Continual Reconfiguration of Neural Activity
. . . and its Implications for Stable Decoding

ME Rule, AR Loback, DV Raman, LN Driscoll, CD Harvey, TS O'Leary

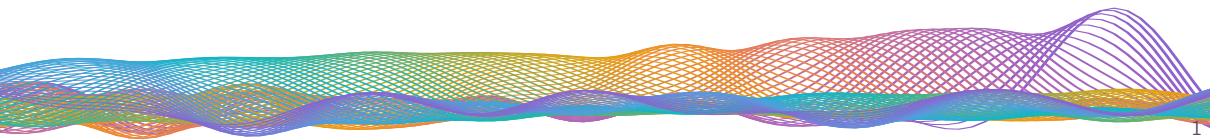
BCI Unconference, 23 July 2020

Using data from:

Driscoll LN et al. (2017) *Dynamic reorganization of neuronal activity patterns in parietal cortex.* Cell 170.5: 986-999.

Based on work published in:

Rule ME, Loback AR, et al. (2020) *Stable task information from an unstable neural population.* eLife. doi:10.7554/eLife.51121



Invasive cortical BCIs

Implanted multi-electrode arrays in cortex

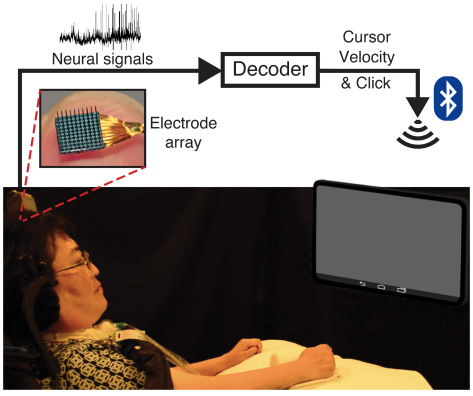
- High bandwidth, high performance

They work! In humans since 2004[1]

- Robot arms[2] and computers[3]
- Email, browse web at 13-31 char/min[4]

Decode neural population activity

- Motor cortex: movement commands
- **Cognitive BCIs:** goals/coordinates?[5]



[4]Nuyujukian et al. 18

[1]Hochberg et al. '06 [2]e.g. Hochberg et al. '12; Vogel et al. '15; Wodlinger et al. '15, many others

[3]e.g. Bacher et al. '15; Jarosiewicz et al. '15, '17, many others [5]see Andersen et al. '05; Aflalo et al. '15

Calcium imaging: high-volume recording for BCI research

Ca^{2+} imaging BCIs

In mice[a], nonhuman primates[b]

Driscoll et al. '17:

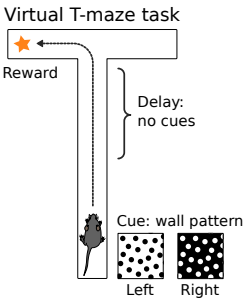
Track population over weeks

Posterior Parietal Cortex (PPC)

Study how neural code changes

- Neural codes *"drift"*
- Not recording instability![c]

Plasticity **in well-learned tasks!**

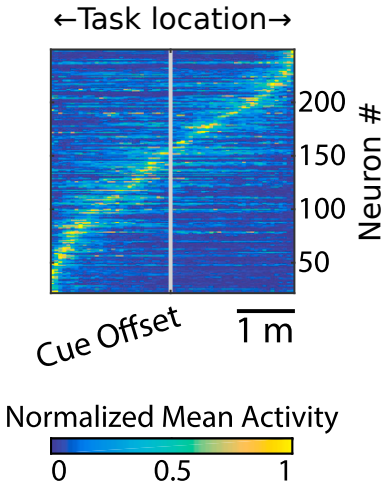


[a] Clancy & Mrsic-Flogel '19; Liberti &al. 29

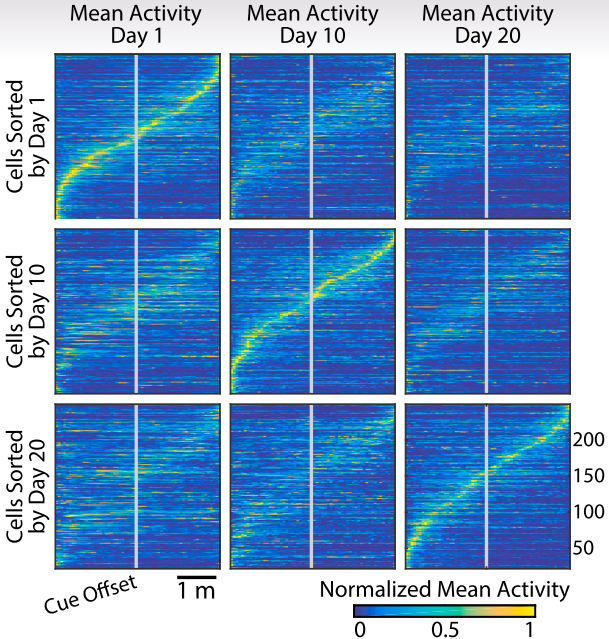
[b] Trautmann &al. 19; Bollimunta &al. 20

