Multivariate decoding of visual working memory

School of Psychology Research Seminar

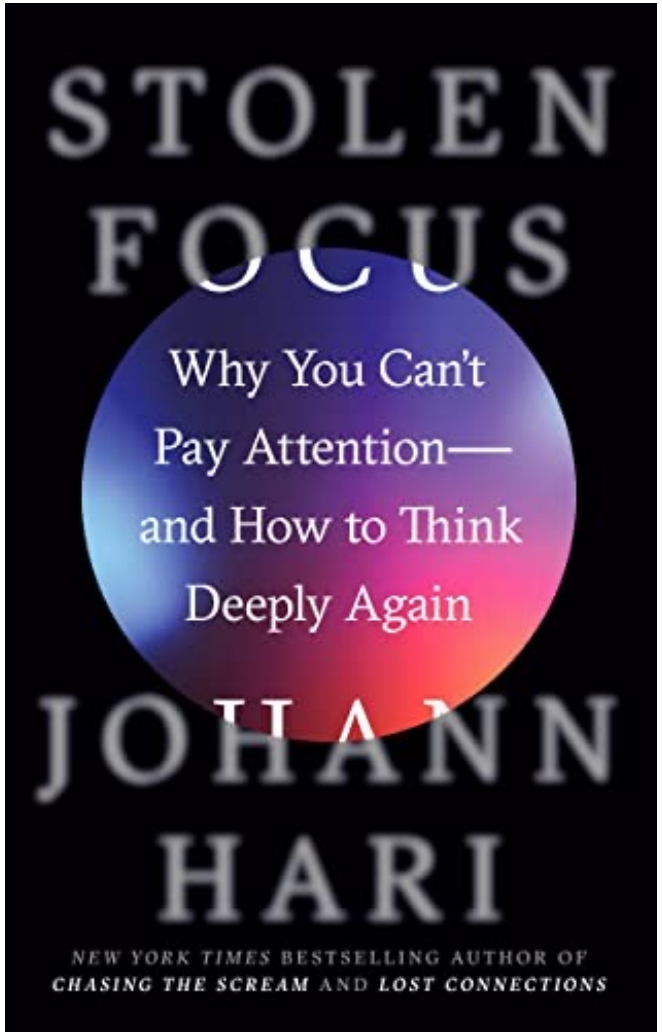
July 2024

Adelaide University

Why study attention and memory?

- Our attention is very limited
- Therefore, our attention is *precious*
- We should want the right things to take up our attention!

Why study attention and memory?



New York Times Bestseller, Book of the Year by Financial Times, etc.

Taps into the collective feeling that we are losing our ability to ***focus***

In my opinion, a very average book…

Why study attention and memory?

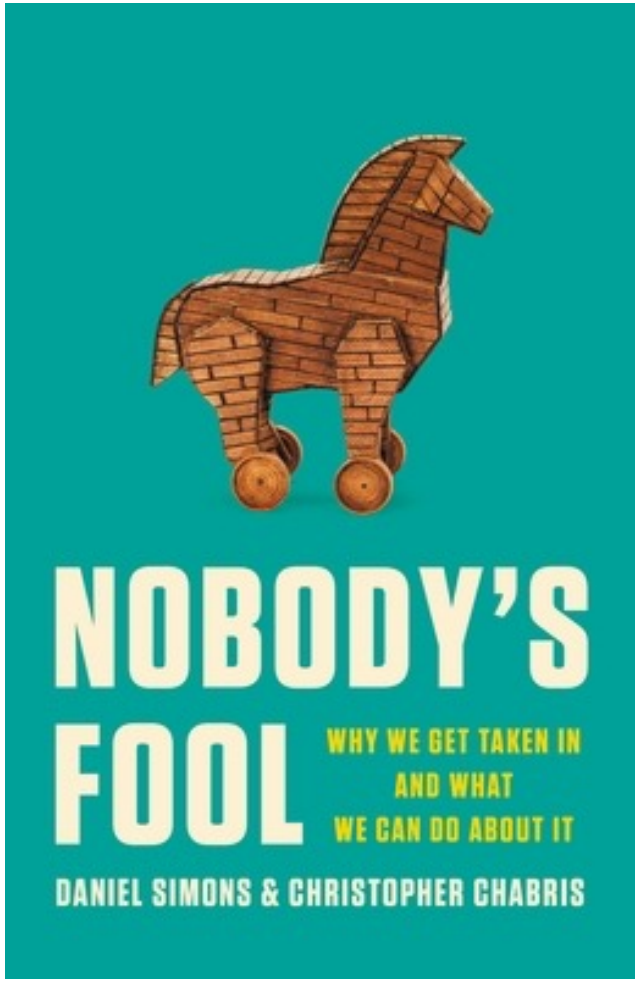
I'm a journalist working on a story about whether social media's impact on attention spans is impacting professions that require greater attention to detail such as surgeons.

Also, looking at whether there is a digital attention divide between Gen Z compared to older generations. As a result, have university professors had to change their teaching methods because of attention span for younger people.

Is there an area or faculty in particular that could talk to me on this? Either on the teaching methods or the impact to medical professions such as surgeons.

- Does social media impact attention spans? If so, in what ways and who?
- Is there an 'attention divide' between Gen Z and older generations?
- How is attention implicated and required in different professions?
- Should teaching methods be tailored to varying attention spans?

Why study attention and memory?



The researchers behind the "invisible gorilla" study!

We can be deceived when made to attend to the wrong things.

1. How is information represented in mind?
2. A brief overview of multivariate decoding
3. Decoding the contents of working memory

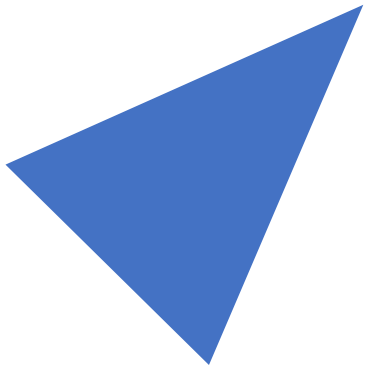
What *is* visual working memory?

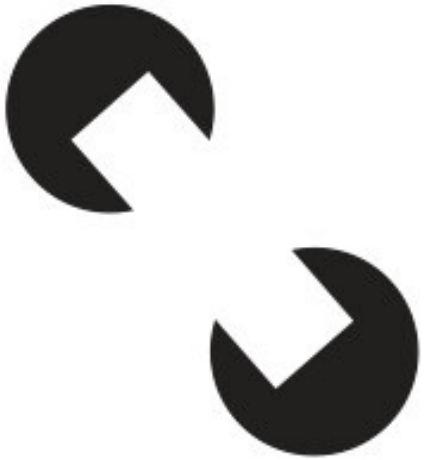
- "The system responsible for maintaining visual information in a state of heightened accessibility for ongoing perception and cognition."

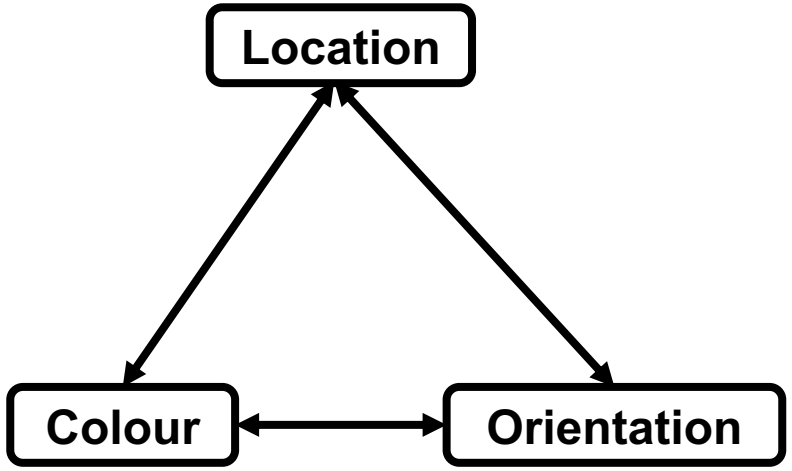
- This same definition could also describe visual **attention**
  - Perhaps also visual imagery, psychological introspection

- The core question: **How is information represented in mind?**

Representations in the mind







Constituents?
Illusory objects?

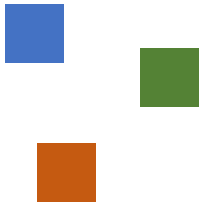
Memories across space and time?

What *is* visual working memory?

Object-based theory

"slot models"

(Luck and Vogel, 1997;
Zhang and Luck, 2008)



Feature-based theory

"*resource models*"

(Alvarez and Cavanagh, 2004;
Wilken and Ma, 2004)

Luck, S. J., & Vogel, E. K. (1997). https://doi.org/10.1038/36846
Zhang, W., & Luck, S. J. (2008). https://doi.org/10.1038/nature06860
Alvarez, G. A., & Cavanagh, P. (2004). https://doi.org/10.1111/j.0963-7214.2004.01502006.x
Wilken, P., & Ma, W. J. (2004). https://doi.org/10.1167/4.12.11

What *is* visual working memory?

- An enduring theoretical framework has been

Object-based theory

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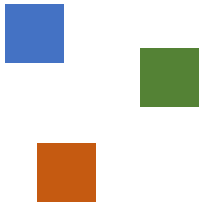

versus

Feature-based theory

"*resource models*"

