Learning Causes Changes to Natural Neural Patterns

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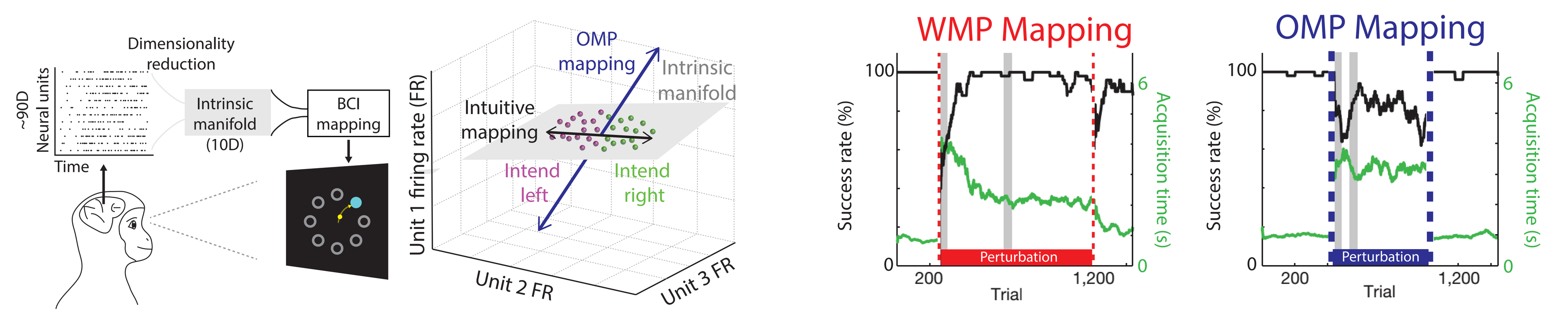
Introduction

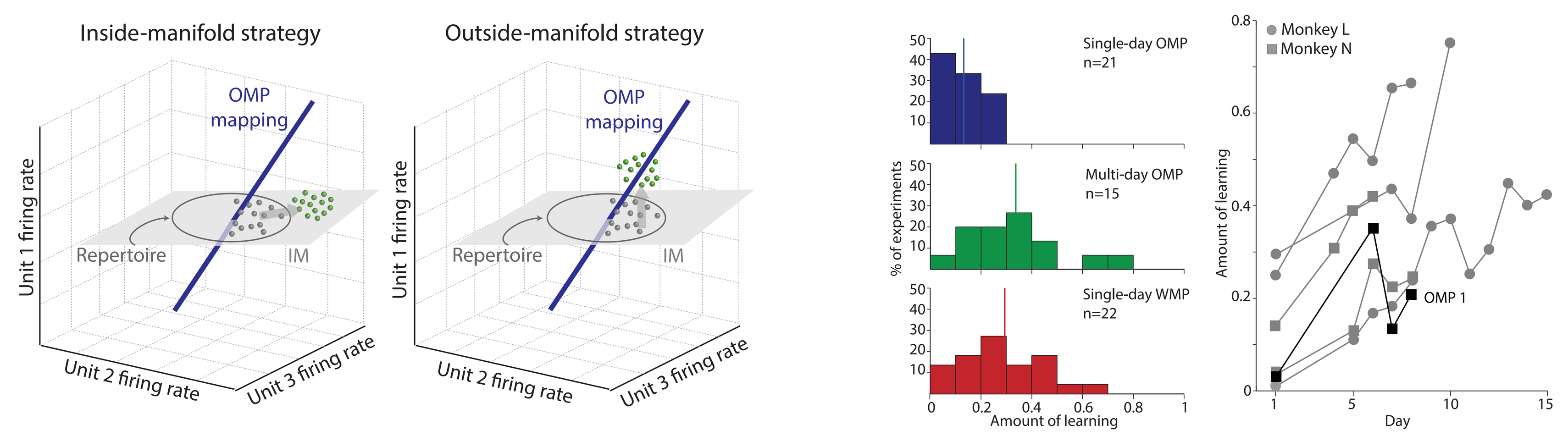
How does learning affect natural neural patterns? Using data from Brain-Computer Interface (BCI) experiments, we seek to show that learning novel neural patterns yields greater change in natural neural activity than explainable due to neural drift or learning neural re-associations.