[c] Perge &al. 13; Downey &al. 18

Neural tunings tile the task



Driscoll et al. 2017



Driscoll et al. 2017

The brain is robust to changing neural codes, how?

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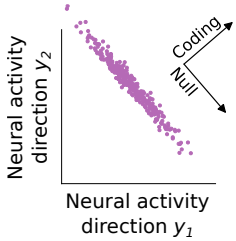
Invariance:

- Change in null-space of readout



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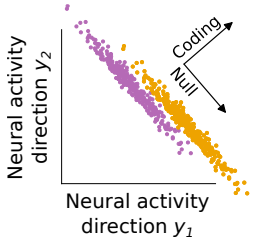

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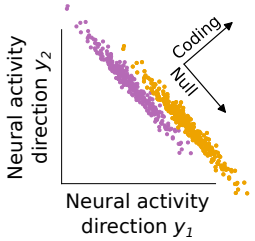
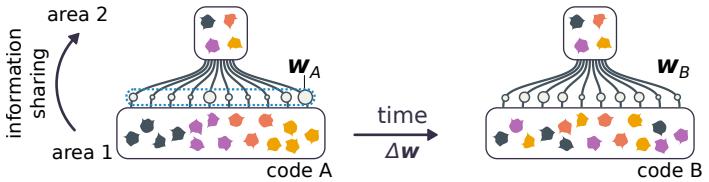
Coordination:

- Slow change, downstream areas adapt





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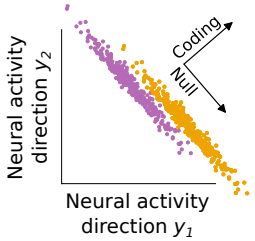
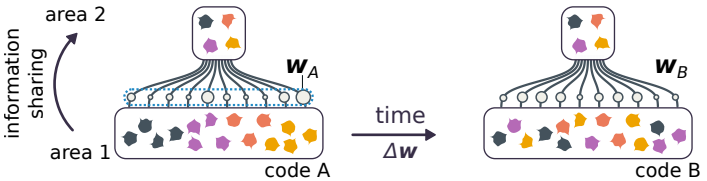
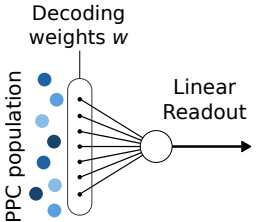
Analyse Driscoll et al. '17

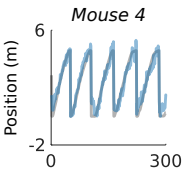
- Drift preserves an invariant readout
- Rate of plasticity needed to track drift is plausible





Single-day decoders generalize poorly





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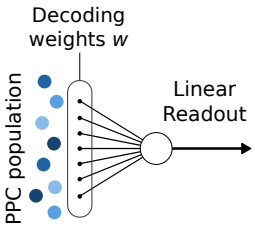
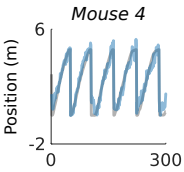
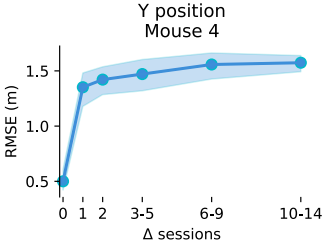


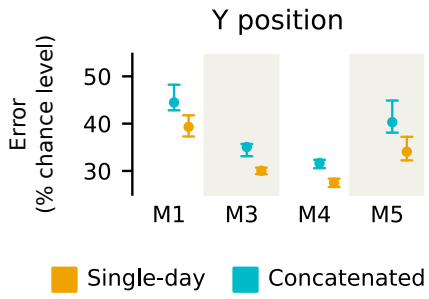




. . . but hint at long-term stable structure

Long-term ≈ stable subspace exists, drift is constrained

Fixed decoder trained over (subset of) data *concatenated* from 7-10 days nearly as good as single-day



