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Reward and force modulation of neurons in the primate primary somatosensory cortex (S1)

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Introduction

We analyzed spike data recorded from the primary somatosensory cortex (S1) of two Non-human Primates (NHP), Monkey S and P. Data was recorded during a value cued grip force task performed by the NHPs where they had to apply and maintain a cued level of grip force on a force transducer to enable a virtual robot arm to pick up and transport an object. Juice was given for successful completion of rewarding trials.

Methods

Grip-Force Task

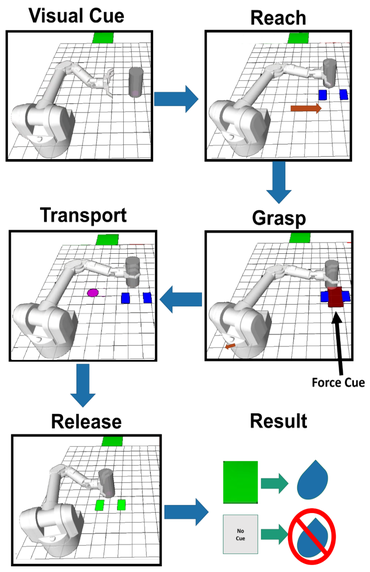


Fig 1. Diagram of the Grip force task showing each phase

Task Description

- There were two blocks of data for each NHP:
  - Cued
    - A visual cue (green square) indicated rewarding trials. The absence of a cue indicated a non-rewarding trial.
  - Uncued
    - No cue provided regardless of trial type.

- Each block contained rewarding (R1) and non-rewarding (R0) trial types.

1. A target object appears, the simulated robotic arm reaches the target automatically.
2. The NHP applies and maintains grip force during grasp and transport to complete the task.
3. Successful completion of a rewarding trial results in a delivery of juice to the NHP, where non-rewarding successful trials did not.

Data analysis

- Force Significance: The significance (F-test, p-value< 0.05) between the applied grip force and spike rate was measured for all units.
- Reward Significance: We detected significant units (t-test, p-value <0.05) related to reward using 500ms post result spiking activity.
- Significant units common to both force and reward during cued and non-cued blocks were examined further.
- Multiple Linear Regression (MLR) was applied to observe force prediction accuracy.
- Units that had a significantly (F-test, p-value <0.05) different tuning curve between rewarding and non-rewarding trials in cued blocks were identified [1].

Results

Raster Plots for Cue and Reward

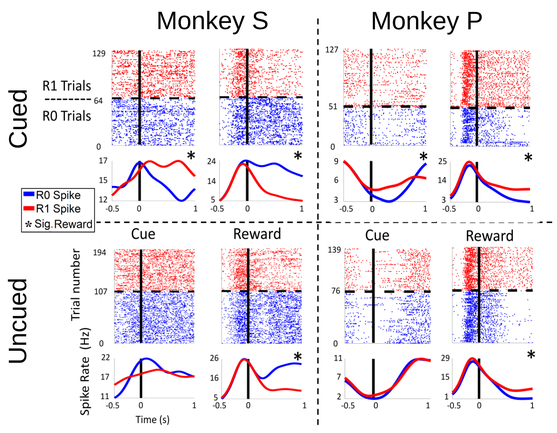


Fig 2. Raster plots showing spikining activity around cue and reward delivery periods for cued and non-cued trials. The smoothened spike rate is below each raster plot. The star on the plots represents the significance for reward level.

Raster Plots for Force

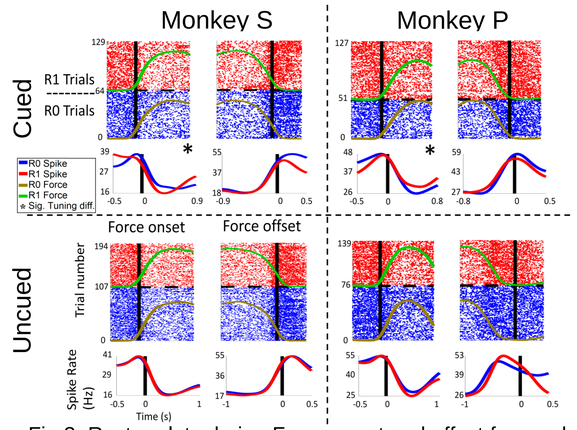


Fig 3. Raster plots during Force onset and offset for cued and uncued blocks, including mean force. The smoothed spike rate is plotted for R0 and R1 trials. The significant difference between rewarding and non-rewarding tuning curves is represented with the star symbol.

Units Significant for Force and Reward

- Monkey S had 53 units that showed significance for both force and reward.
- Monkey P had 22 units that showed significance for force and reward.

Force Prediction

Block Type	Monkey S	Monkey P
Cued	0.86	0.83
Uncued	0.83	0.82

Table 1. R-square values between predicted and actual force for cued and non-cued blocks.

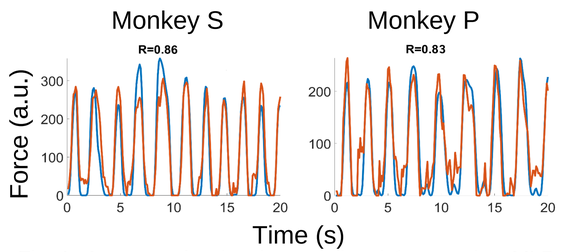
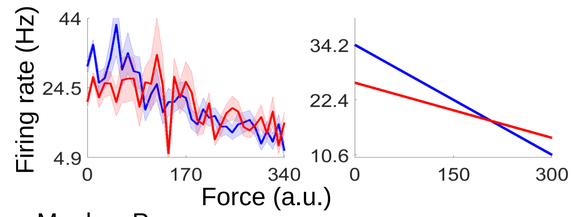


Fig 4. An example showing predicted force using MLR and applied grip force for monkey S and P.

Tuning Curve

Significantly Differently Tuning curve

- Monkey S



- Monkey P

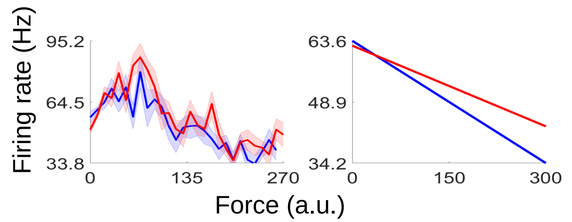


Fig 5. Examples of tuning curves from two units, one from each monkey, having significantly different curves between cued and non-cued rewarding and nonrewarding trials.

	Monkey S	Monkey P
Number of units	21	30

Table 2. The number of units with significantly different tuning curves between rewarding and non-rewarding trials.

Conclusions

- S1 units accurately represent grip force.
- S1 units that encode force are also by modulated by reward.
- The representation of the force can be modulated through reward expectation.

Acknowledgement

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References

1. Zhao, Y., Hessburg, J.P., Kumar, J.N.A. and Francis, J.T., 2018. Paradigm shift in sensorimotor control research and brain machine interface control: the influence of context on sensorimotor representations. *Frontiers in neuroscience*, *12*.