Background: BCI paradigm to study learning



The intrinsic manifold, the low-dimensional factor space within the neural population space, constrains learning. WMP mappings are well learned within a single session. OMP mappings are not well learned within a single session.

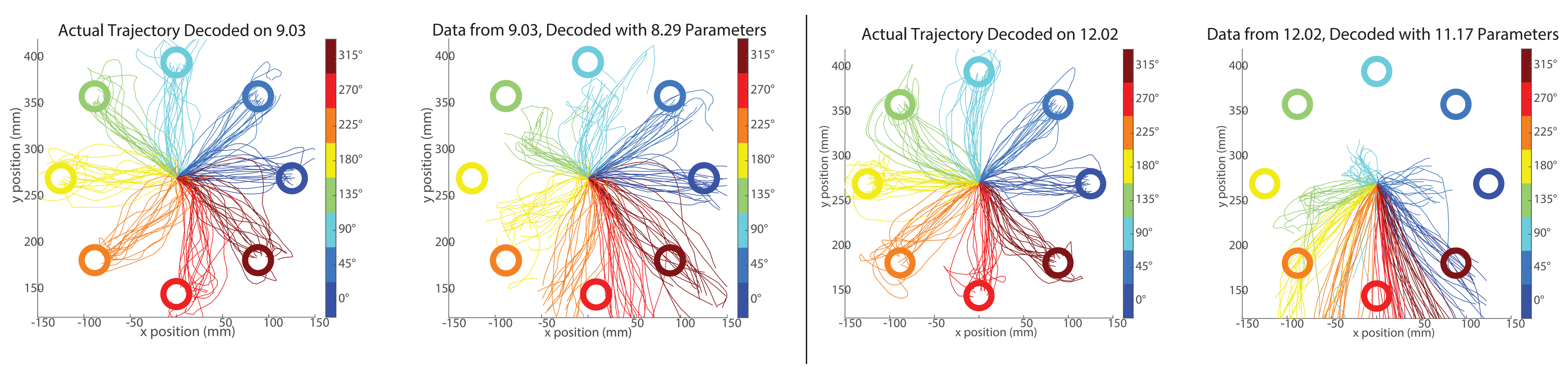
Sadtler et al., *Nature* 2014



Long-term practice and coaching can lead to learning of OMP mappings.