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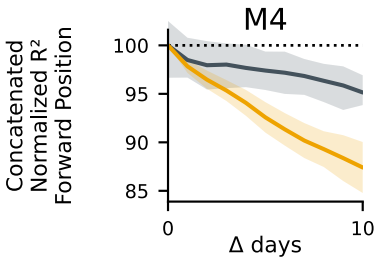
Unconstrained drift would more rapidly degrade performance



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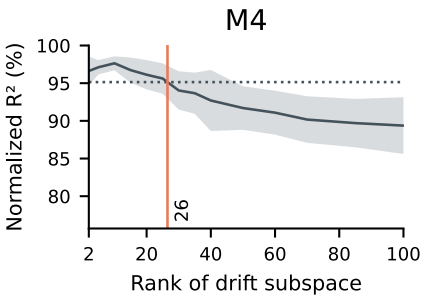
Results consistent with low-rank drift



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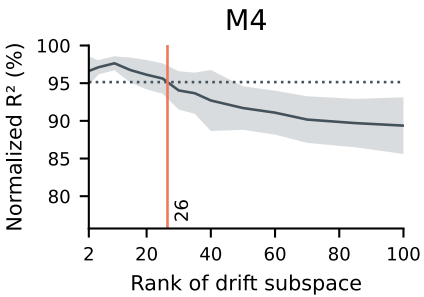
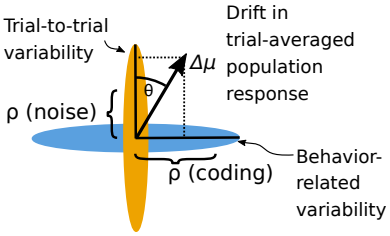
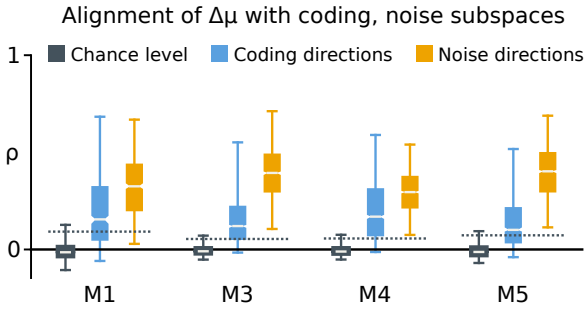
Results consistent with low-rank drift

c.f. Sussillo et al. '16: Robustness achieved in part by using months of training data



Drift resembles trial-to-trial variability

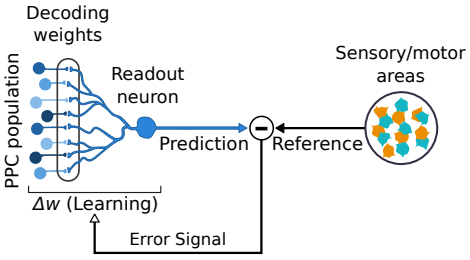


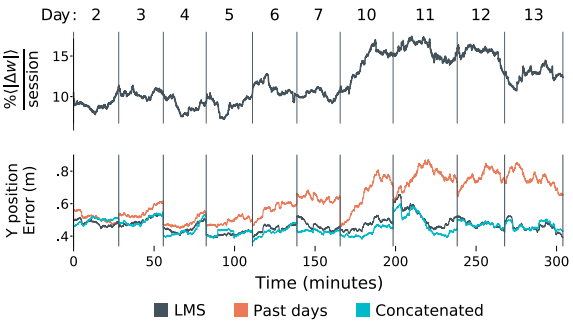


. . . But a significant amount of drift lies in directions that seem to encode task information

≈ Stable subspace can be identified, tracked with modest plasticity

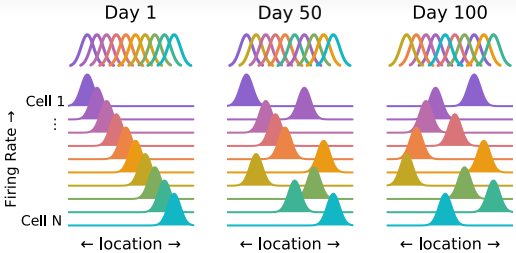
Distributed representations could detect tuning changes, adjust decoding weights

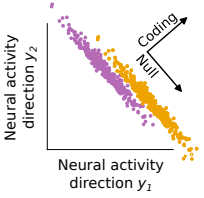


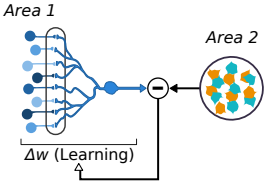


(∼10-15% weight change per session for ∼100 cells, more cells → less plasticity)