(Alvarez and Cavanagh, 2004;
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Luck, S. J., & Vogel, E. K. (1997). https://doi.org/10.1038/36846
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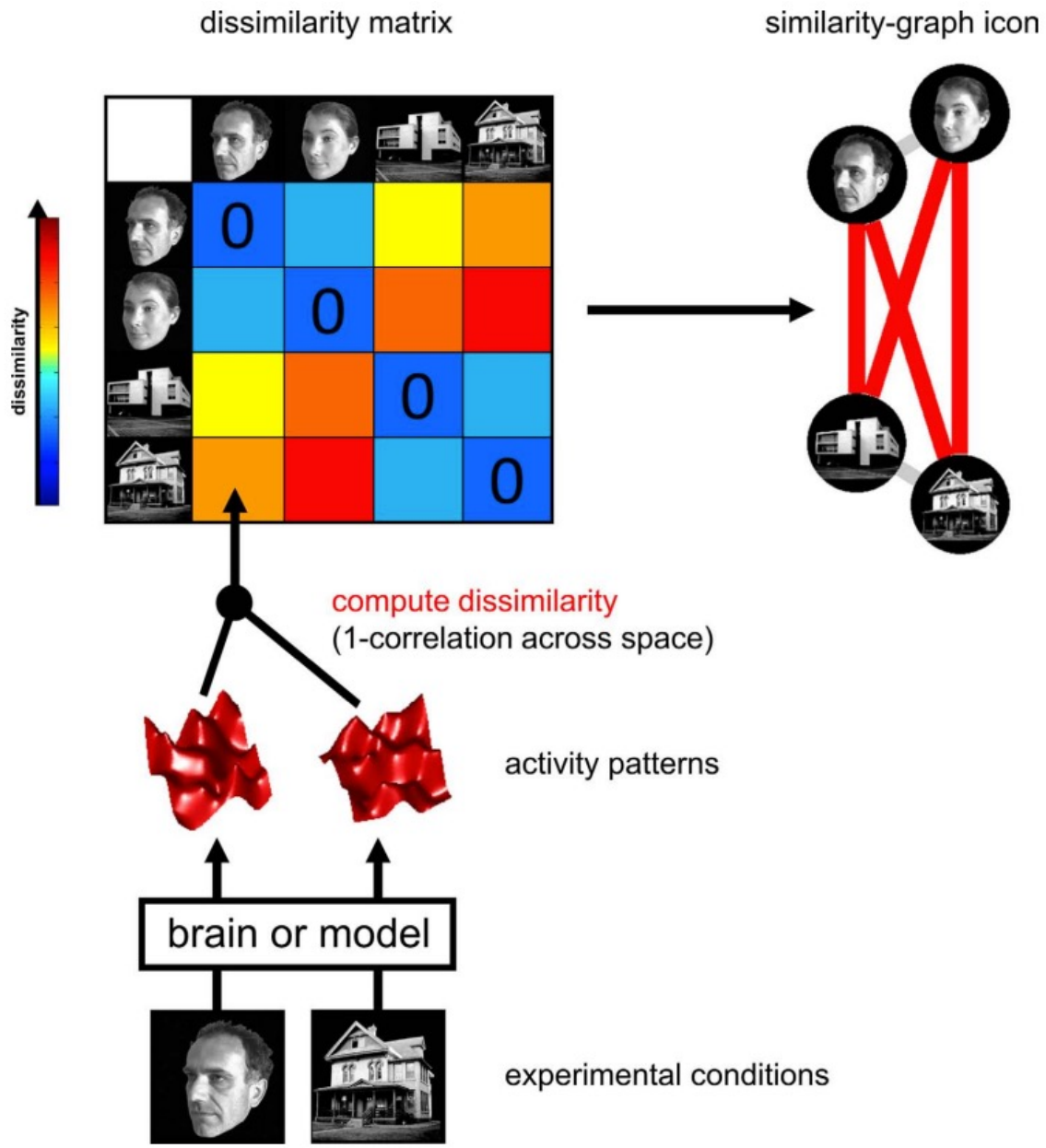
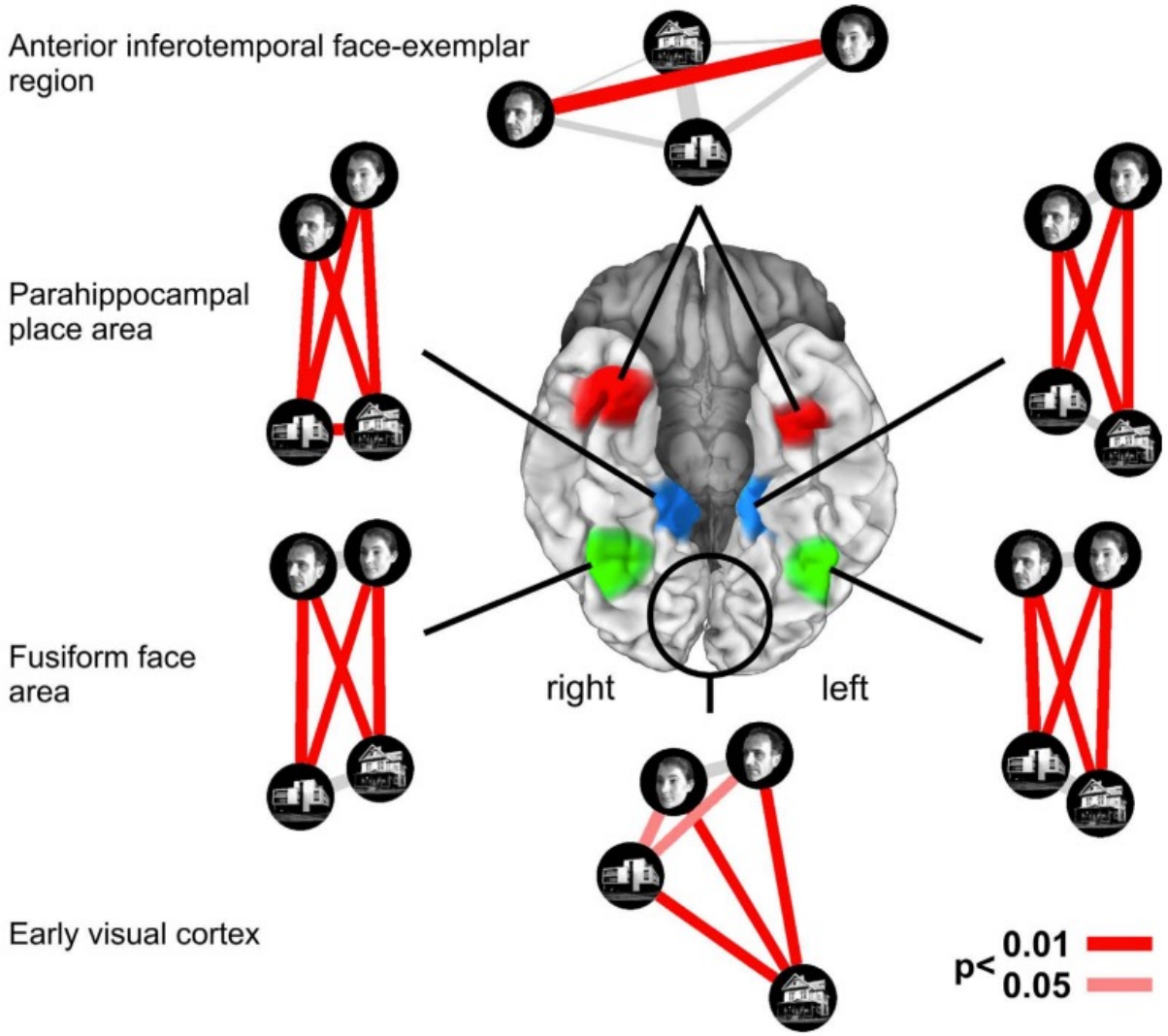
Wilken, P., & Ma, W. J. (2004). https://doi.org/10.1167/4.12.11

A brief overview of multivariate decoding



Kriegeskorte, N., Mur, M., & Bandettini, P. A. (2008). Representational similarity analysis-connecting the branches of systems neuroscience. *Frontiers in systems neuroscience*, *2*, 249.



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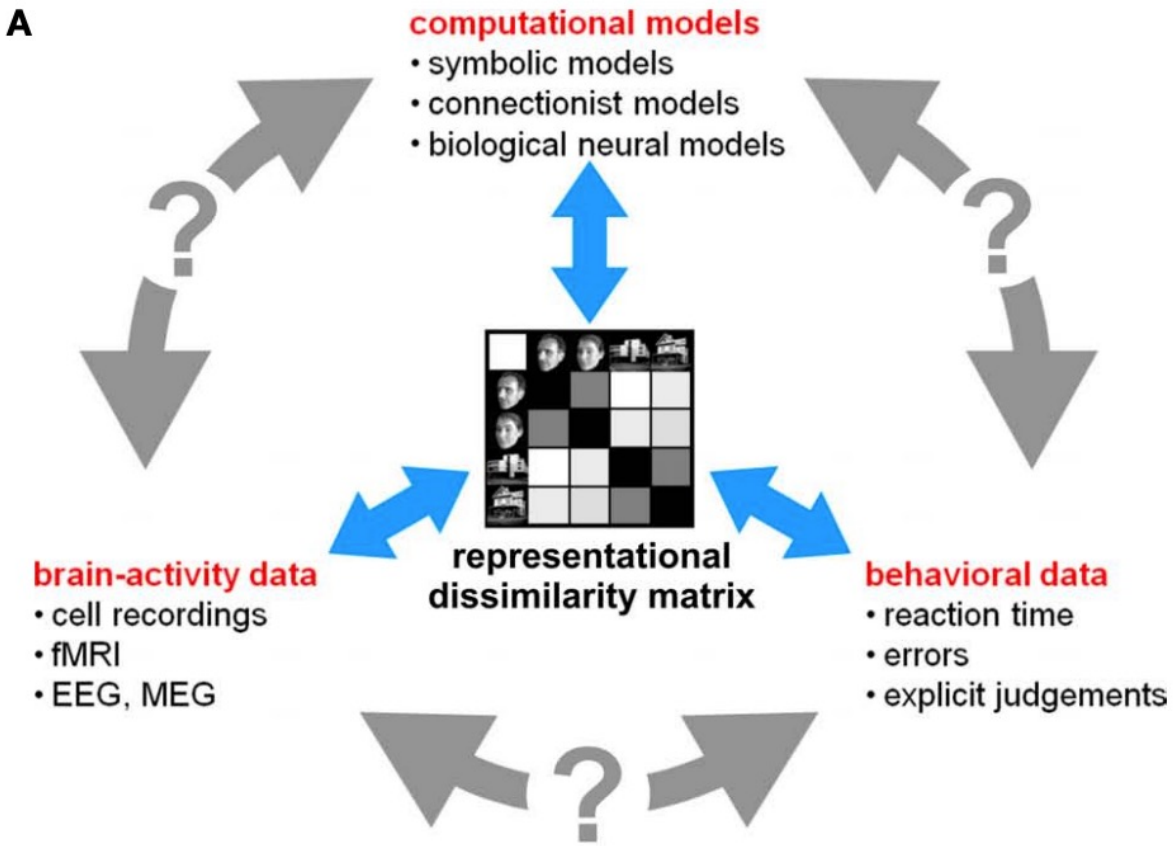
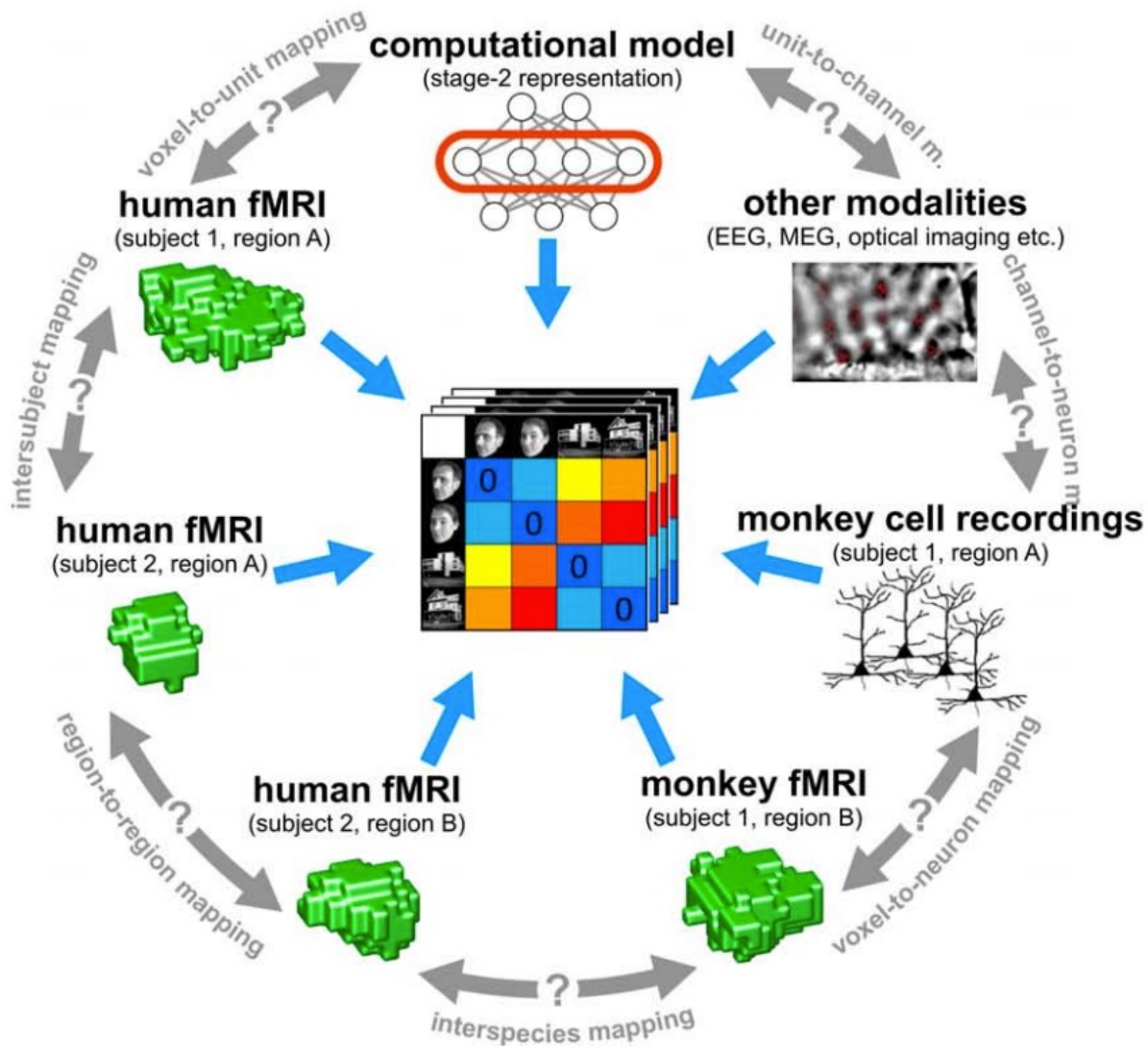
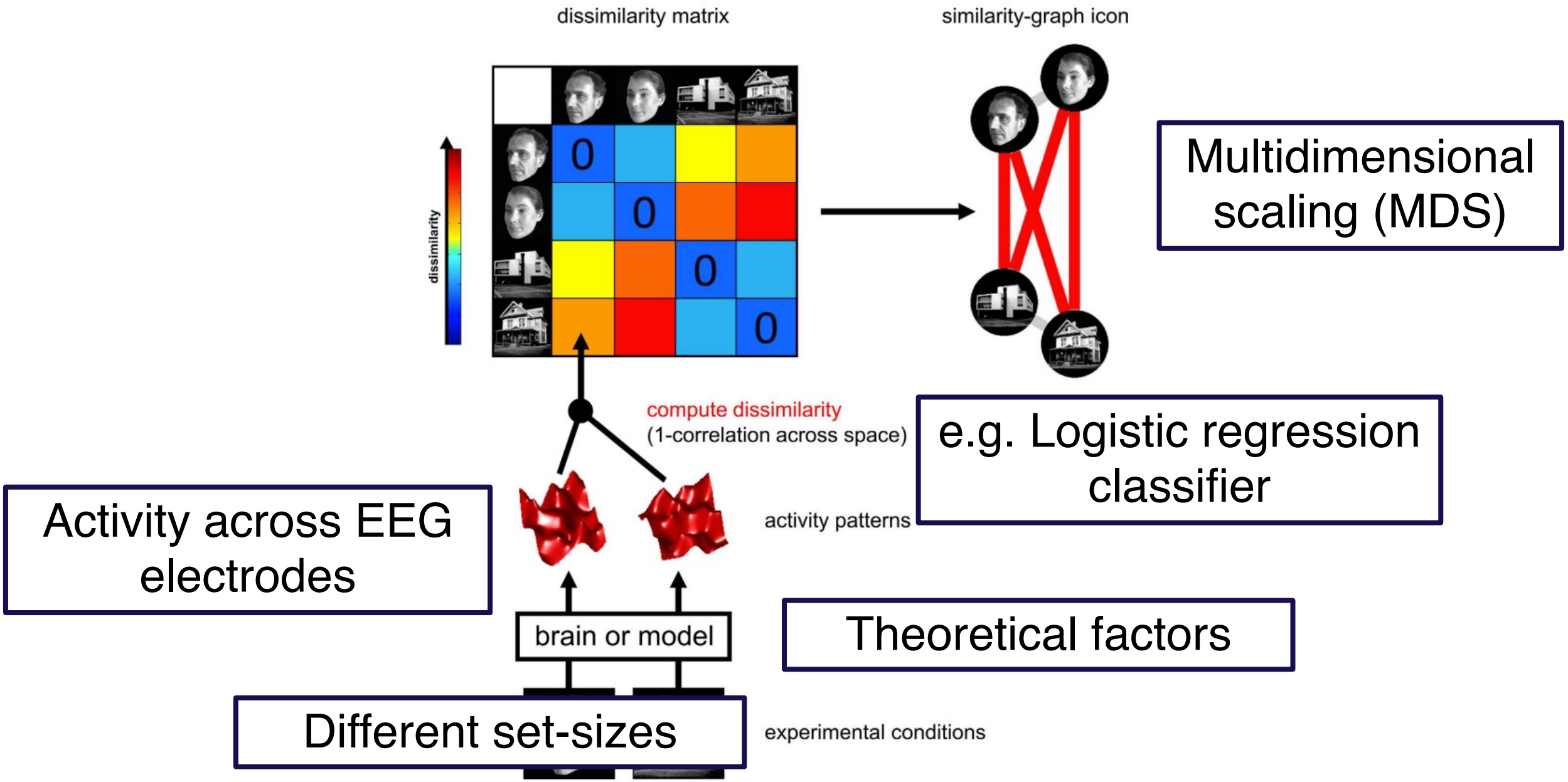
A