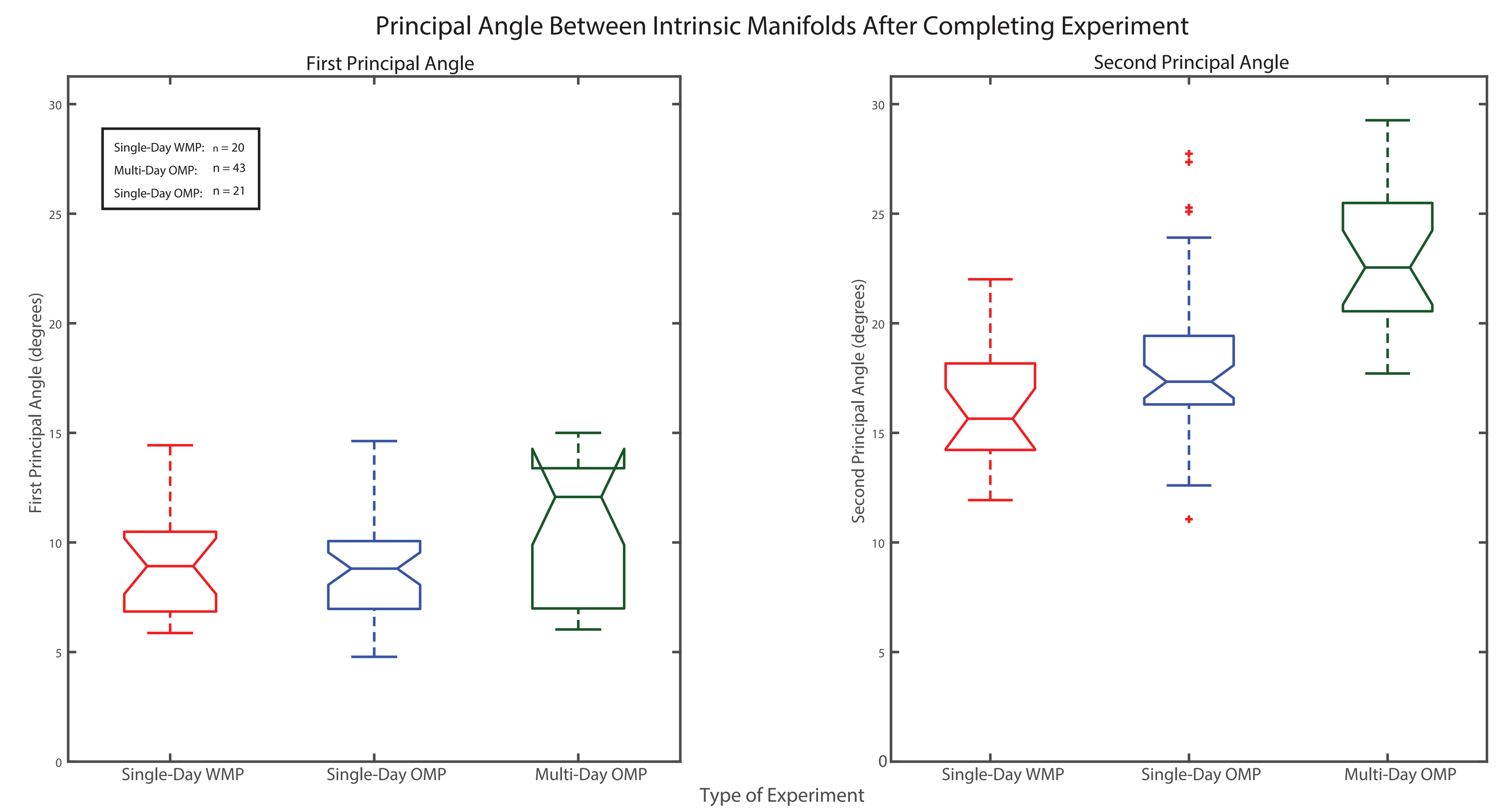
Oby et al., *PNAS* 2019

Decoding Parameters Differ Between Days



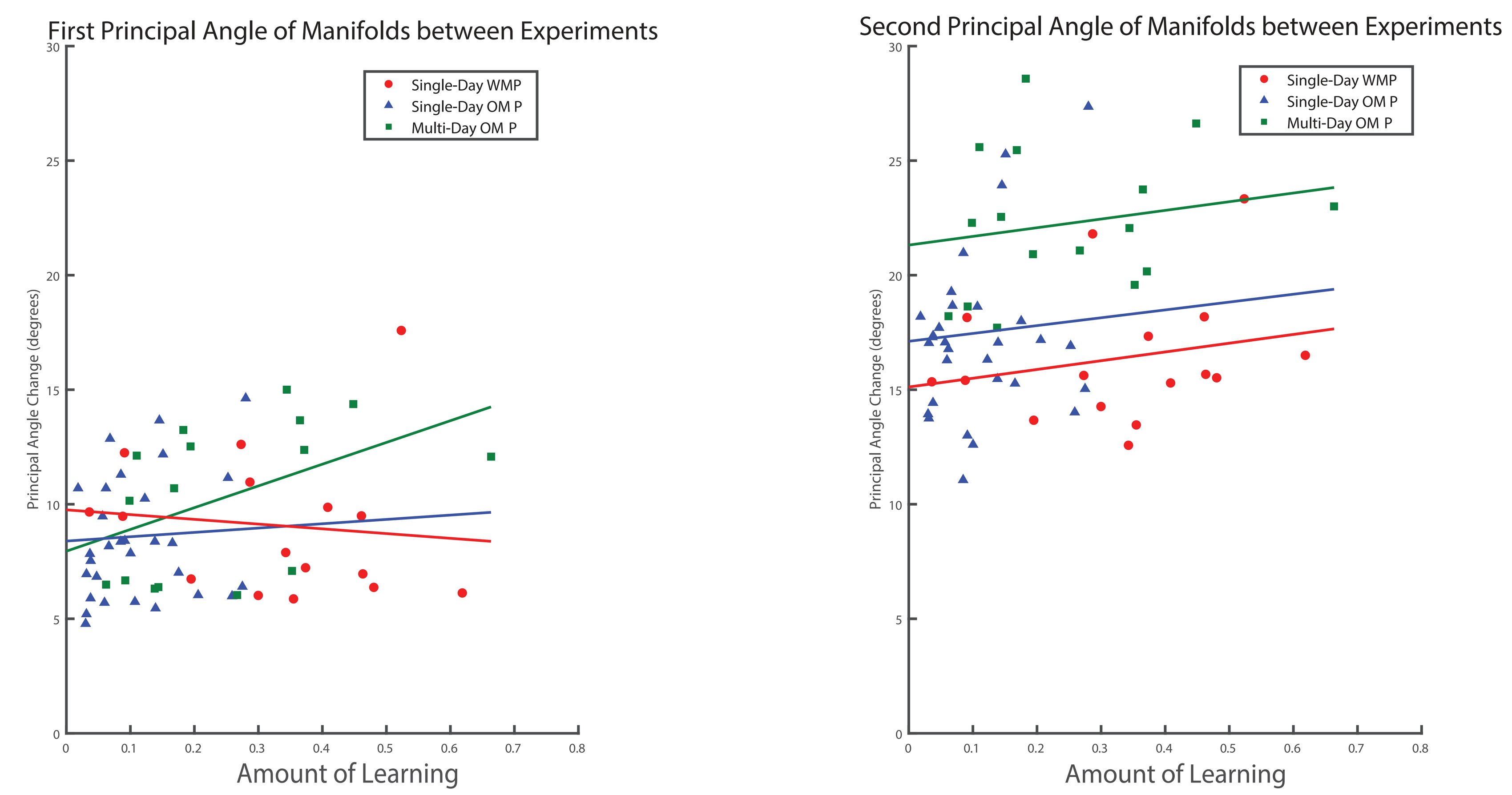
- Errors in both decoded magnitude and angle occur when using decoder parameters from a different day than the trial data.
- Possible explanations for variations in error include time between trials, type of learning between trials, or random noise.

Type of Learning Affects Change in Manifold



- After learning an outside-manifold perturbation mapping, the lowest two principal angles between the 10D intrinsic manifold used by the decoder both increase more than after other types of learning.
- The second principal angle showed significantly greater change after multi-day OMP experiments than either type of single-day experiment, passing the t-test for both, with p-values less than 10^{-4}.

