Widespread motor-correlated activity in the primary somatosensory and motor cortices

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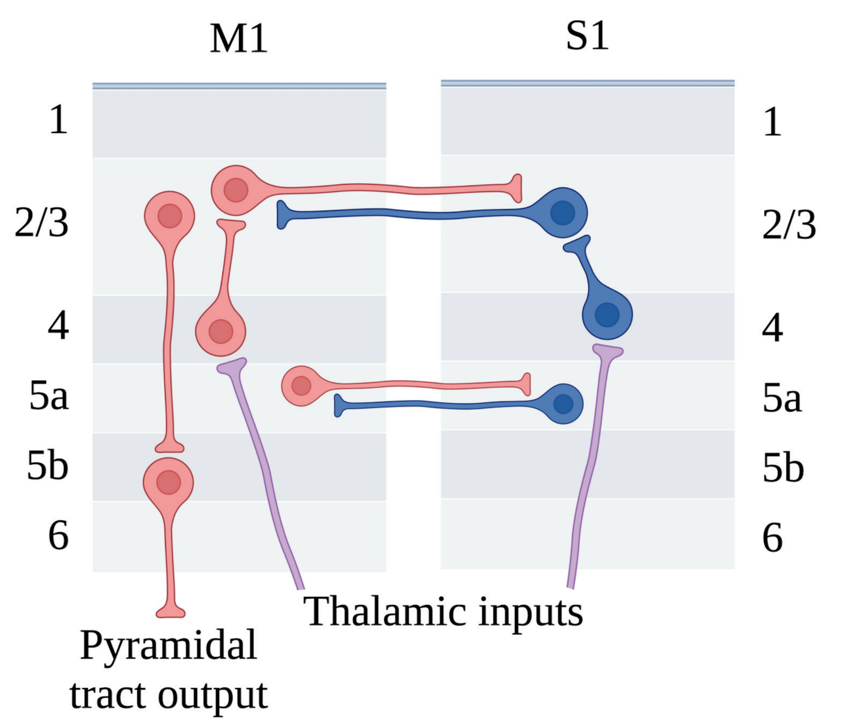
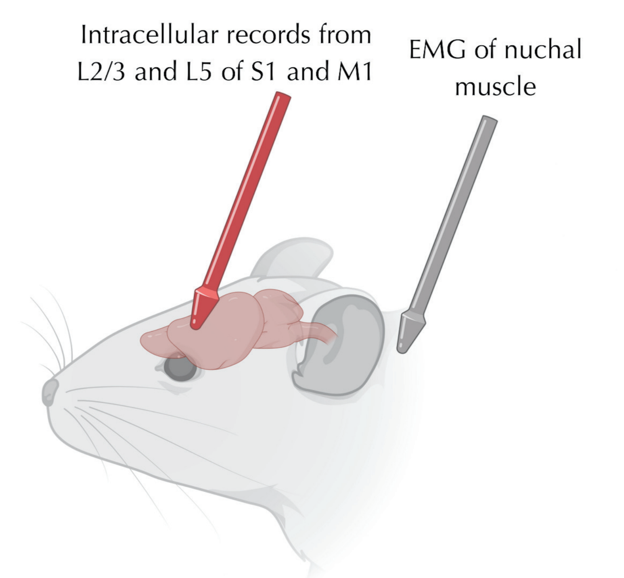
Introduction

Neuronal activation throughout the cortex correlates strongly with the animal's movement (1). Movement-related cortical activity in the sensory areas is thought to function as corollary discharge and to modulate sensory processing during self-generated motor activity (2). However, the exact cortical computations associated with these cortex-wide motor signals are not fully elucidated.