computational models
• symbolic models
• connectionist models
• biological neural models
representational dissimilarity matrix
brain-activity data
• cell recordings
• fMRI
• EEG, MEG
behavioral data
• reaction time
• errors
• explicit judgements

B


computational model
(stage-2 representation)
voxel-to-unit mapping
unit-to-channel m.
human fMRI
(subject 1, region A)
other modalities
(EEG, MEG, optical imaging etc.)
intersubject mapping
channel-to-neuron m.
human fMRI
(subject 2, region A)
monkey cell recordings
(subject 1, region A)
region-to-region mapping
human fMRI
(subject 2, region B)
monkey fMRI
(subject 1, region B)
voxel-to-neuron mapping
interspecies mapping



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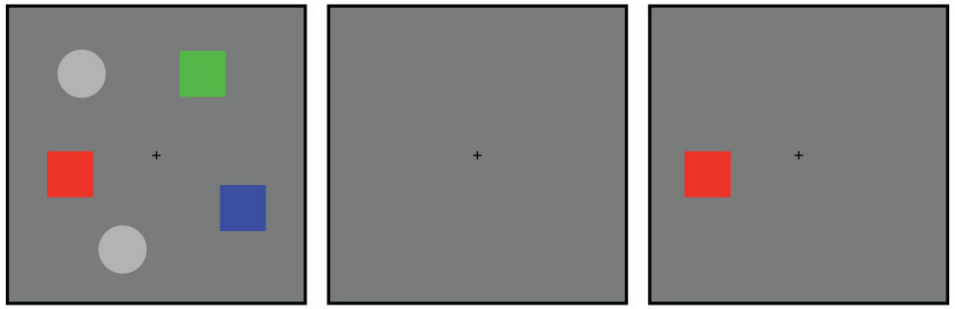
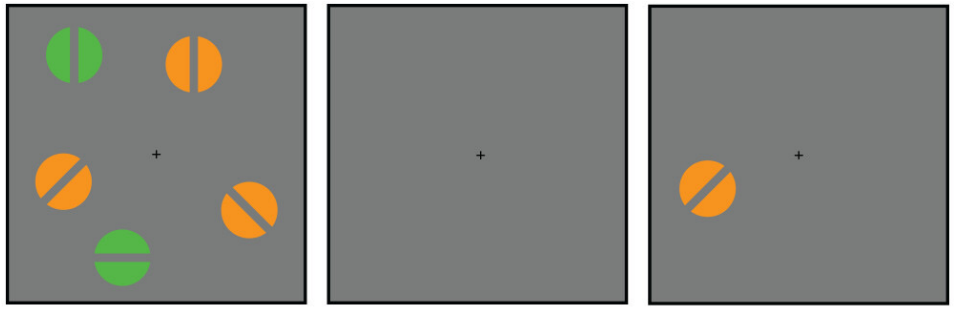
Multivariate classification of working memory

