Visual target and task-critical feedback uncertainty impair different stages of reach planning in motor cortex

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Keywords

Visual uncertainty, brain-computer interface, motor goal

Overview of supplementary information

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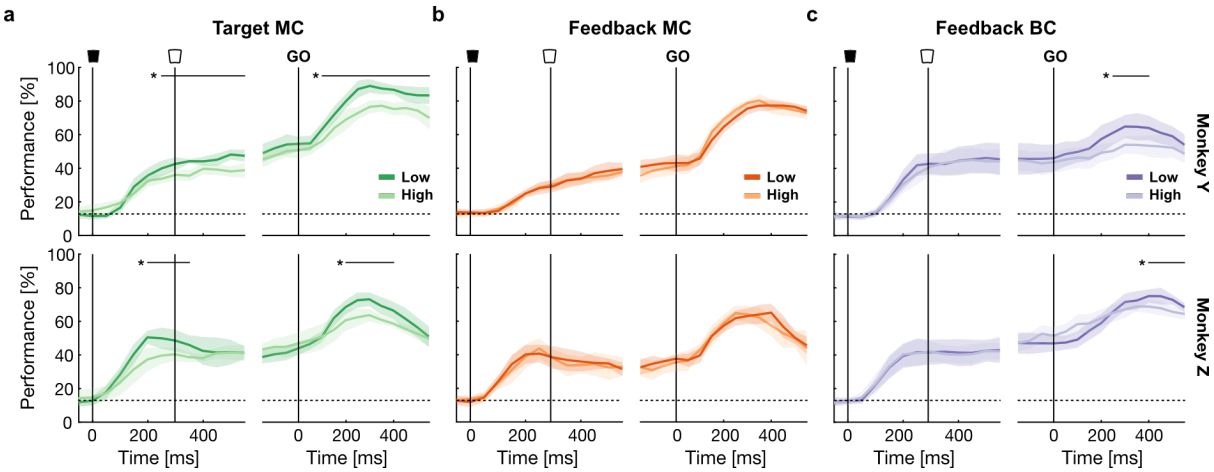
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Supplementary Fig. S1: Time-continuous within-level decoding of reach direction for each monkey. a. Decoding performance of support vector machine (SVM) decoders trained on spike densities of 100 ms time intervals shifted by 50 ms for target MC (manual control). Performance was estimated for each session and uncertainty level independently using 5-fold cross-validation. Shaded areas depict 95% CIs for averaged performance across sessions. Dotted lines indicate chance level at 12.5%. Lightness indicates uncertainty level (low: light, high: dark). Upper row shows results for monkey Y and lower row for monkey Z. Filled black arc: target cue onset, empty arc: target cue offset, and GO: go cue. Horizontal bars indicate time windows in which accuracies were significantly different for SVMs trained on different uncertainty levels (*p<0.05, permutation test). **b.** Same as in (**a**) but for feedback MC. **c.** Same as in (**a**) and (**b**) but for feedback BC (brain control). N=8 sessions/monkey for target MC and N=10 sessions/monkey for feedback MC and BC.

