B) Group mean and SE stretch response of the elbow extensor muscles. The data are plotted in the same format as **(A)**. Grey dots represent the mean SLR$_{mechanical}$ and LLR$_{mechanical}$ of the flexor muscles of each participant. Colored diamonds are the group averages.

(C) and **(D)** Shortening responses of elbow flexor muscles (antagonists) are displayed following the same layout as **(A)** and **(B)**.

Statistically significant effects are highlighted with %-changes in the outcome variable.
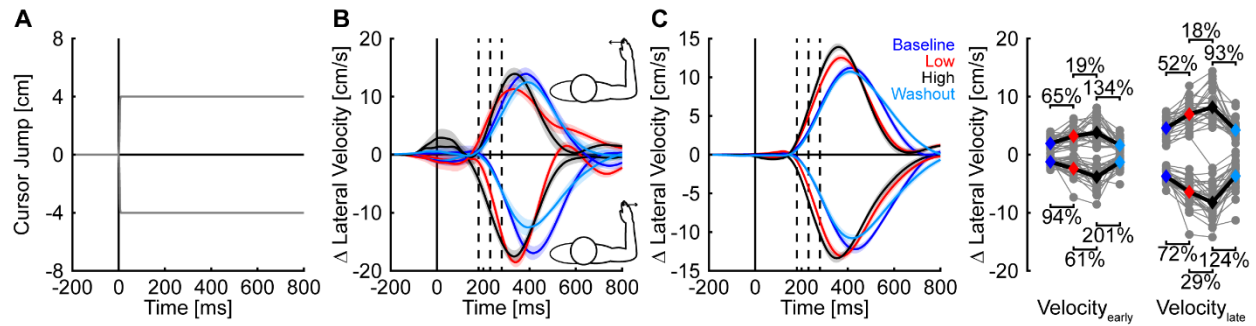
Related to Figure 6.

Figure S3. Lateral velocities during persistent visual probes.
(A) Visual probes were randomly interleaved throughout the entire experiment. The hand-aligned cursor (grey solid line) jumped perpendicular to the reach direction (±4 cm) at movement onset (t=0 ms). Participants had to respond to the visual probes to complete the trial successfully.
(B) Mean and SE lateral velocities of an exemplar participant are shown for each phase of the experiment. The data are aligned with perturbation onset. The dashed vertical lines separate the early ($Velocity_{early}$: 180 to 230 ms) and late ($Velocity_{late}$: 230 to 280 ms) response time windows.
