1   **Supplementary Information**
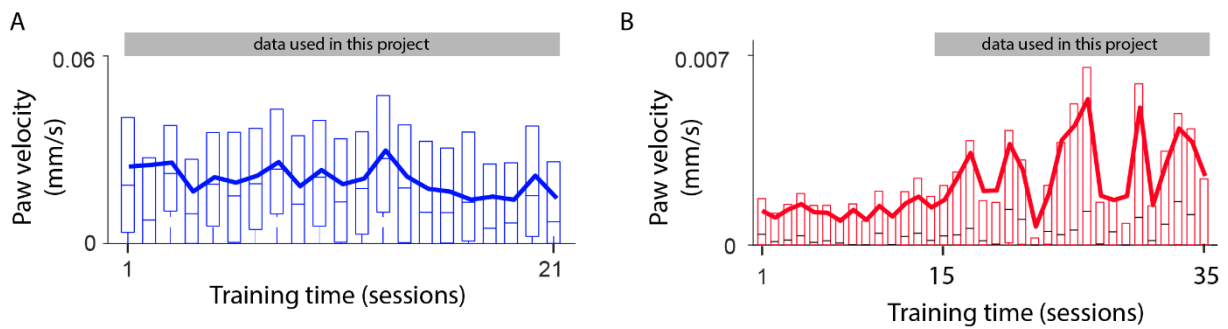

2

3   **Supplementary Figure 1.** Development of the paw velocities across recording sessions. A: Paw velocity

4   for the locomotor task. Outliers and upper whisker artefacts have been removed from the box-plot to

5   improve visibility. The solid line is the average paw velocity. The gray bar on the top indicates which

6   data has been used for this project. B: Same outline as in A but for the joystick task. The paw velocity

7   changed at session 15. Thus, data was used only after 15 training sessions.
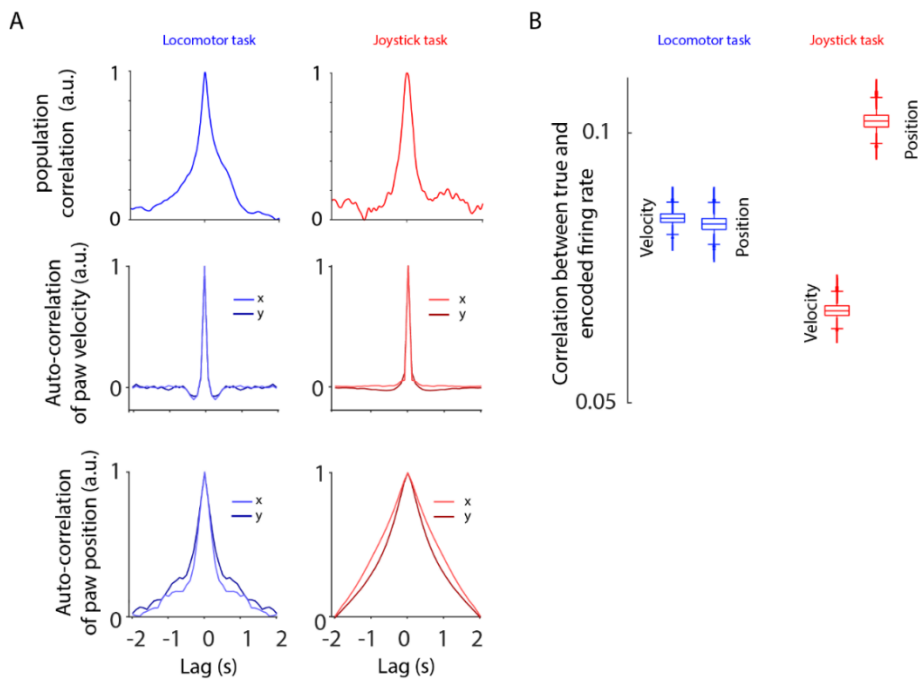
8

9   **Supplementary Figure 3.** Ruling out a putative behavioral impact on population correlations.

10   A: Population activity correlation for the locomotor task and the joystick task (top row).

11   Autocorrelation of the paw velocity for the locomotor task and the joystick task (second row), and of

12   the paw position for the locomotor task and the joystick task (bottom row). B: Encoding performance

13   using only position or direction of the right paw.