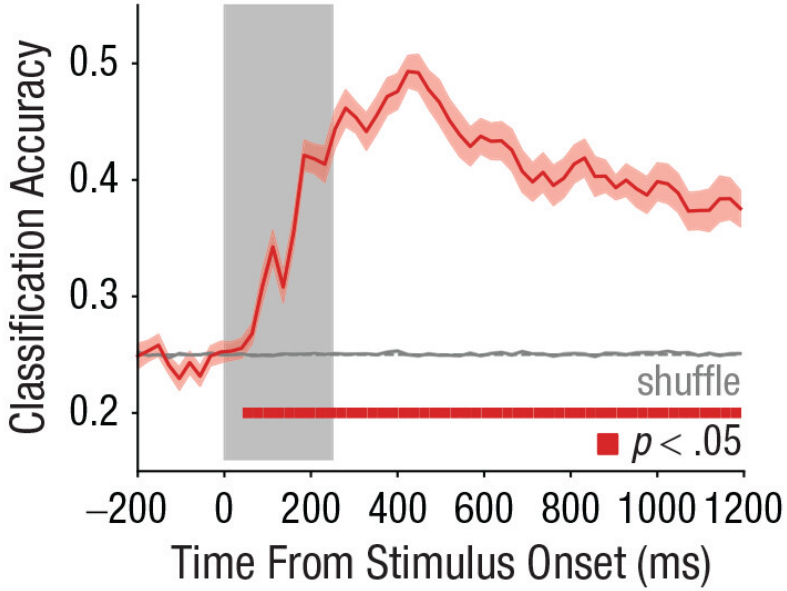
Experiment 1: Color



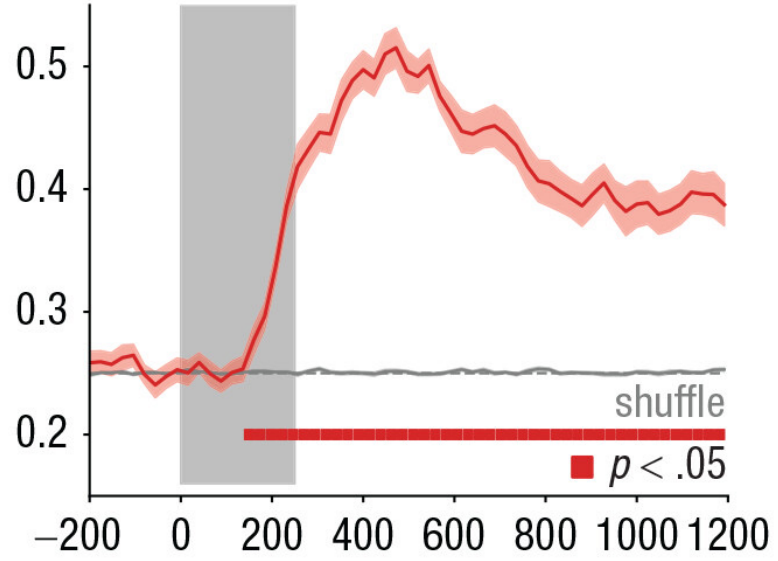
Experiment 2: Orientation

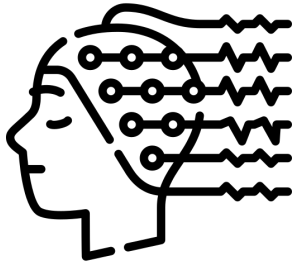


Train and test



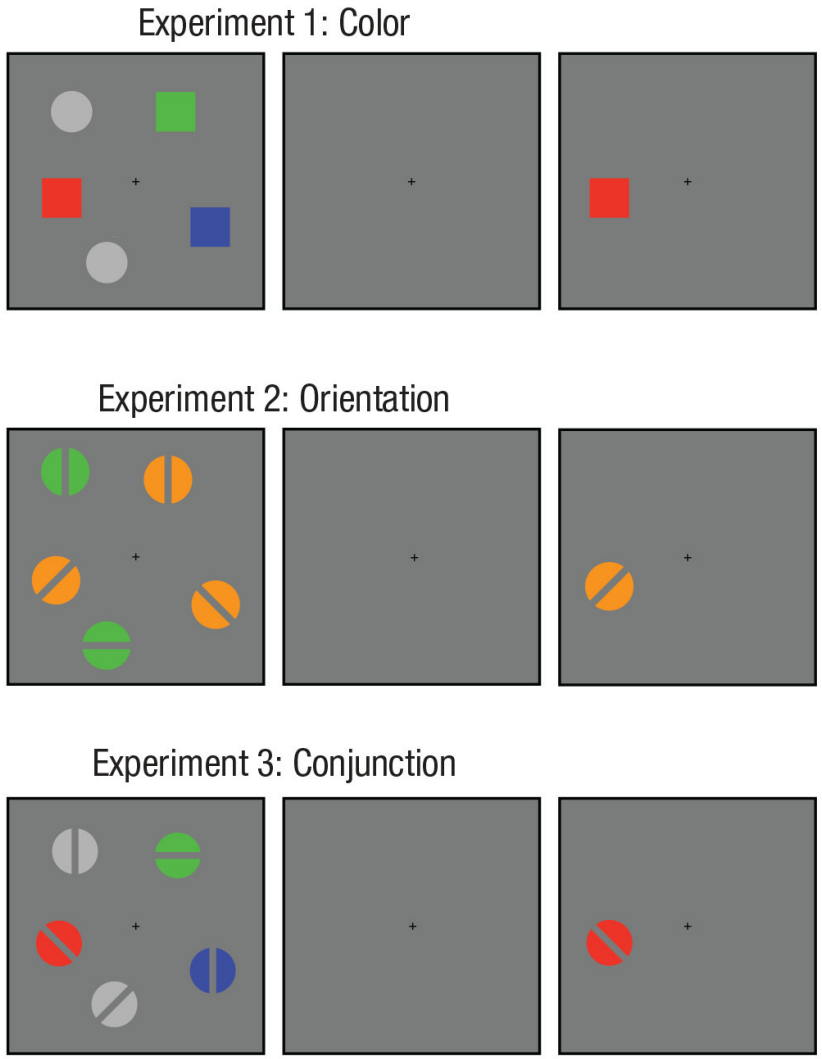
Train and test





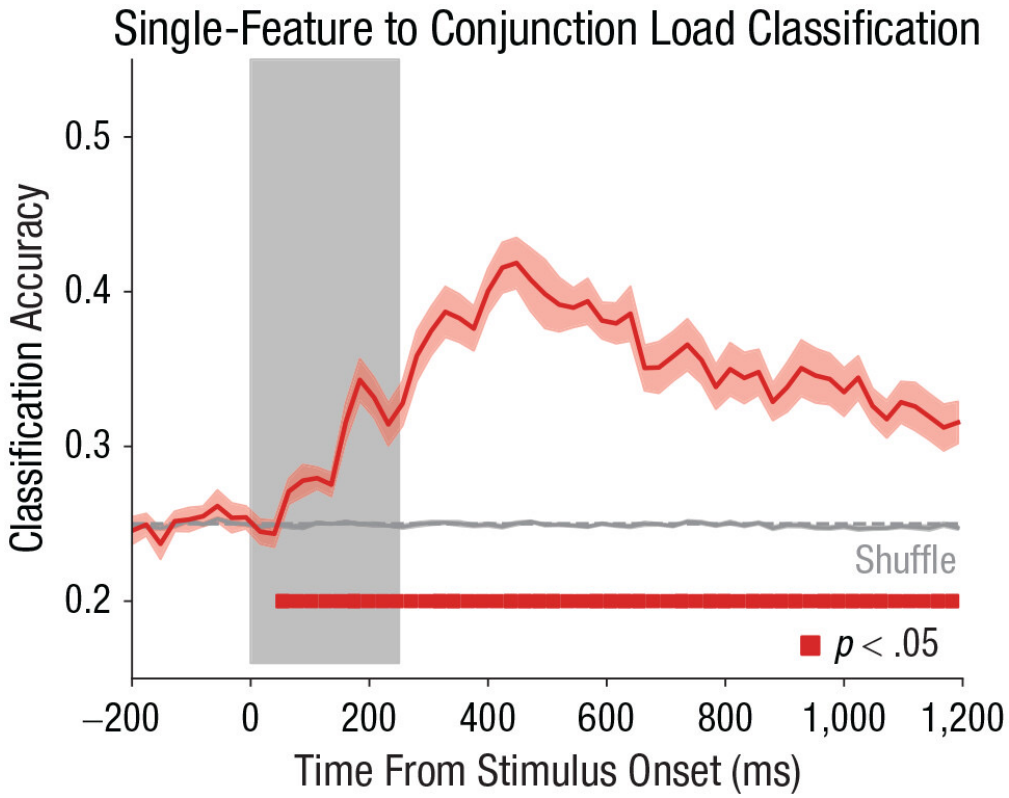
Thyer et al. (2022) *Psychological Science*

Multivariate classification of working memory



Train

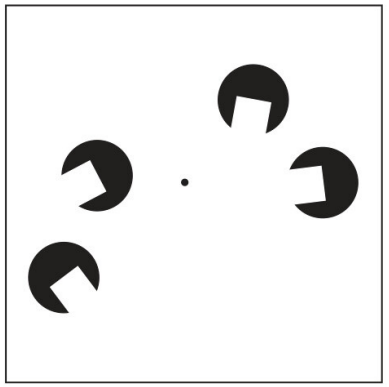
Test



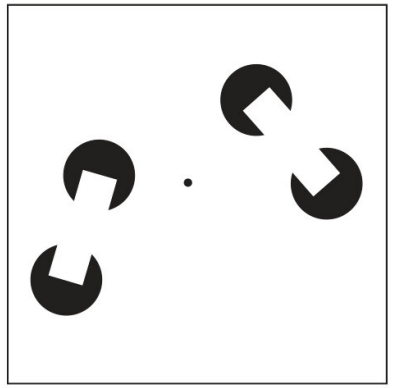
Thyer et al. (2022) *Psychological Science*

Multivariate classification of working memory

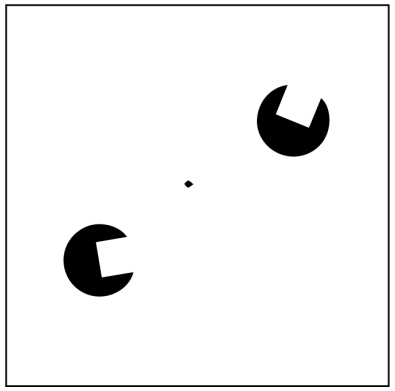
4 Ungrouped

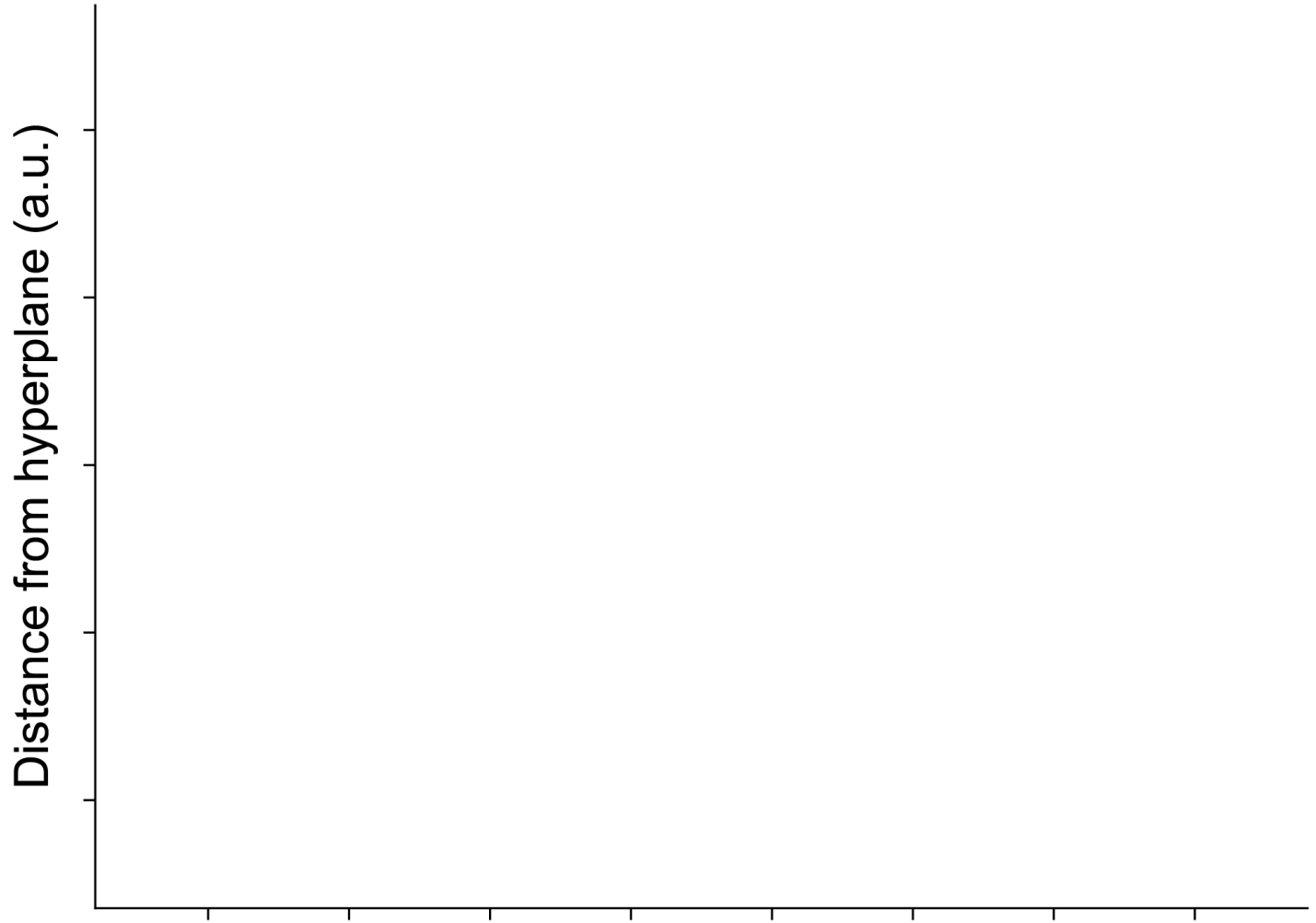


4 Grouped



2 Ungrouped





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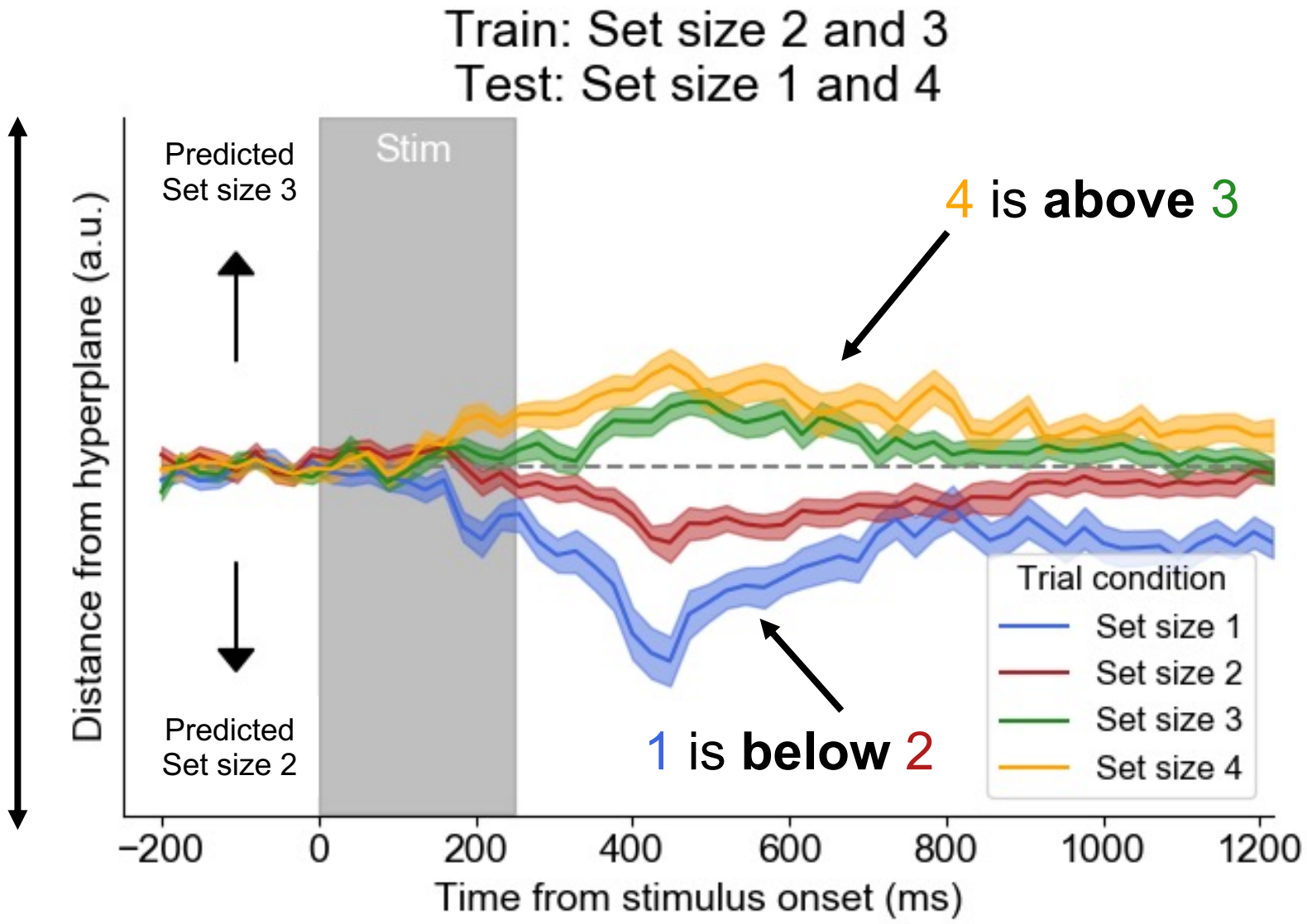
Multivariate classification of working memory

Working memory load signal



Remembering moving objects

Piotr Styrkowiec*

Will Epstein

Ron Gneezy

Edward Awh

Edward Vogel

What *is* visual working memory?