(C) Group mean and SE lateral velocities are shown for each experimental phase (same layout as **(B)**). Grey dots represent the means of the individual lateral velocities of each participant across the experimental phases for the $Velocity_{early}$ and $Velocity_{late}$. Colored diamonds indicate the means. Statistically significant effects are highlighted with %-changes in the outcome variable. Related to Figure 7.
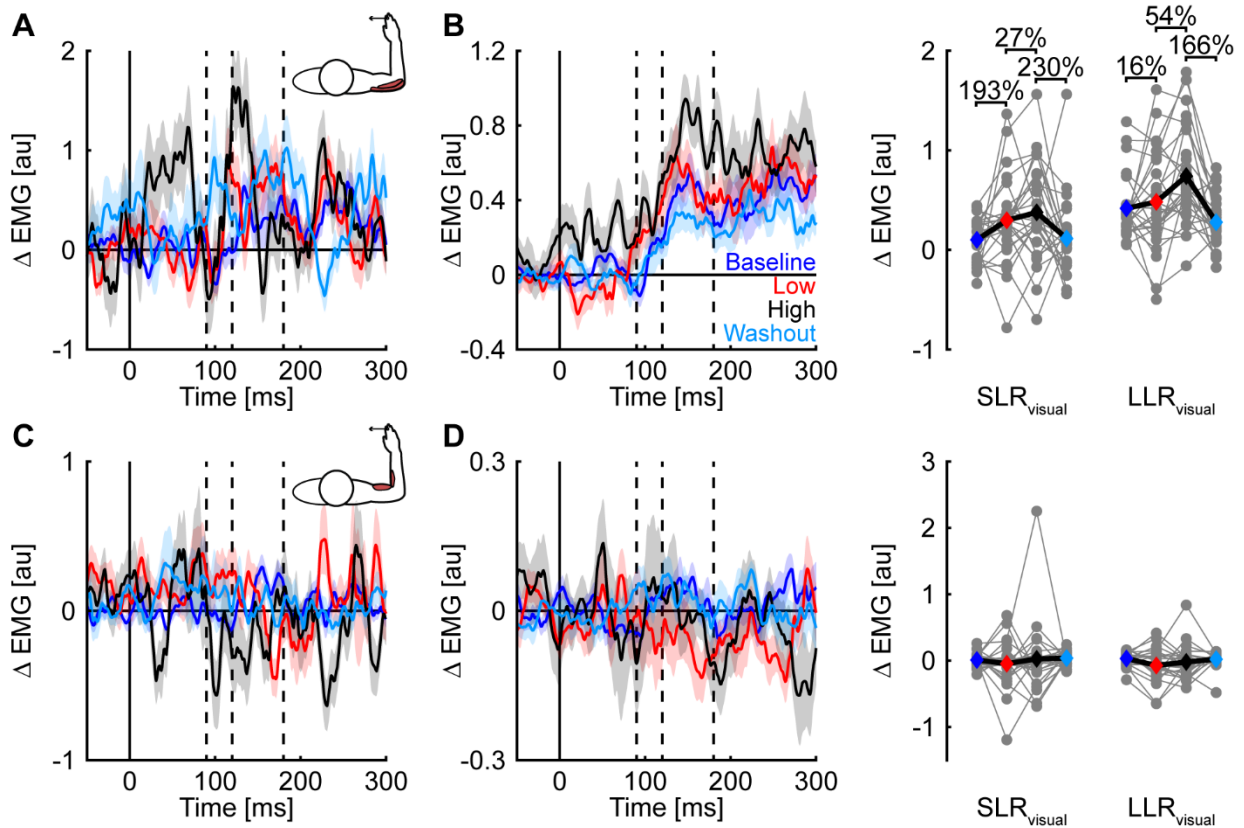
Figure S4. Muscle responses during transient visual probes (leftward cursor jumps).
(A) Mean and SE muscle response of the elbow extensor muscles (agonists) of the same exemplar participant as in **Figure 7** across the different experimental phases. The average muscle activity of unperturbed reaches was subtracted from the corresponding muscle responses in each phase of the experiment. The data are aligned with the onset of the cursor jump (t=0 ms). Dashed vertical lines separate the short-latency (SLR_{visual}: 90 to 120 ms) and long-latency (LLR_{visual}: 120 to 180 ms) responses to visual probes.
(B) Group mean and SE muscle response of elbow extensor muscles are shown for each experimental phase (same layout as **(A)**). Grey dots represent the mean SLR_{visual} and LLR_{visual} of the elbow flexor muscles of each participant across the experimental phases. Colored diamonds indicate the means.
(C) & **(D)** Responses of elbow flexor muscles (antagonists) are displayed following the same layout as **(A)** & **(B)**.
Statistically significant effects are highlighted with %-changes in the outcome variable.