1

14   **Supplementary Table 1**

Animal	SU mod	SU all	MU mod	MU all	SU+MU mod	SU+Mu all	Session count
148	162	565	463	852	625	1417	15
220	199	493	410	706	609	1199	11
221	86	519	337	858	423	1377	16
222	367	1321	679	1566	1046	2887	21
223	706	1816	893	1708	1599	3524	20
224	212	686	589	1186	801	1872	17
Sum	1733	5400	3371	6876	5103	12276	100

15   Counts of neuronal units recorded during the locomotor task. mod - modulated units.

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17   **Supplementary Table 2**

Animal	SU mod	SU all	MU mod	MU all	SU+MU mod	SU+MU all	Session count
148	30	217	73	266	103	483	5
220	0	0	0	0	0	0	0
221	9	161	53	253	62	414	5
222	72	344	238	536	310	880	7
223	63	324	175	349	238	673	4
224	28	171	98	255	126	426	4
Sum	202	1217	637	1659	839	2876	25

18   Counts of neuronal units recorded during the joystick task. mod - modulated units.

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20 **Supplementary Table 3**

Fig.	Groups: **a** refers to animal count, **u** refers to sorted unit count, u_c = u/7 refers to corrected unit count used for significance	Statistical Analysis
Fig. 1l	Locomotor task, Motor-Sensory, (u = 5103, u_c=729) Joystick task, Motor-Sensory, (u = 839, u_c = 120)	Two-tailed paired t-test, *P* < 0.0001 Two-tailed paired t-test, *P* < 0.0001
Fig. 2d	Locomotor task, Absolute lag, (u = 5137, u_c=729) Locomotor task, Duration (6 bins), (u = 5137, u_c=729)	RM One-Way ANOVA, F (5, 723) = 474, *P* < 0.0001
Fig. 2d	Joystick task, Absolute lag, (u = 839, u_c = 120) Joystick task, Duration (6 bins), (u = 839, u_c = 120)	RM One-Way ANOVA, F (5, 114) = 72, *P* < 0.0001
Fig. 2d (left)	Locomotor task, S1 Duration, (u = 1651, u_c=236) Locomotor task, M1 Duration, (u = 2316, u_c=331) Locomotor task, M2 Duration, (u=1136, u_c=163)	RM One-Way ANOVA, F (2, 726) = 171, *P* < 0.0001 Post Hoc: 3-way Bonferroni: S1-M1: p=0.0021 M1-M2: p=0.024 S1-M2: p<0.0001
Fig. 2d (right)	Joystick task, S1 Duration, (u = 252, u_c=36) Joystick task, M1 Duration, (u = 323, u_c=46) Joystick task, M2 Duration, (u= 264, u_c=38)	RM One-Way ANOVA F (2, 117) = 16, *P* < 0.0001 Post Hoc: 3 way Bonferroni: S1-M1: p<0.0001 M1-M2: p<0.0001 S1-M2: p<0.0001
Fig. 3f	Locomotor task, Relative time constant, (a = 6) Joystick task, Relative time constant (a = 5)	Two-tailed t-test, *P* = 0.20 Two-tailed t-test, *P* = 0.043
Fig. 3h	Locomotor task, Absolute time constant, (a = 6) Joystick task, Absolute time constant (a = 5)	RM One-Way ANOVA, F (3, 18) = 6.6, *P* = 0.0033 Post Hoc: 6-way Bonferroni: Lowest paw velocity in the Joystick task vs Highest paw velocity in the Locomotor task: p = 0.037 Lowest paw velocity in the Joystick task vs Highest paw velocity in the Joystick task: p = 0.004
Fig. 4d	Locomotor task, low-pass versus high-pass, Pearson correlation, (a = 6) Joystick task, low-pass versus high-pass, Pearson correlation, (a = 5)	Two-tailed t-test, *P* = 0.016 Two-tailed t-test, *P* = 0.0091
Fig. 4d	Locomotor task, high-pass, Lag, (a = 6) Joystick task, high-pass, Lag, (a = 5)	Two-tailed t-test, *P* = 0.33 Two-tailed t-test, *P* = 0.01
Fig. 4d	Locomotor task, low-pass, Lag, (a = 6) Joystick task, low-pass, Lag, (a = 5)	Two-tailed t-test, *P* = 0.0013 Two-tailed t-test, *P* = 0.0029
Fig. 4e	Locomotor task, Pearson correlation, (a = 6)	RM One-Way ANOVA F (6, 35) = 3.6, *P* = 0.007 Post Hoc: 21-way Bonferroni: 5 Hz vs 1 Hz: p = 0.04
Fig. 4e	Joystick task, Pearson correlation, (a = 6)	RM One-Way ANOVA F (6, 28) = 3.5, *P* = 0.01