- An enduring theoretical framework has been

Object-based theory

"slot models"

(Luck and Vogel, 1997;
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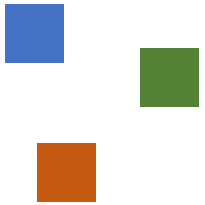

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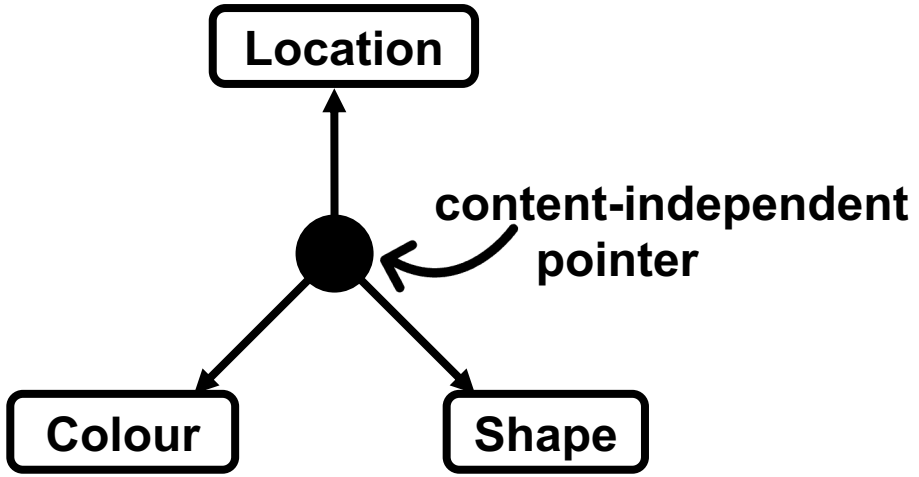
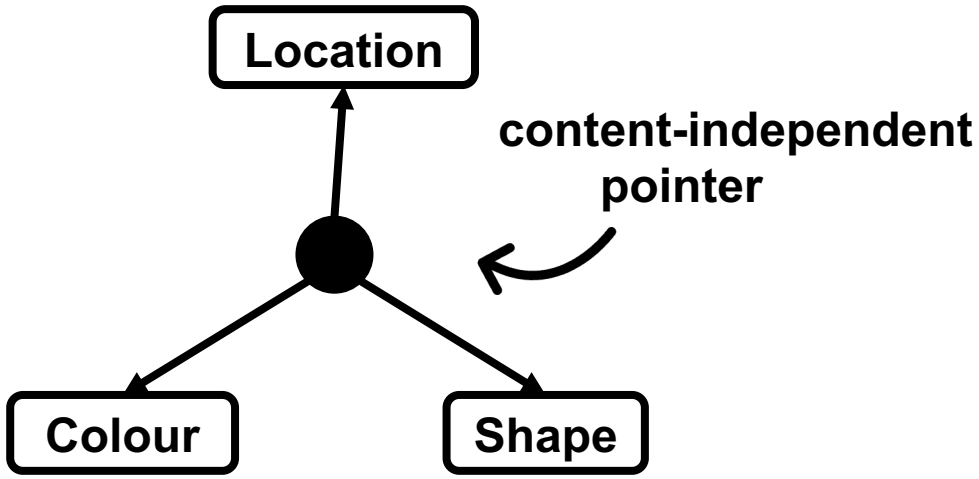
Pointers in working memory

- Pylyshyn (2009) proposed the visual system has an indexing mechanism that keeps track of an individual object through its changes
  - This index is ***abstracted*** from the contents of the object

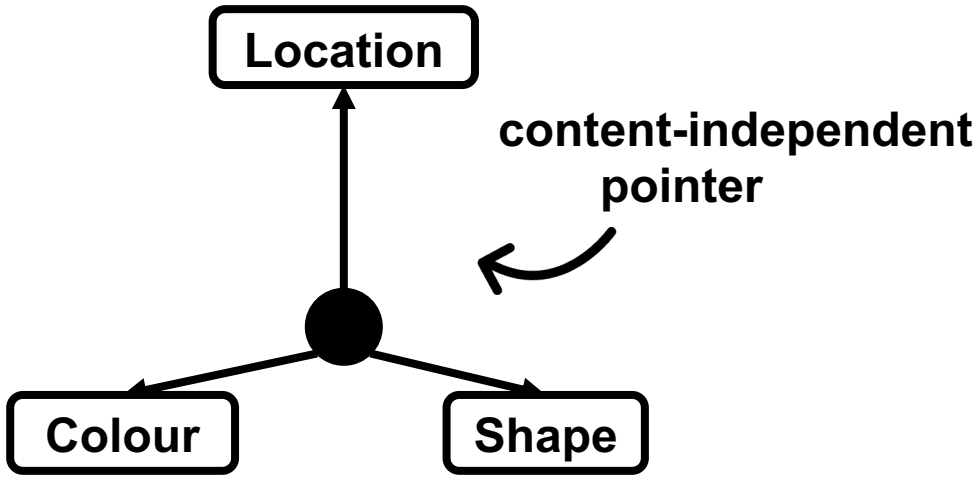
- We propose that items in working memory are assigned to a content-independent pointer