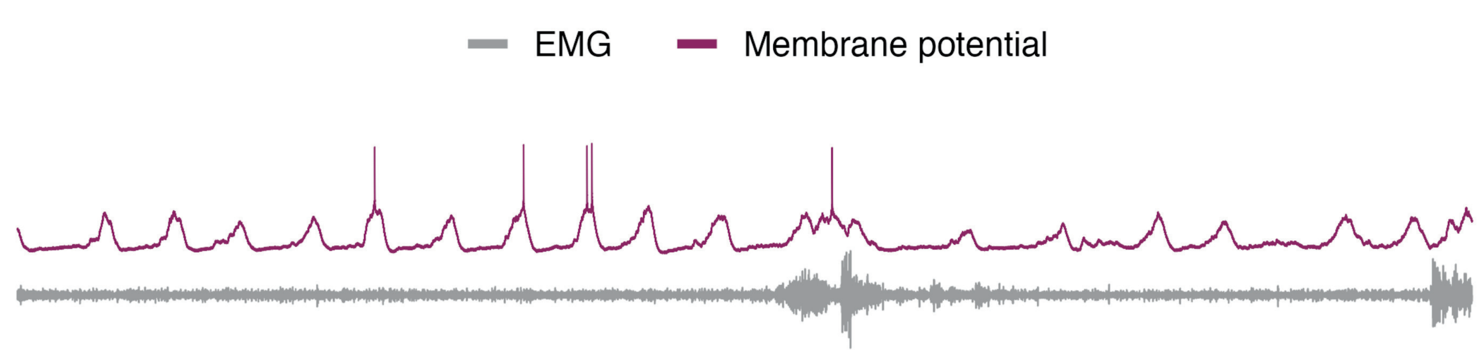


The reciprocal connections between the primary motor (M1) and primary somatosensory (S1) cortices are thought to play a role in sensorimotor integration during active behaviours (3).

Methods



Study design. Electromyography (EMG) of nuchal muscle (neck) and membrane potential recordings from L2/3 and L5 of S1 and M1 were performed in awake, head-restrained mice. 4 female mice were used. The mice were not subjected to any task and performed spontaneous movements.



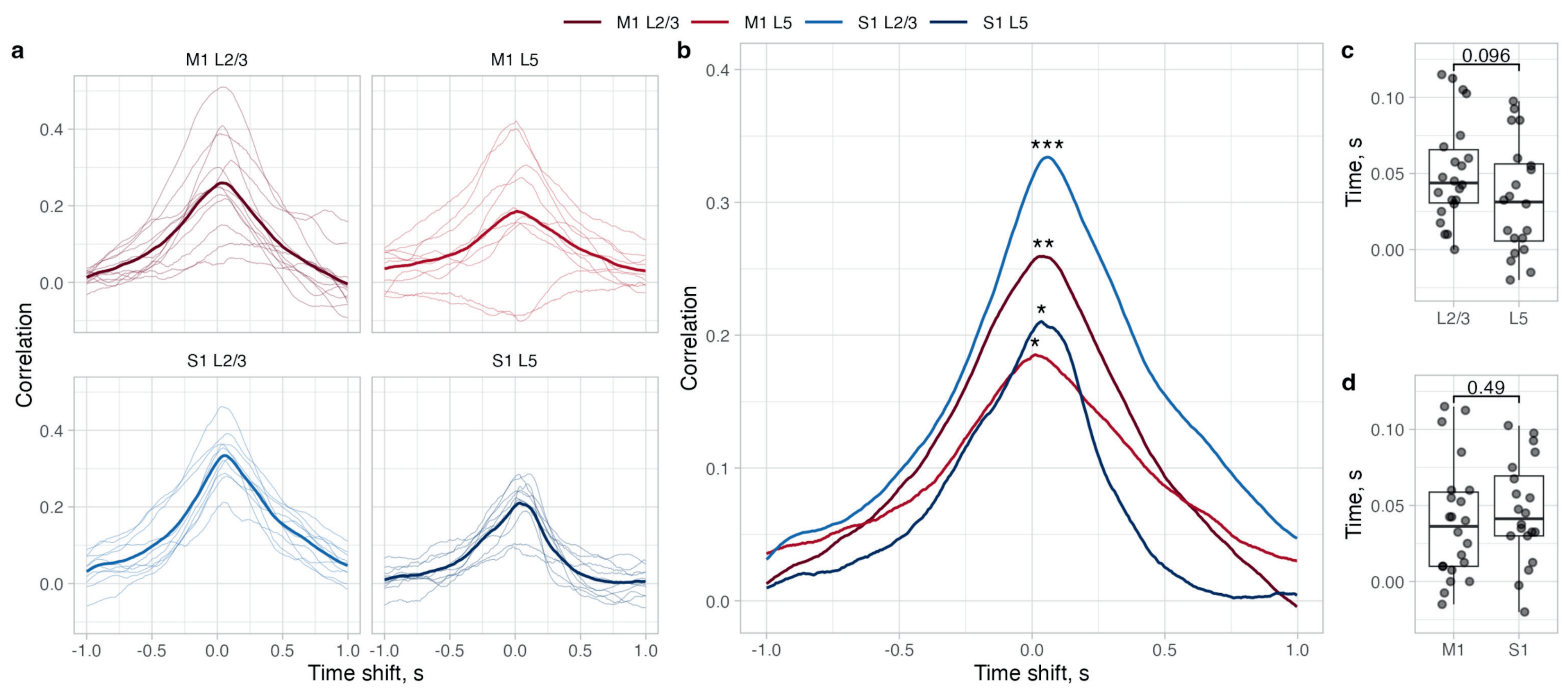
Simultaneous recording of EMG activity and membrane potential of L5 neuron from S1. Membrane potential is more depolarised and less variable during EMG bursts.