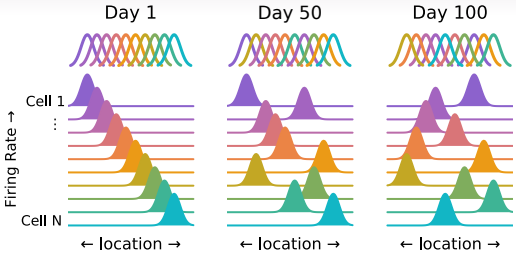
Drift is constrained

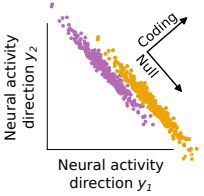


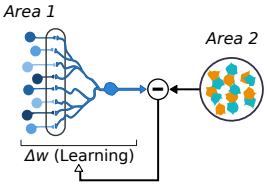




- Drift is constrained
- Some benign: like inter-trial variability







- Drift is constrained
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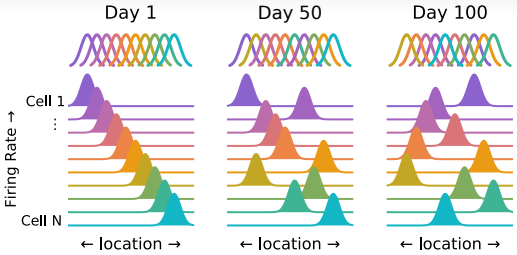
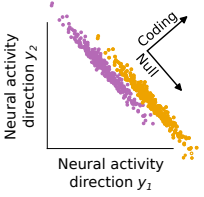
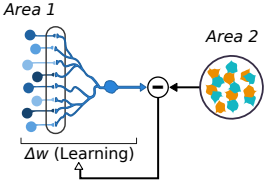
- Disruptive drift is slow (easily tracked)







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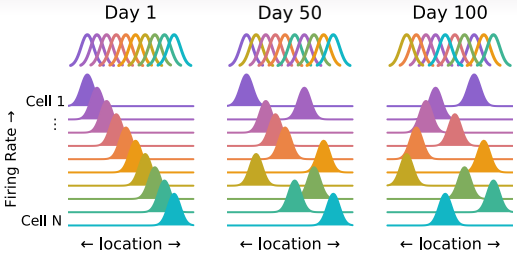
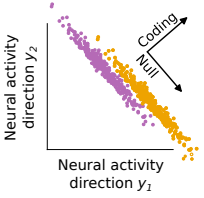
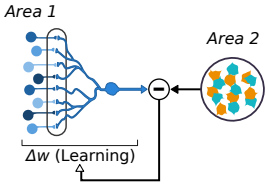
With enough data, $\approx$ stable codes can be found, but...

- Volatile codes still carry information
- Multiple codes with differing stability?







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With enough data, ≈ stable codes can be found, but...

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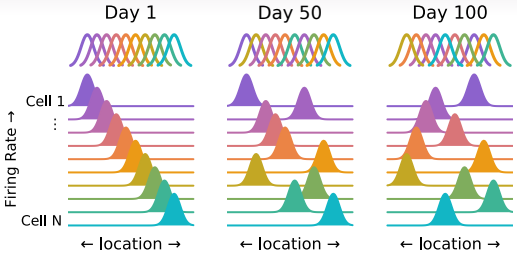
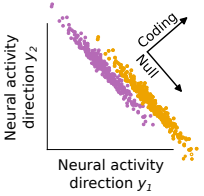
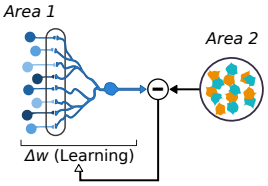
Implications for decoding:

- Long term: track ≈ stable subspace
- Use to bootstrap decoder recalibration
- Short term: detect & use volatile codes

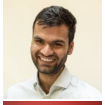






Coauthors:


Adrianna Loback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Laura Driscoll


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Chris Harvey

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Fulvio Forni


Alon Rubin


Yaniv Ziv

Aspects of this work published in:

Rule ME, Loback AR, Raman DV, Driscoll L, Harvey CD, O'Leary T. 2020. Stable task information from an unstable neural population. bioRxiv

Rule ME, O'Leary T, Harvey CD. 2019. Causes and consequences of representational drift. Current opinion in neurobiology 58:141–147

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