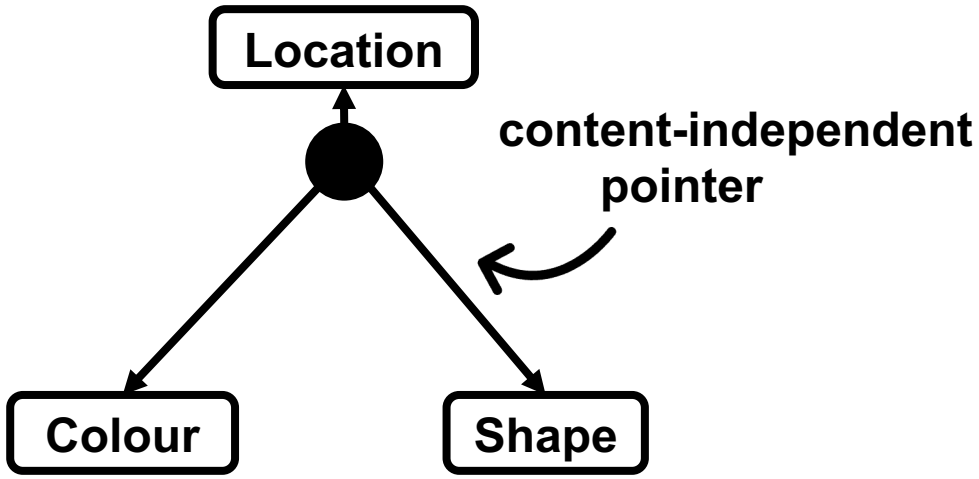
Pointers and tracking objects



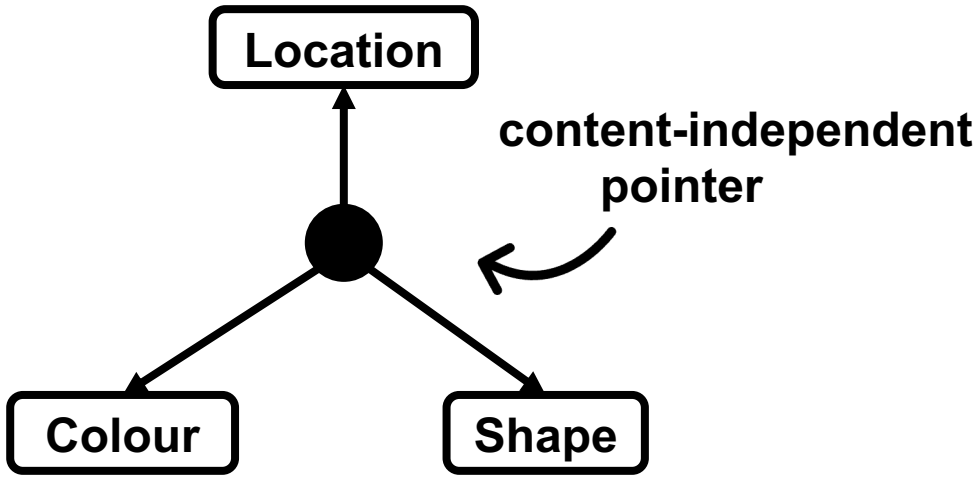
Pointers and tracking objects



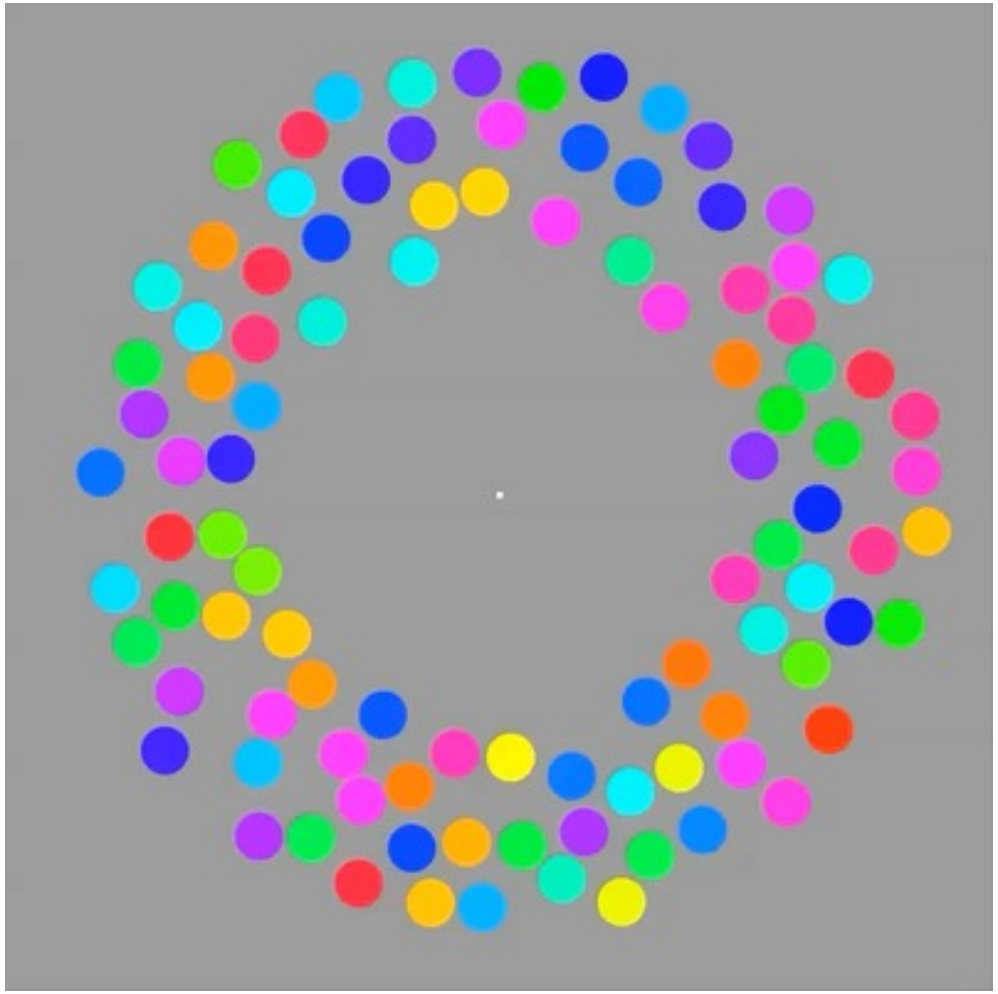
Pointers and tracking objects

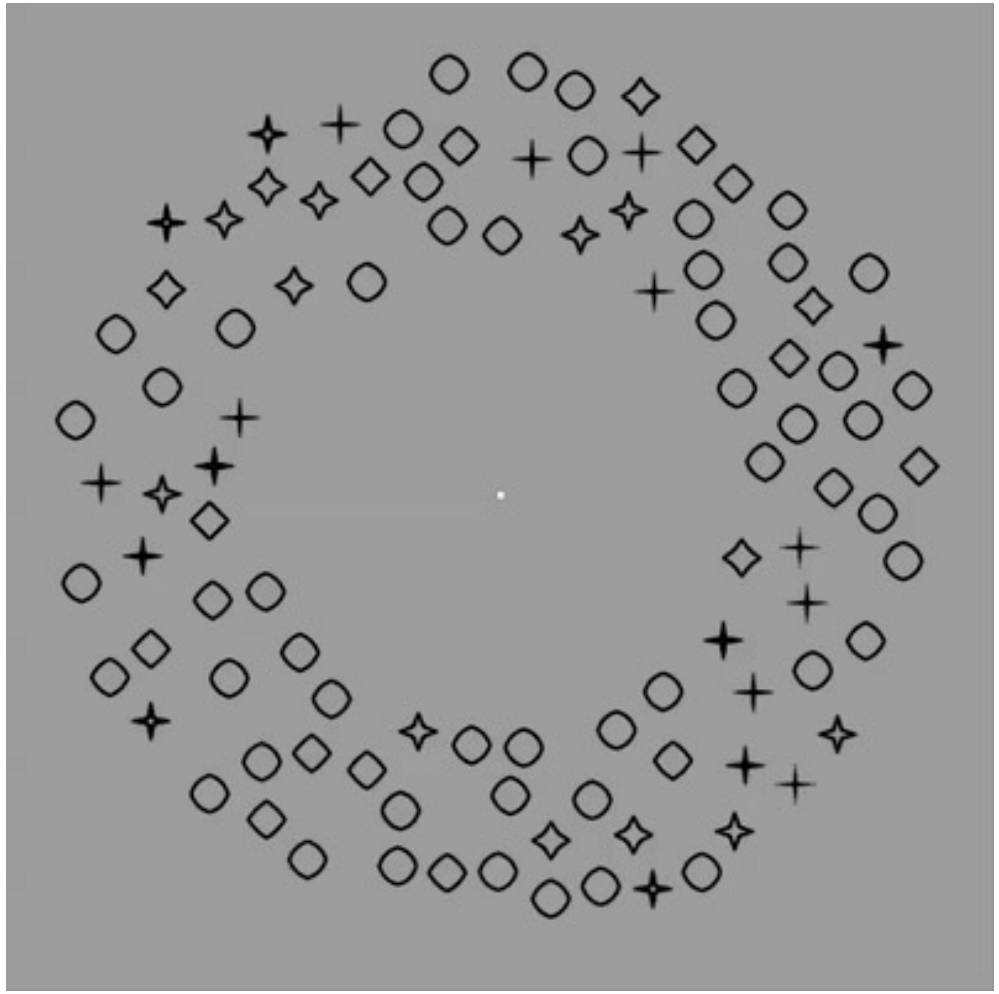


Pointers and tracking objects



Motion silencing

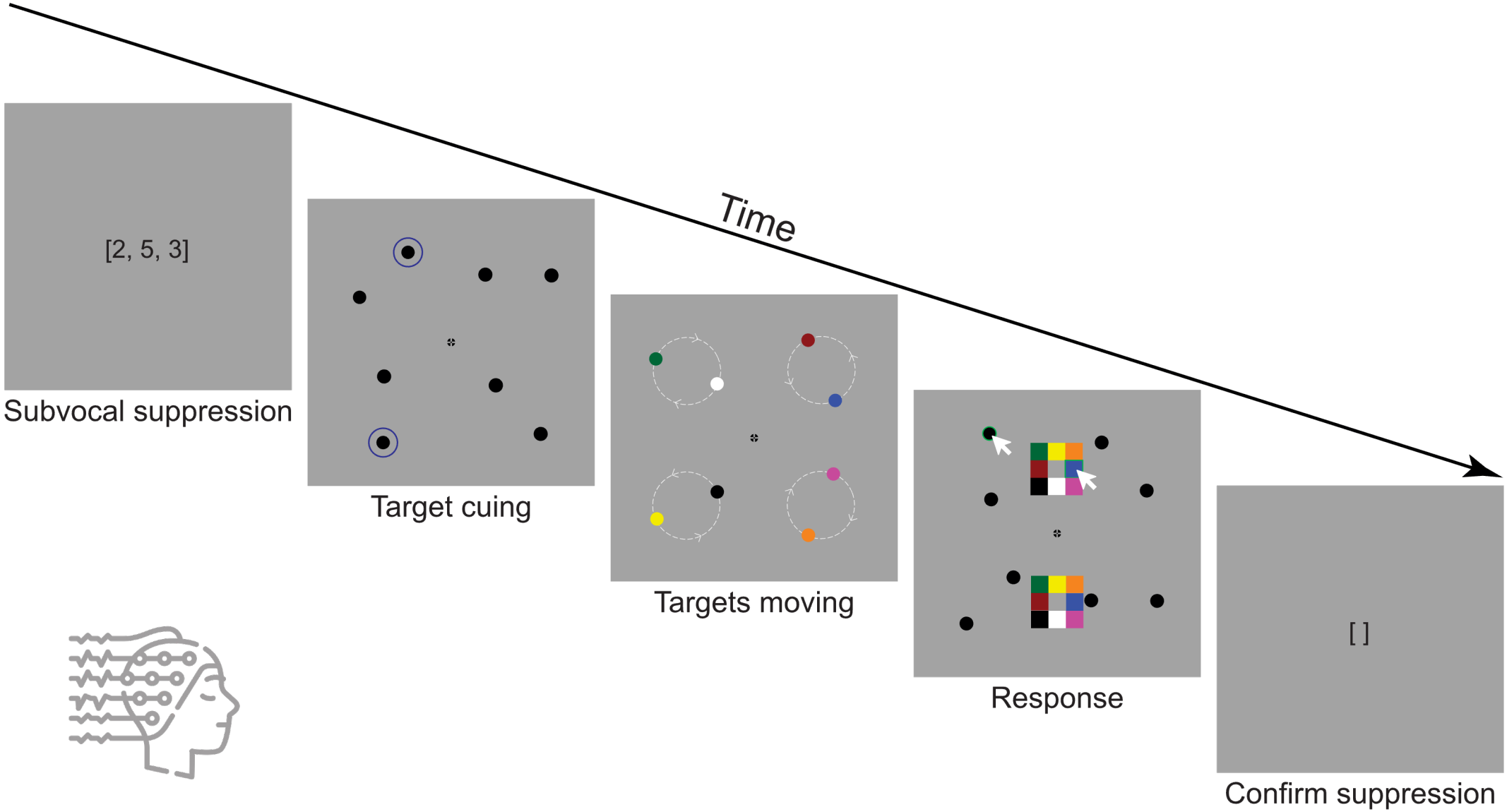




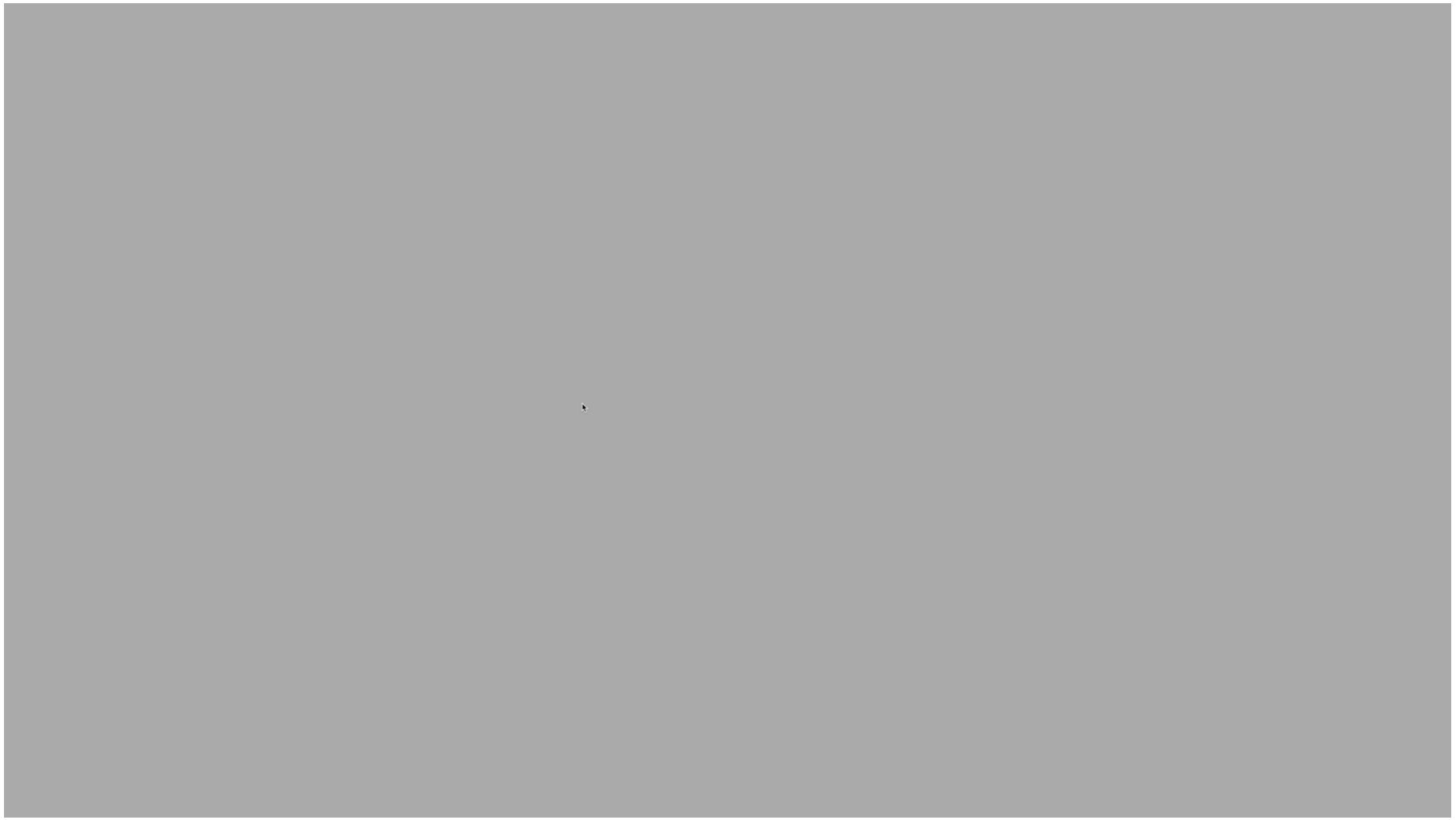
Video from Jordan Suchow's YouTube channel: https://www.youtube.com/watch?v=-KhPYdge9RU

Suchow, J. W., & Alvarez, G. A. (2011). Motion silences awareness of visual change. *Current Biology*, *21*(2), 140-143.