References

1. Stringer, C., Pachitariu, M., Steinmetz, N., Reddy, C. B., Carandini, M., & Harris, K. D. (2019). Spontaneous behaviors drive multidimensional, brainwide activity. American Association for the Advancement of Science (AAAS). https://doi.org/10.1126/science.aav7893
2. Petersen, C. C. H. (2019). Sensorimotor processing in the rodent barrel cortex. Springer Science and Business Media LLC. https://doi.org/10.1038/s41583-019-0200-y
3. Matyas, F., Sreenivasan, V., Marbach, F., Wacongne, C., Barsy, B., Mateo, C., … Petersen, C. C. H. (2010). Motor Control by Sensory Cortex. American Association for the Advancement of Science (AAAS). https://doi.org/10.1126/science.1195797

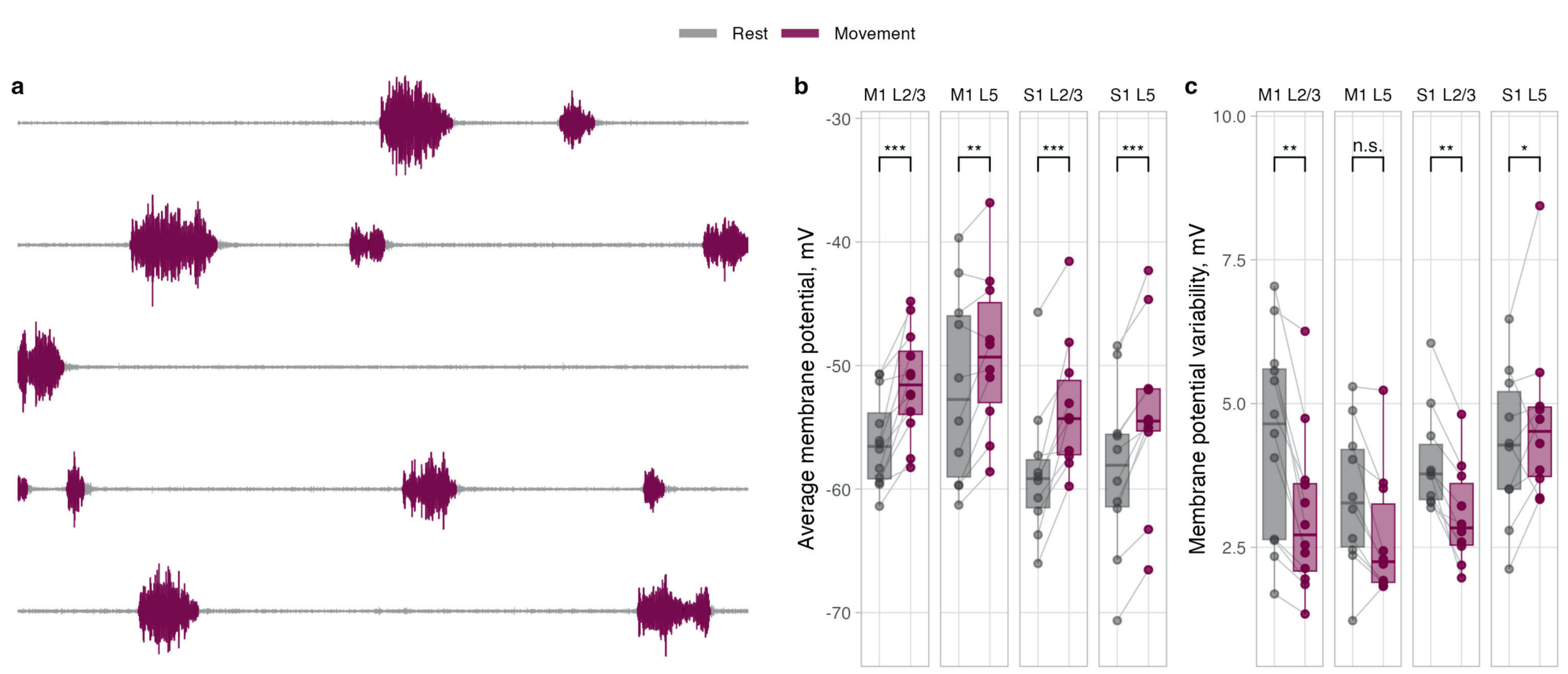
Results

Membrane potential correlates with muscle activity



The lagged correlation between the EMG activity and the membrane potential is not significantly different between M1 and S1. (a) The vast majority of cells show positive correlation between membrane potential and EMG. However, some of the cells in L5 of M1 are negatively correlated with the muscle activity, indicating M1 inhibition during movement. **(b)** In all cortical regions, the correlation peaks after movement onset. The time of the correlation peak does not differ between layers **(c)** or cortices **(d)**.