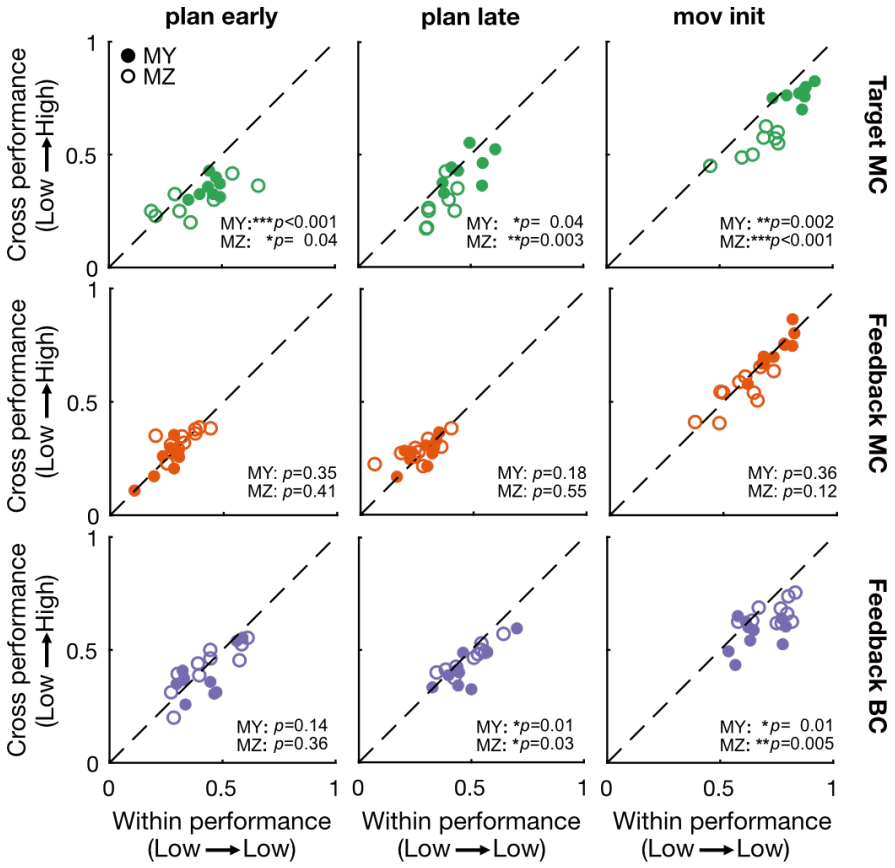
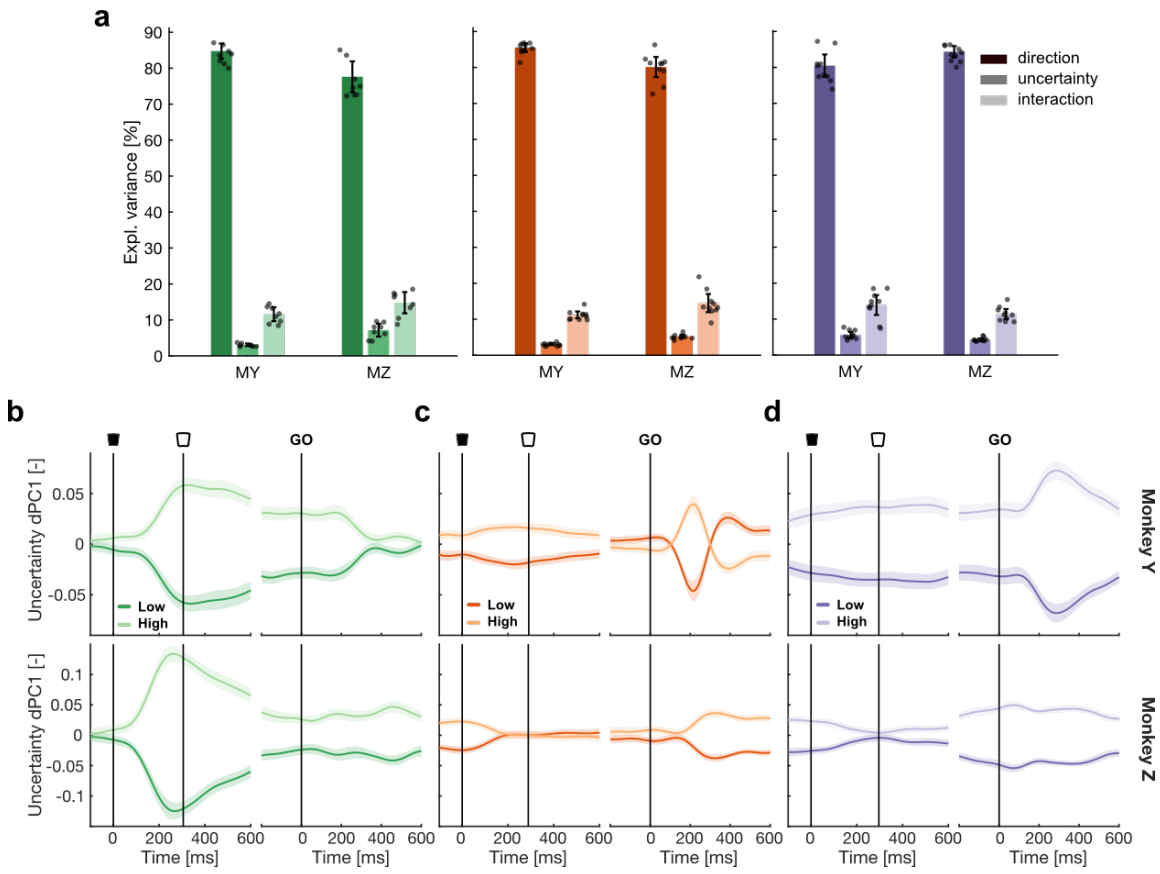
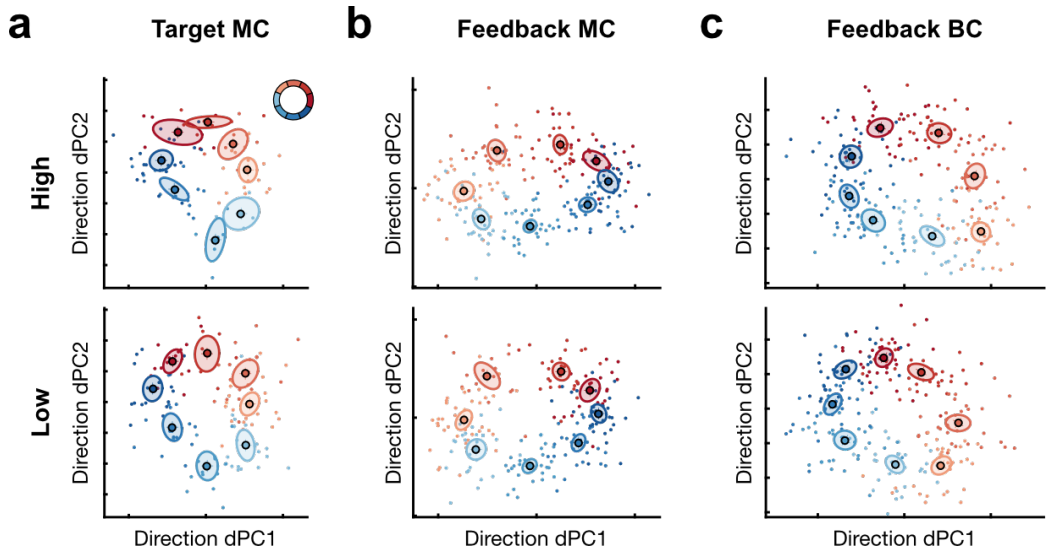