Method


Time
[2, 5, 3]
Subvocal suppression
Target cuing
Targets moving
Response
[ ]
Confirm suppression

Method



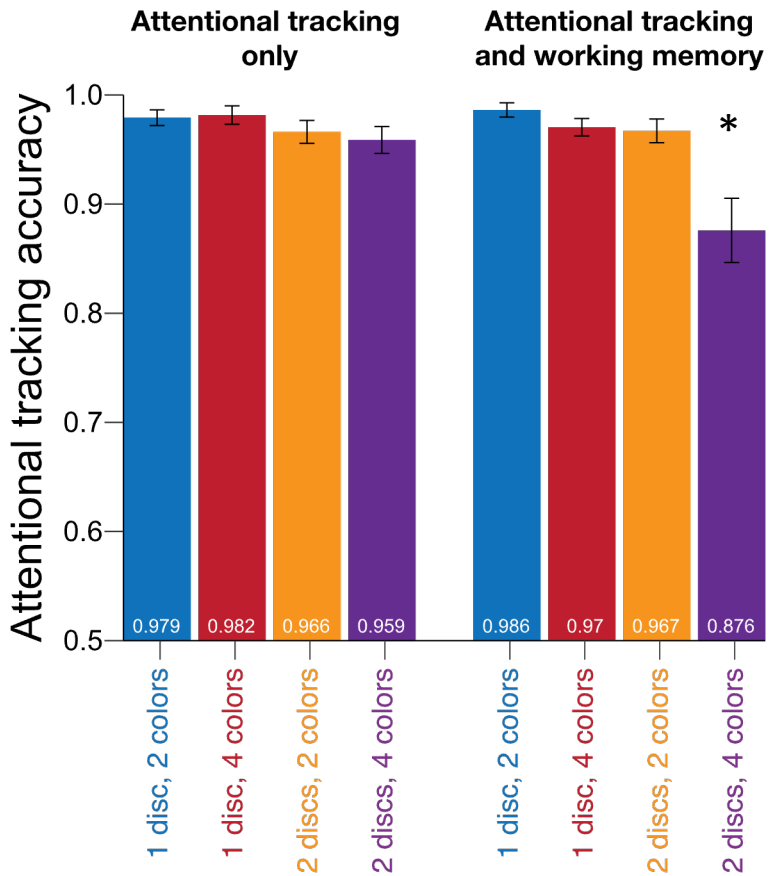
Attentional tracking only
[track discs, ignore colors]
1 disc, 2 colors
1 disc, 4 colors
2 discs, 2 colors
2 discs, 4 colors

Attentional tracking and working memory
[track discs and remember colors]
1 disc, 2 colors
1 disc, 4 colors
2 discs, 2 colors
2 discs, 4 colors

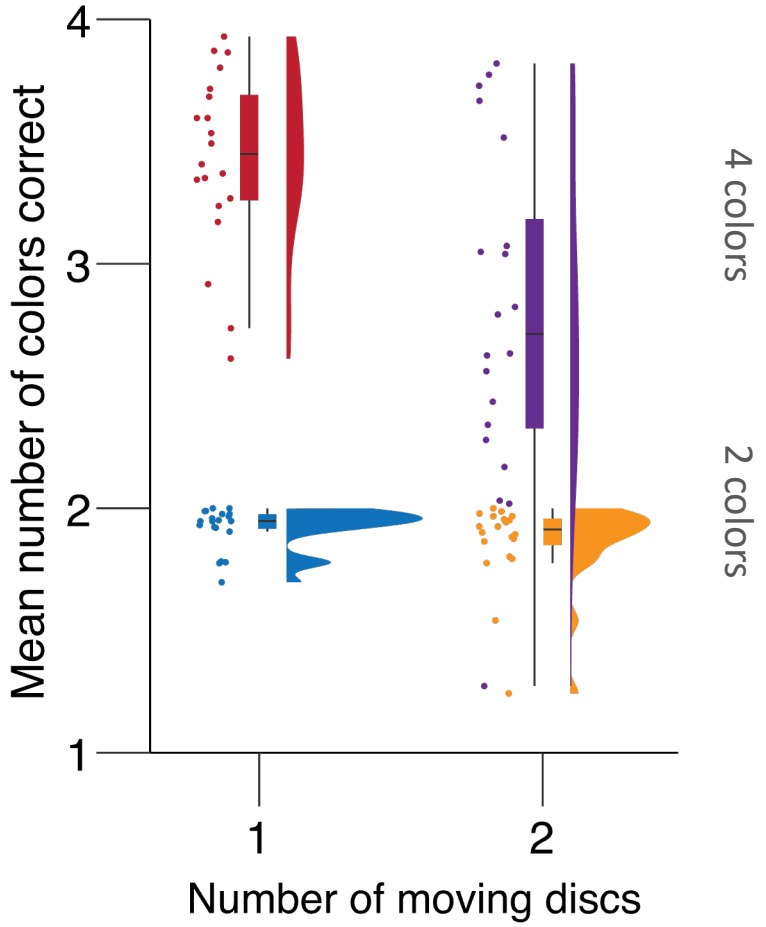
96 trials per condition
16 blocks
20 participants

Behavioral results

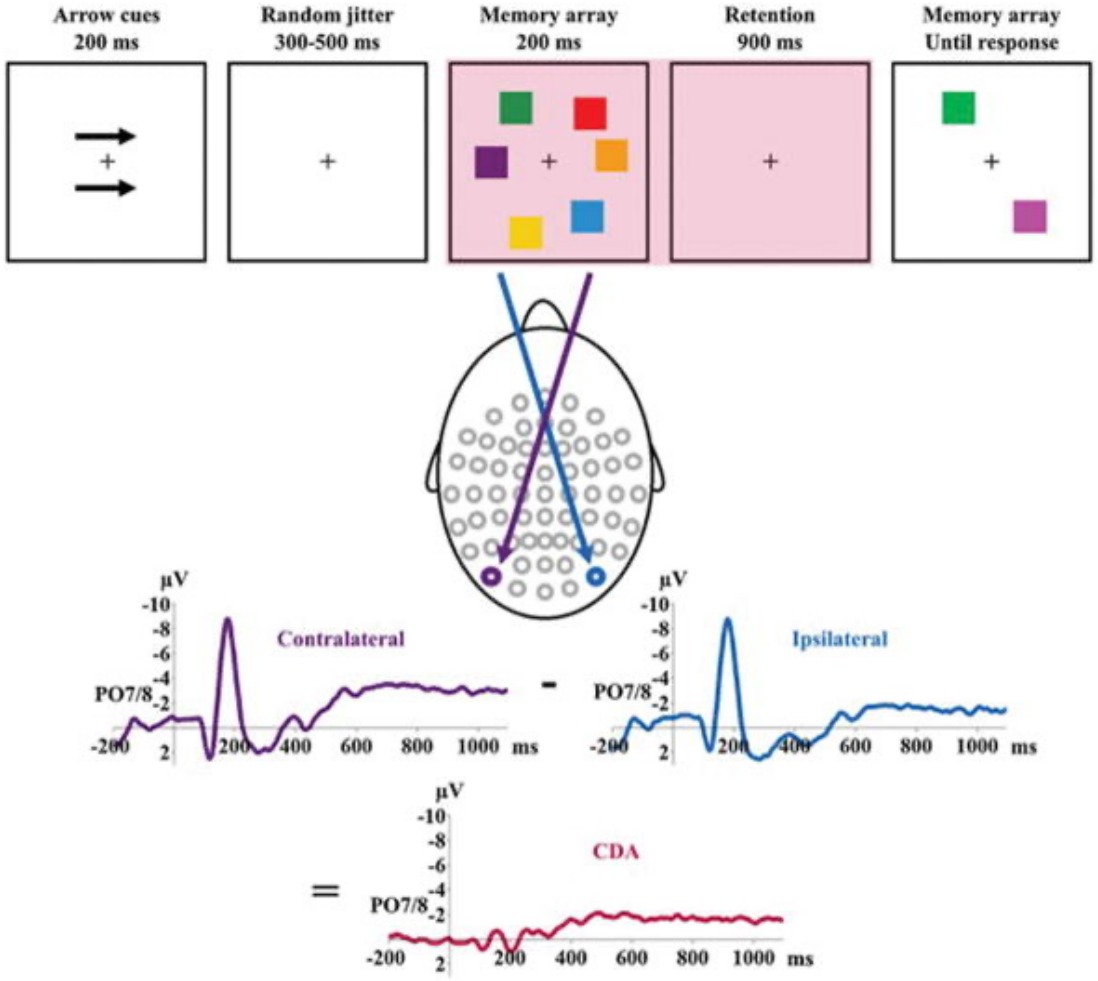
Attentional tracking performance

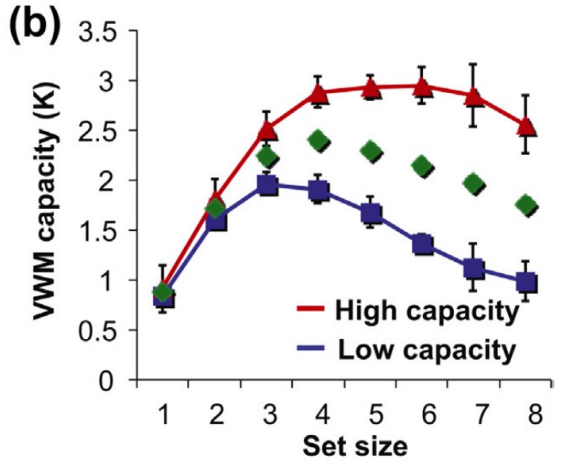


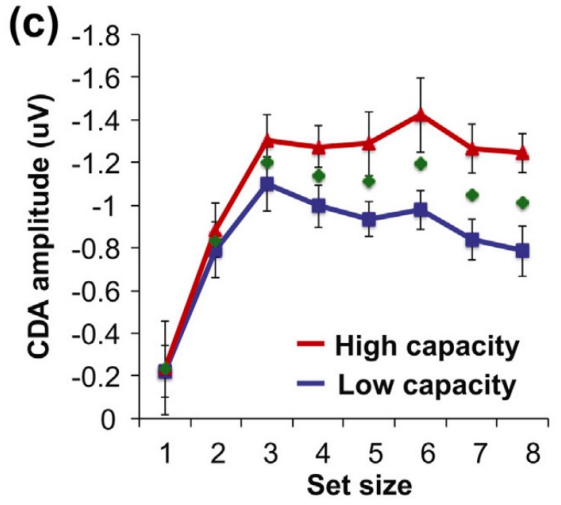
Working memory performance (number of colors correct)