Membrane potential depolarises during movement

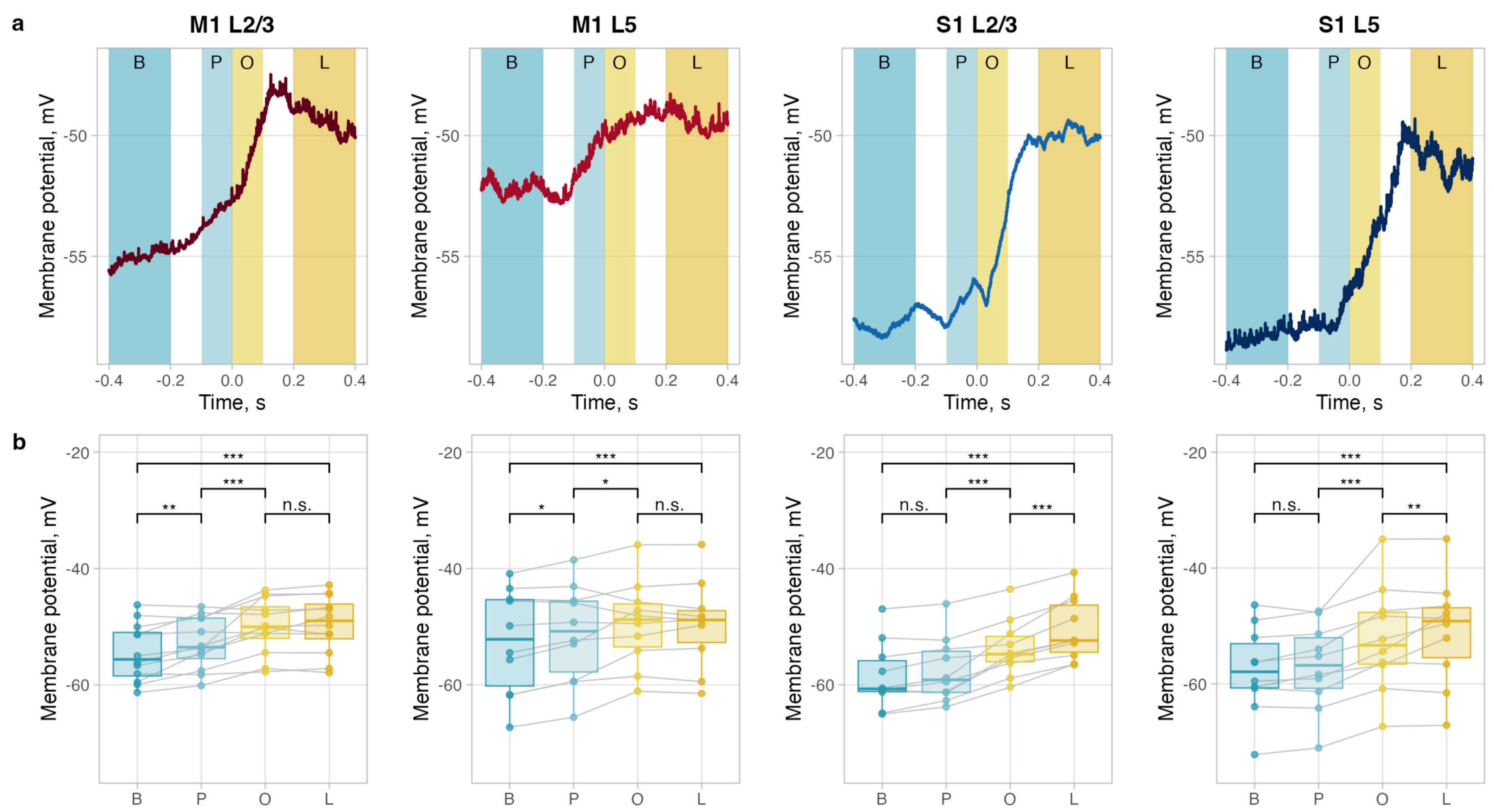


Membrane potential dynamics change during movement. (a) The recordings were subdivided into periods of rest and movement based on the EMG signal. **(b)** During movement, the membrane potential is significantly depolarised in all regions. **(c)** In L2/3, the membrane potential variability is significantly decreased. In L5 of S1, it is significantly increased due to large number of fired action potentials.

Funding

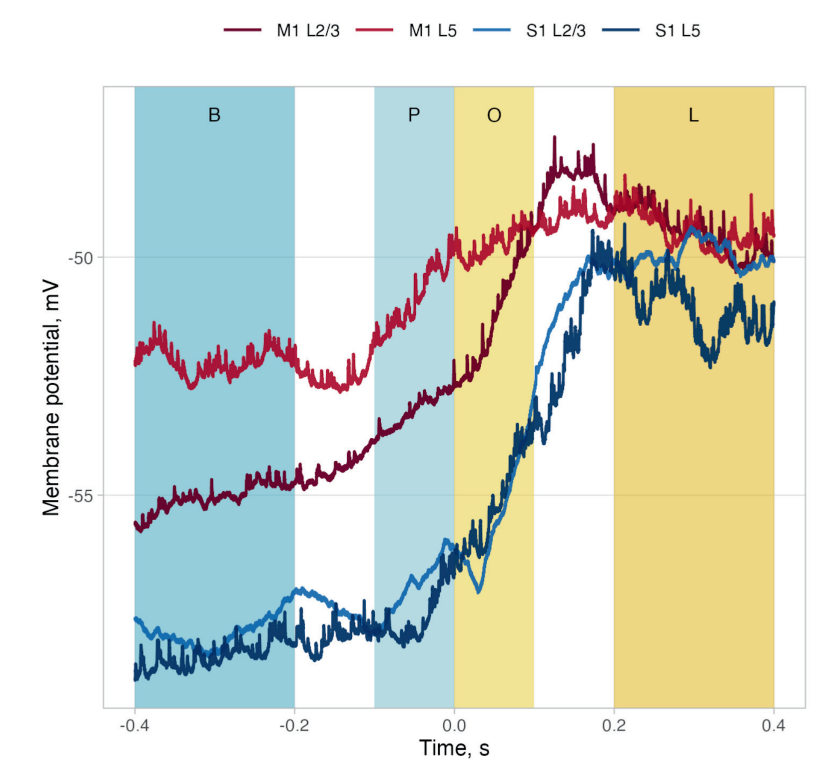
NHMRC (APP1086082 and APP1063533, L.M.P), the Sylvia and Charles Viertel Charitable Foundation (L.M.P), the Australian Research Council (L.M.P), IBRO (Return Home Fellowship and Early Career Award; R.G.) and MJJ fellowship (R.G.)

M1 depolarises before, S1 – after movement onset



Membrane potential dynamics change during different phases of movement onset in M1 and S1. (a) Average membrane potential in each region. The movement onset was divided into four epochs of interest (Baseline, B; Pre-movement, P; Movement onset, O; and Late Movement, L). **(b)** The most significant change in membrane potential depolarisation occurs before movement onset in M1, and after movement onset in S1.

By the late movement phase, the differences in membrane potential were negligible between the regions. The change in membrane potential depolarisation in S1 was higher than in M1.



Conclusions

1. The membrane potential in both S1 and M1 is highly correlated with movement.
2. The membrane potential is depolarised and has lower variability during movement.
3. M1 depolarises before, S1 – after movement onset.
4. Despite different resting membrane potential, all neurons are activated to the same membrane potential during EMG activity.

The main take-away

S1 and M1 are activated similarly during movement