Fig. S2: Cross-level decoding for individual sessions. Decoding performance of support vector machine (SVM) decoders trained and tested on low uncertainty trials (Low/Low) plotted against performance of decoders trained on low and tested on high uncertainty trials (Low/High). Results from monkey Y (MY) in filled circles and monkey Z (MZ) in open circles. Performance was evaluated for three non-overlapping 200 ms time windows (plan early, plan late and movement initiation), presented in different columns. Target MC (manual control) in green, feedback MC in orange, and feedback BC (brain control) in purple, presented in different rows. Dashed black line represents the unity line. *p<0.05, **p<0.01, and ***p<0.001 for one-tailed one-sample t-tests on the performance difference between within- and cross-decoding. N=8 sessions/monkey for target MC and N=10 sessions/monkey for feedback MC and BC.



Supplementary Fig. S3: Neural state space results for each monkey. a. Explained variance of each dPC (demixed principal component) task parameter for each monkey (MY and MZ) for target MC (manual control, green), feedback MC (orange) and feedback BC (brain control, purple). Lightness indicates task parameter: reach direction (dark), uncertainty (medium), reach direction and uncertainty interaction (light). Bars indicate average across sessions and back points represent individual sessions. Error bars indicate 95% CIs across sessions. N=8 sessions/monkey for target MC and N=10 sessions/monkey for feedback MC and BC. **b-d.** Projection of neural activity onto the first uncertainty dPC over time for monkey Y (upper row) and monkey Z (lower row), averaged across sessions and reach directions. Filled black arc: target cue onset, empty arc: target cue offset, and GO: go cue. Same colors as in (**a**). Lightness indicates uncertainty level (high: light and low: dark). Shaded areas correspond to 95% CIs across sessions and reach directions. N=64 sessions x reach directions/monkey for target MC and N=80 sessions x reach directions/monkey for feedback MC and BC.



Supplementary Fig. S4: Distribution of neural states in reach direction dPC (demixed principal component) space. a. Projections onto the first two directional dPCs for the same session of Monkey Y as shown in Figure 5a at movement initiation under conditions of low (lower row) and high (upper row) target uncertainty (Target MC, manual control). Large points represent trial- and time-averaged projections for each reach direction, indicated by different colors. Small points correspond to time-averaged projections of individual trials. Ellipses denote 95% confidence intervals around the mean projections. **b.** Same as in (**a**) but for a corresponding session of feedback MC. **c.** Same as in (**a**) and (**b**) but for a corresponding session of feedback BC (brain control).

Supplementary Table S1: Summary of experimental sessions.