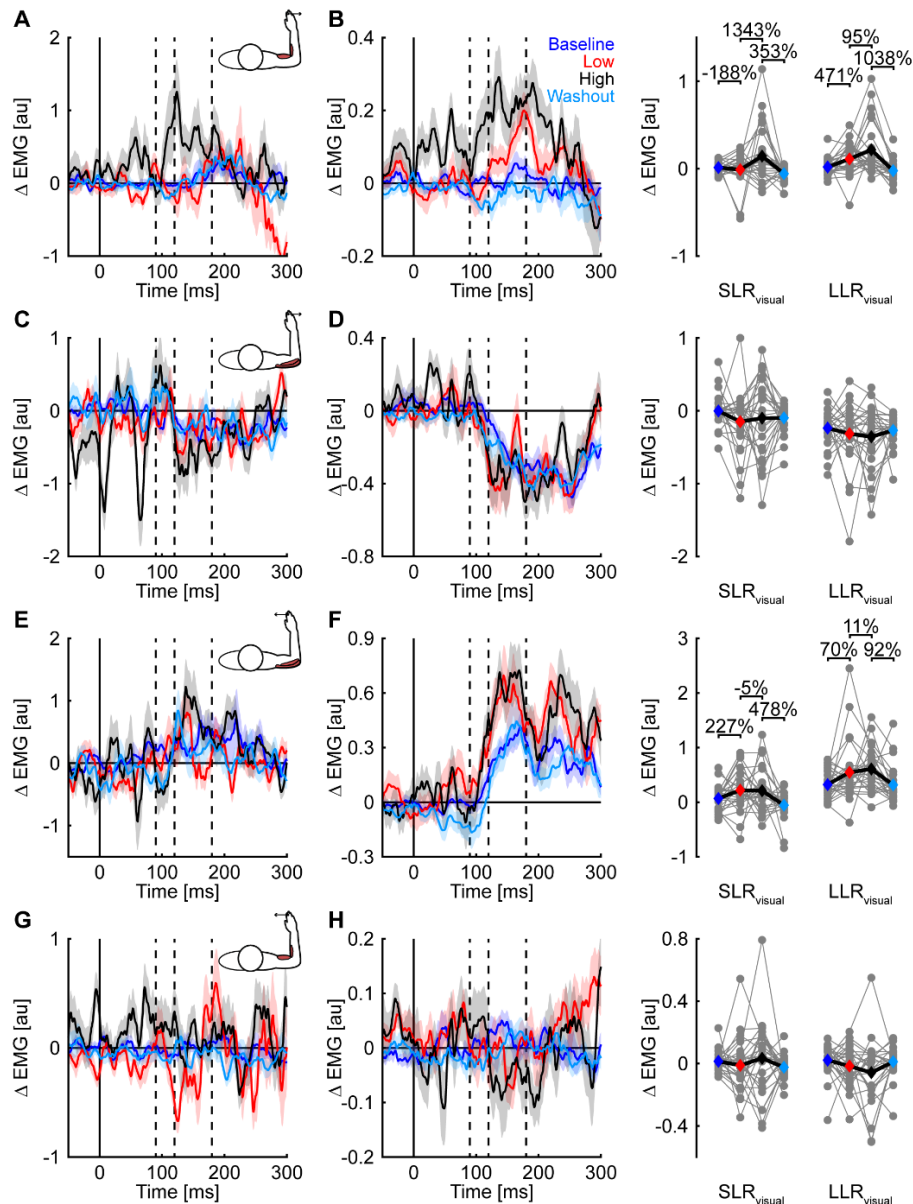Related to Figure 7.

Figure S5. Muscle responses during persistent visual probes.
(A) Mean and SE muscle response of the elbow flexor muscles (agonists) of the same exemplar participant as in **Figure 10** during rightward cursor jumps across the different experimental phases. The average muscle activity during unperturbed reaches was subtracted from the corresponding muscle responses in each phase of the experiment. The data are aligned with the onset of the cursor jump (t=0 ms). Dashed vertical lines separate the short-latency (SLR_{visual}: 90 to 120 ms) and long-latency (LLR_{visual}: 120 to 180 ms) responses to visual probes.
(B) Group mean and SE muscle response of elbow flexor muscles are shown for each experimental phase (same layout as **(A)**). Grey dots represent the mean SLR_{visual} and LLR_{visual} of the elbow flexor muscles of each participant across the experimental phases. Colored diamonds indicate the means.
(C) & **(D)** Responses of elbow extensor muscles (antagonists) are displayed following the same layout as **(A)** & **(B)**.
(E) and **(F)** Responses of the elbow extensor muscles (agonists) and **(G)** and **(H)** responses of the elbow flexor muscles (antagonists) during leftward cursor jumps are displayed following the same layout as **(A)** and **(B)**.
Statistically significant effects are highlighted with %-changes in the outcome variable.
Related to Figure 7.

Table S1. Results of mixed model analyses of variance to examine order effects in *Experiment 2*. Related to STAR Methods. SLR: Short-latency response (25 to 50 ms). LLR: Long-latency response (50 to 100 ms).