		Post Hoc: 21-way Bonferroni:
		10 Hz vs 0.5 Hz: p = 0.034
		5 Hz vs 0.5 Hz: p = 0.034
Fig. 4f	Locomotor task, Lag, (a = 6)	RM One-Way ANOVA F (6, 35) = 5.8, $P = 0.0002$
		Post Hoc: 21-way Bonferroni:
		50 Hz vs 0.5 Hz: p = 0.0021
		20 Hz vs 0.5 Hz: p = 0.042
		10 Hz vs 0.5 Hz: p = 0.0017
		5 Hz vs 0.5 Hz: p = 0.0089
		2 Hz vs 0.5 Hz: p = 0.0009
Fig. 4f	Joystick task, Lag, (a = 6)	RM One-Way ANOVA F (6, 28) = 2.5, $P = 0.045$
		Post Hoc: 21-way Bonferroni:
		10 Hz vs 0.5 Hz: p = 0.045

Supplementary Note 1: *The difference in stability of population activity cannot be explained by behavioral differences across the two tasks*

Could the differences in stability of the population activity be explained by differences in behavior across the two tasks? To address this question, we tested whether the autocorrelation of two easily accessible behavioral parameters can explain the observed effects: (1) paw velocity and (2) egocentric paw position. As the population correlation decayed more slowly in the locomotor task, we would expect a temporally broader behavioral autocorrelation for the locomotor task compared to the joystick task. However, the similarly narrow peaks of the autocorrelation of the paw velocity in both tasks argue that the difference in the stability of the population activity (**Supplementary Fig. 3A, upper panel row**) cannot be explained by differences in paw velocity (**Supplementary Fig. 3A, middle panel row**). Similarly, for the paw position, we would expect a temporally broader behavioral autocorrelation for the locomotor task compared to the joystick task to explain the stability differences of the population activity. Instead, the autocorrelation of the paw position was narrower during the locomotor task than during the joystick task (**Supplementary Fig. 3A, lower panel row**). Thus, neither the velocity autocorrelation, nor the position autocorrelation, could explain the differences in population activity stability. Alternatively, neurons preferentially encode the position during the locomotor task, and the velocity during the joystick task. If this were true, the broad population

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39 correlation during locomotion could be explained by the broad position autocorrelation and the

40 narrow population correlation during the joystick task could be explained by the narrow velocity

41 autocorrelation. To this end we tested the encoding preference (position or velocity) of the neurons in

42 the two tasks. The neurons showed an encoding preference for position in the joystick task

43 (**Supplementary Fig. 3B**), which stands in contrast to the more precise auto-correlation for paw

44 velocities in the joystick task. These opposing results suggest that differences in the stability of

45 population activity cannot be explained by a differential encoding preference of position and velocity.

46 To summarize, there is a strong decorrelation during paw movements in the joystick task, which cannot

47 be explained by means of differences in behavioral statistics.

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49 **Supplementary Note 2:** *Adaptation mechanisms and compatibility with prolonged movements*

50 Adaptation mechanisms at any stage between the cortex and the muscles could serve as the biological

51 equivalent of a high pass filter. The high pass filter should detect fast changes in the activity. On the

52 level of neuronal spiking this can be a change from a high firing rate to a low firing rate, or vice versa.

53 On the level of summed synaptic input this can be the change from a large input current or a low input

54 current, or vice versa. There are numerous neuronal phenomena that describe high-pass filtering on

55 the time scale of hundreds of milliseconds, such as spike rate adaptation[1], short term synaptic

56 depression[2], integrating inhibitory neurons[3], low-pass filtering across gap junction connected

57 interneurons[4], and depolarization block[5]. The underlying mechanisms of those phenomena can follow

58 the slowly evolving motor planning and sensory integration activity by means of the intracellular

59 calcium concentration, amount of release ready vesicles in the presynaptic terminal, the firing rate of

60 integrating inhibitory neurons, or the number of inactivated sodium channels, respectively.

61 The generation of prolonged movements under the control of an adaptation related high pass

62 mechanism would require a subcortical process that can be triggered by short lasting inputs. In the

63 lamprey, the reticulospinal cells transform a short duration sensory input into a long-lasting excitatory

64   command[6]. In the zebrafish, high frequency stimulation in the brain stem initiates sustained locomotor

65   behavior[7]. Similarly, in the basal ganglia of rodents, neurons are activated during the initiation and

66   termination of movement sequences[8]. In the mouse, the lower pyramidal tract neurons have been

67   shown to have a preference for motor execution[9] and are thus good candidates for contributing to

68   sustaining movements. These neuronal processes in combination with our proposed high pass filtering

69   mechanisms would allow for movements of different durations.

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