Session	Monkey	Task condition	Trials Low	Trials High	Units
1	MY	Target MC	167	165	50
2	MY	Target MC	188	184	50
3	MY	Target MC	161	158	51
4	MY	Target MC	128	128	55
5	MY	Target MC	175	164	59
6	MY	Target MC	232	218	52
7	MY	Target MC	176	168	60
8	MY	Target MC	290	281	55
9	MZ	Target MC	136	151	48
10	MZ	Target MC	105	121	49
11	MZ	Target MC	85	126	46
12	MZ	Target MC	125	132	47
13	MZ	Target MC	158	150	48
14	MZ	Target MC	147	166	49
15	MZ	Target MC	305	243	36
16	MZ	Target MC	211	163	35
1	MY	Feedback MC	132	115	83
2	MY	Feedback MC	180	153	54
3	MY	Feedback MC	167	147	53
4	MY	Feedback MC	164	162	46
5	MY	Feedback MC	191	174	50
6	MY	Feedback MC	159	145	44
7	MY	Feedback MC	201	182	44
8	MY	Feedback MC	162	145	41
9	MY	Feedback MC	189	164	45
10	MY	Feedback MC	134	118	47
11	MZ	Feedback MC	161	152	44
12	MZ	Feedback MC	233	217	34
13	MZ	Feedback MC	202	189	45
14	MZ	Feedback MC	188	162	54
15	MZ	Feedback MC	96	82	36
16	MZ	Feedback MC	106	106	37
17	MZ	Feedback MC	150	136	34
18	MZ	Feedback MC	159	154	35
19	MZ	Feedback MC	161	159	33
20	MZ	Feedback MC	130	128	32
1	MY	Feedback BC	145	148	43
2	MY	Feedback BC	259	289	43
3	MY	Feedback BC	96	119	44
4	MY	Feedback BC	240	255	39
5	MY	Feedback BC	132	142	52
6	MY	Feedback BC	98	96	44
7	MY	Feedback BC	97	96	38
8	MY	Feedback BC	97	96	35
9	MY	Feedback BC	184	144	41
10	MY	Feedback BC	181	144	49
11	MZ	Feedback BC	143	113	35
12	MZ	Feedback BC	226	192	32
13	MZ	Feedback BC	183	144	35
14	MZ	Feedback BC	262	240	45
15	MZ	Feedback BC	327	288	43
16	MZ	Feedback BC	281	288	41
17	MZ	Feedback BC	239	238	50
18	MZ	Feedback BC	119	142	41
19	MZ	Feedback BC	192	194	43
20	MZ	Feedback BC	144	180	33

Supplementary Table S2: Post-hoc results for repeated-measures ANOVA on first uncertainty dPC. Difference between values of epoch 1 and epoch 2. StdError for standard error. Lower (2.5%) and upper (97.5%) confidence levels (CL), and p-values from two-sided post-hoc tests.

Epoch 1	Epoch 2	Difference	StdError	p-value	Lower CL	Upper CL
MC target uncertainty						
plan early	plan late	0.053	8.54e-03	8.22e-05	0.029	0.078
plan early	mov init	0.058	6.03e-03	4.99e-07	0.040	0.075
plan early	baseline	0.077	9.30e-03	2.88e-06	0.10	0.051
plan late	mov init	-4.23e-03	4.89e-03	0.82	-0.018	-9.87e-03
plan late	baseline	0.034	3.38e-03	1.95e-05	0.014	0.034
mov init	baseline	0.020	4.58e-03	0.003	6.60e-03	0.033
MC Feedback uncertainty						
plan early	plan late	-2.52e-03	3.14e-03	0.85	-0.011	6.31e-03
plan early	mov init	-3.83e-03	5.10e-03	0.87	-0.011	0.018
plan early	baseline	-2.74e-03	3.92e.03	0.90	-8.83e-03	0.014
plan late	mov init	-6.35e-03	3.88e-03	0.38	-4.55e-03	0.017
plan late	baseline	-5.23e-03	3.99e-03	0.56	-5.95e-03	0.016
mov init	baseline	-1.08e-03	4.96e-03	0.99	-0.015	0.013
BC Feedback uncertainty						
plan early	plan late	-0.020	5.95e-03	0.02	-0.037	-3.05e-03
plan early	mov init	-0.024	4.53e-03	1.8e-04	-0.037	-0.018
plan early	baseline	6.35e-03	4.16e-03	0.44	-5.35e-03	0.018
plan late	mov init	4.61e-03	5.26e-03	0.81	-0.010	0.019
plan late	baseline	0.013	4.36e-03	0.03	1.18e-03	0.026
mov init	baseline	0.018	5.32-e03	0.01	3.09e-03	0.033