Outcome	Effect	F-Statistic	p	η^2
Movement Time	Sequence	$F(1,26)=1.4$	0.250	0.00
	Phase	$F(2.0,52.4)=1.1$	0.329	0.01
	Interaction	$F(2.0,52.4)=0.7$	0.487	0.00
Variability of hand paths	Sequence	$F(1,26)=0.50$	0.484	0.01
	Phase	$F(1.9,48.4)=184.9$	<0.001	0.81
	Interaction	$F(1.9,48.4)=0.7$	0.513	0.02
Index of the peak forward velocity	Sequence	$F(1,26)=1.5$	0.236	0.05
	Phase	$F(1.9,48.0)=26.3$	<0.001	0.12
	Interaction	$F(1.9,48.0)=1.5$	0.225	0.01
Amplitude of the peak forward velocity	Sequence	$F(1,26)=1.1$	0.305	0.04
	Phase	$F(2.3,58.6)=90.8$	<0.001	0.24
	Interaction	$F(2.3,58.6)=0.0$	0.979	0.00
Flexor EMG (-100 to 100 ms)	Sequence	$F(1,26)=2.3$	0.146	0.06
	Phase	$F(1.3,33.3)=25.8$	<0.001	0.20
	Interaction	$F(1.3,33.3)=0.4$	0.614	0.00
Extensor EMG (-100 to 100 ms)	Sequence	$F(1,26)=0.3$	0.897	0.00
	Phase	$F(1.2,30.8)=20.8$	<0.001	0.14
	Interaction	$F(1.2,30.8)=0.7$	0.431	0.01
Peak hand displacement (Extension)	Sequence	$F(1,26)=0.9$	0.332	0.03
	Phase	$F(1.9,49.9)=38.2$	<0.001	0.22
	Interaction	$F(1.9,49.9)=3.1$	0.058	0.02
Peak hand displacement (Flexion)	Sequence	$F(1,26)=0.3$	0.563	0.01
	Phase	$F(1.9,51.8)=29.4$	<0.001	0.19
	Interaction	$F(1.9,51.8)=3.1$	0.055	0.03
Flexor EMG $SLR_{mechanical}$ (Extension)	Sequence	$F(1,26)=0.0$	0.950	0.00
	Phase	$F(1.6,40.2)=7.5$	0.003	0.12
	Interaction	$F(1.6,40.2)=1.0$	0.354	0.02
Flexor EMG $LLR_{mechanical}$ (Extension)	Sequence	$F(1,26)=0.4$	0.556	0.01
	Phase	$F(3,78)=5.4$	0.002	0.04
	Interaction	$F(3,78)=0.9$	0.462	0.01
Extensor EMG $SLR_{mechanical}$ (Extension)	Sequence	$F(1,26)=0.4$	0.553	0.01
	Phase	$F(2.4,61.9)=1.2$	0.305	0.03
	Interaction	$F(2.4,61.9)=0.1$	0.904	0.00
Extensor EMG $LLR_{mechanical}$ (Extension)	Sequence	$F(1,26)=0.0$	0.890	0.00
	Phase	$F(1.8,47.6)=4.8$	0.015	0.04
	Interaction	$F(1.8,47.6)=0.5$	0.589	0.00
Flexor EMG $SLR_{mechanical}$ (Flexion)	Sequence	$F(1,26)=1.3$	0.263	0.03
	Phase	$F(1.5,37.8)=3.1$	0.070	0.05
	Interaction	$F(1.5,37.8)=0.1$	0.839	0.00
Flexor EMG $LLR_{mechanical}$ (Flexion)	Sequence	$F(1,26)=3.4$	0.077	0.07
	Phase	$F(1.4,36.3)=11.9$	<0.001	0.16
	Interaction	$F(1.4,36.3)=0.3$	0.673	0.01
Extensor EMG $SLR_{mechanical}$ (Flexion)	Sequence	$F(1,26)=0.9$	0.351	0.01
	Phase	$F(2.2,57.2)=1.9$	0.153	0.04
	Interaction	$F(2.2,57.2)=0.2$	0.872	0.00
Extensor EMG $LLR_{mechanical}$ (Flexion)	Sequence	$F(1,26)=0.1$	0.784	0.00
	Phase	$F(3,78)=7.4$	<0.001	0.02
	Interaction	$F(3,78)=3.5$	0.020	0.01