Amount of OMP Learning Correlates to Changes



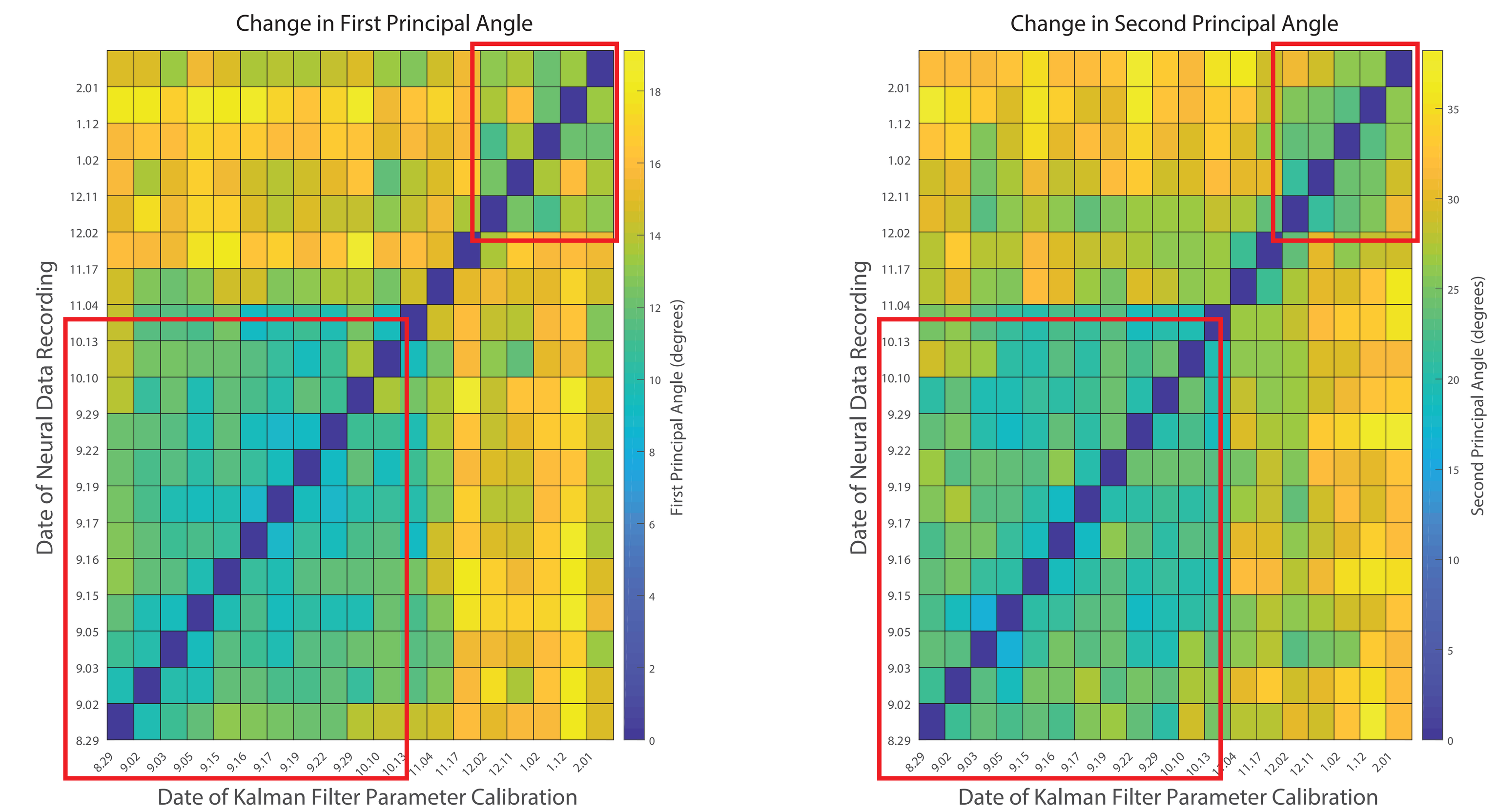
-As amount of learning an outside-manifold perturbation increases, the principal angle between the intrinsic manifolds tends to increase (p-value = 0.0653, r= 0.4713).
-Amount of Learning defined by Oby, et. al as reward rate, given performance on Intuitive Mapping and adjusted for mapping difficulty.

References:

1. Oby, E. R., Golub, M. D., Hennig, J. A., Degenhart, A. D., Tyler-Kabara, E. C., Yu, B. M., Chase, S.M., Batista, A. P. (2019, July 23). New neural activity patterns emerge with long-term learning. Retrieved from https://www.pnas.org/content/116/30/152102.

2. Sadtler, P. T., Quick, K. M., Golub, M. D., Chase, S. M., Ryu, S. I., Tyler-Kabara, E. C., Yu, B.M., Batista, A. P. (2014, August 27). Neural constraints on learning. Retrieved from https://www.nature.com/articles/nature13665

Manifold Changes Appear to Hold Across Time



Red boxes indicate days when no OMP mapping was well learned.

Discussion

- Learning novel neural patterns appears to cause changes in the intrinsic manifold.
- Increased changes in the intrinsic manifold were seen after OMP sessions with greater learning.
- Neural drift occurs over time and may confound the results.

Future Directions

- Analyze relationship between control space, intuitive mapping, and intrinsic manifold
- Determine whether intrinsic manifold grows or rotates
- Use an Internal Model Estimate to compare internal models of the decoder

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