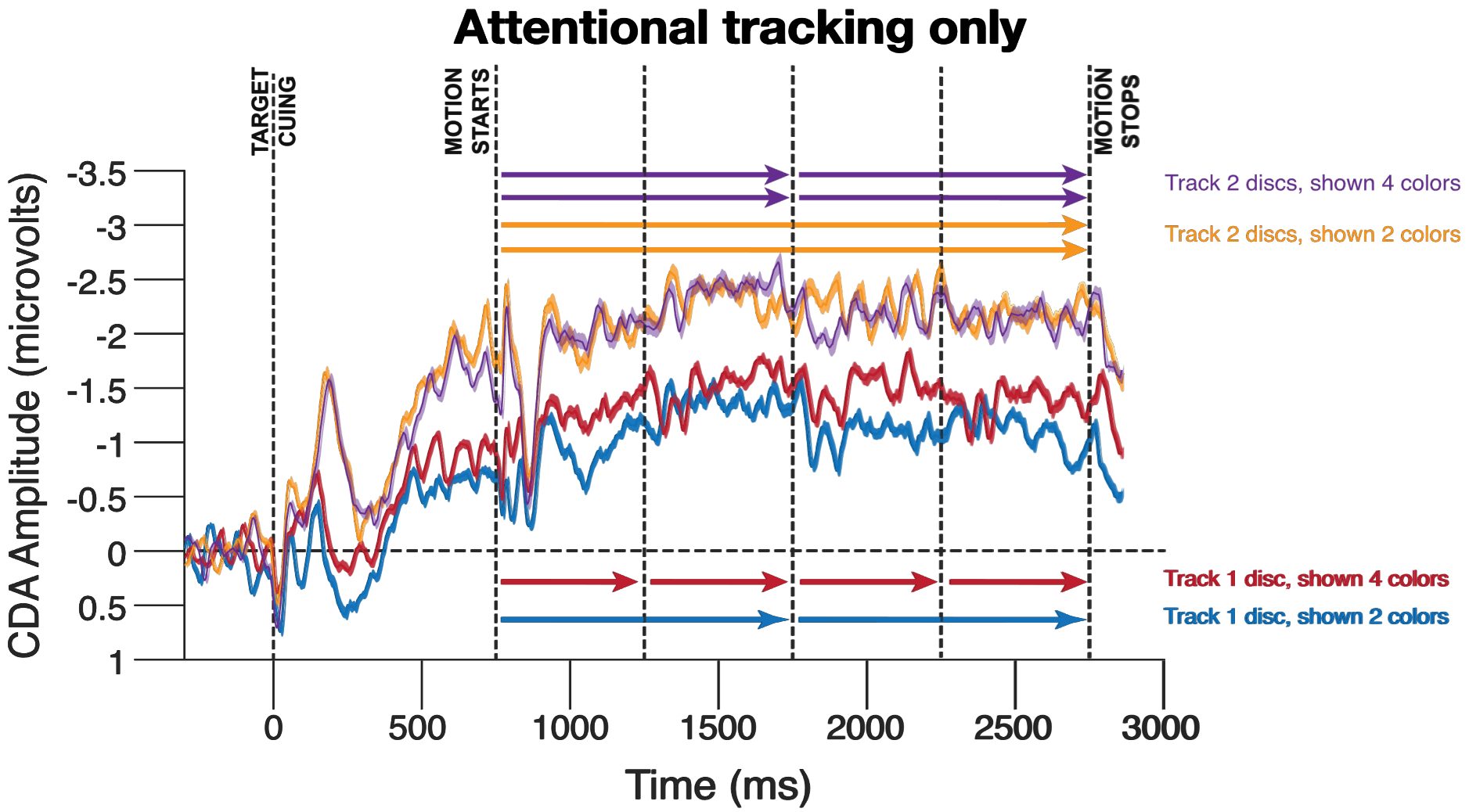
Univariate measure – the event-related potential





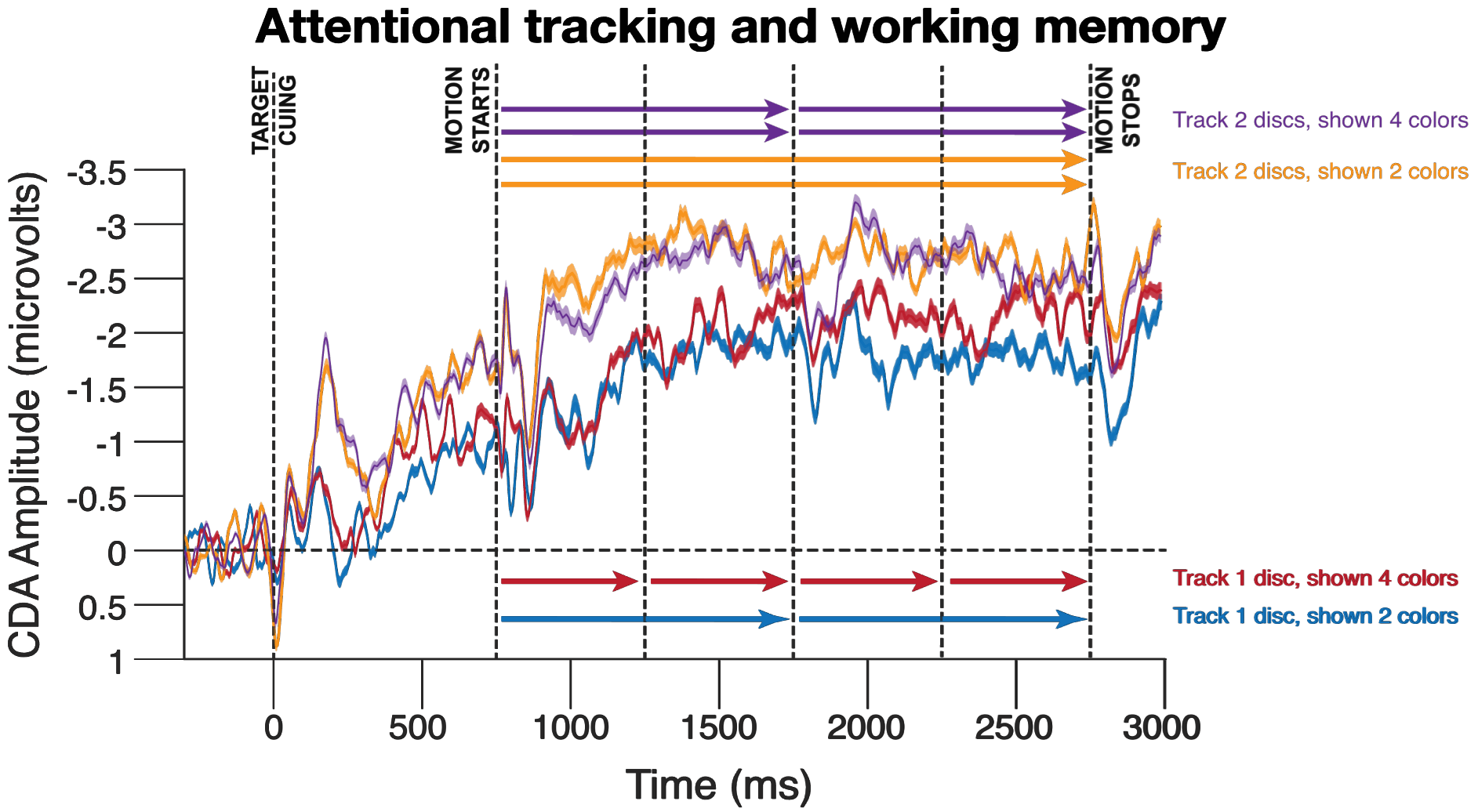


Event-related potential – the contralateral delay activity



CDA was calculated using the PO3/PO4, PO7/PO8, P3/P4, and P7/P8 electrode pairs

Event-related potential – the contralateral delay activity



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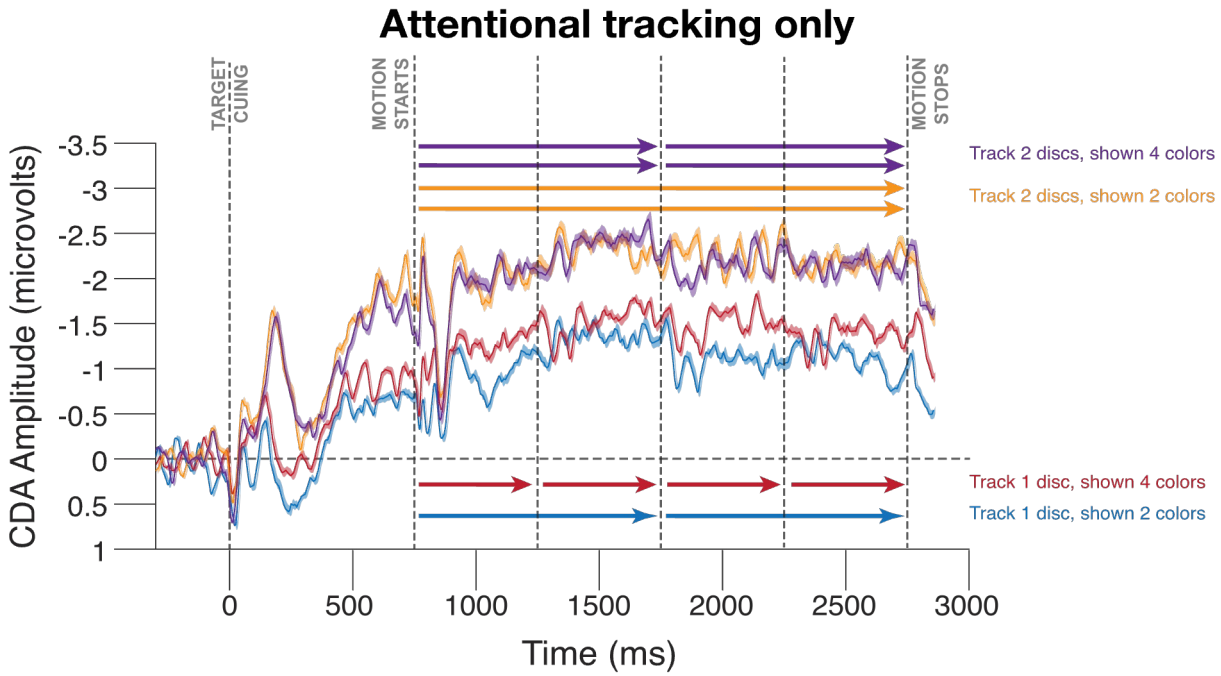
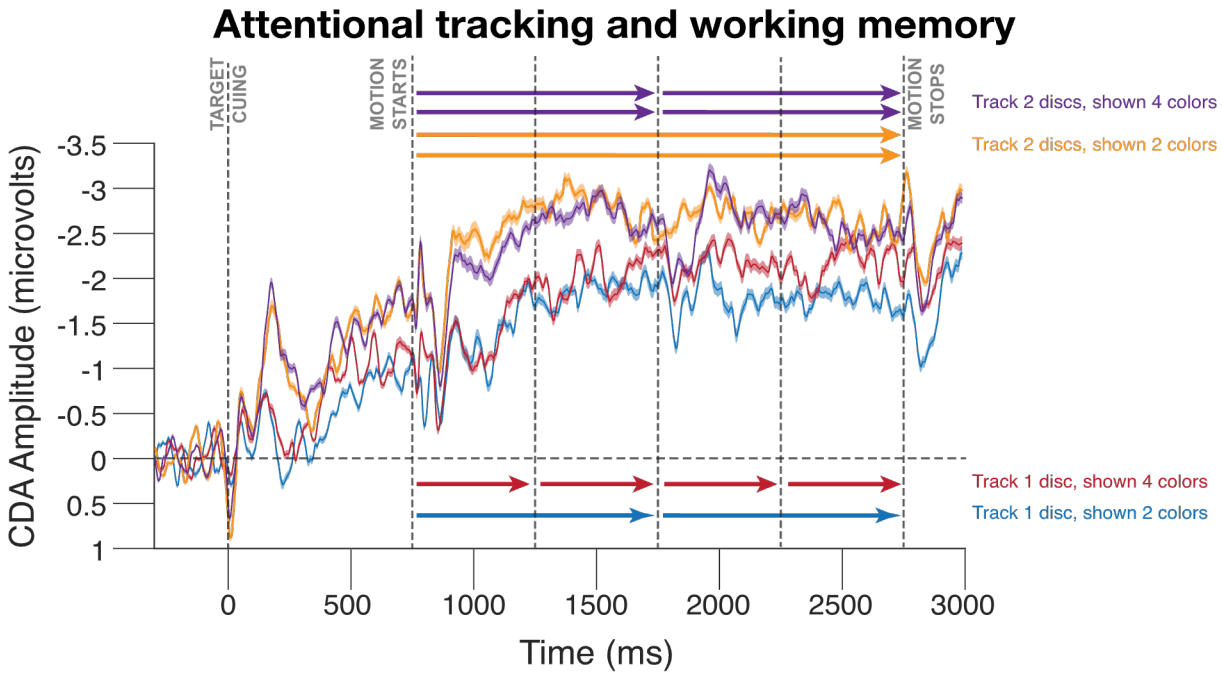
Event-related potential – the contralateral delay activity





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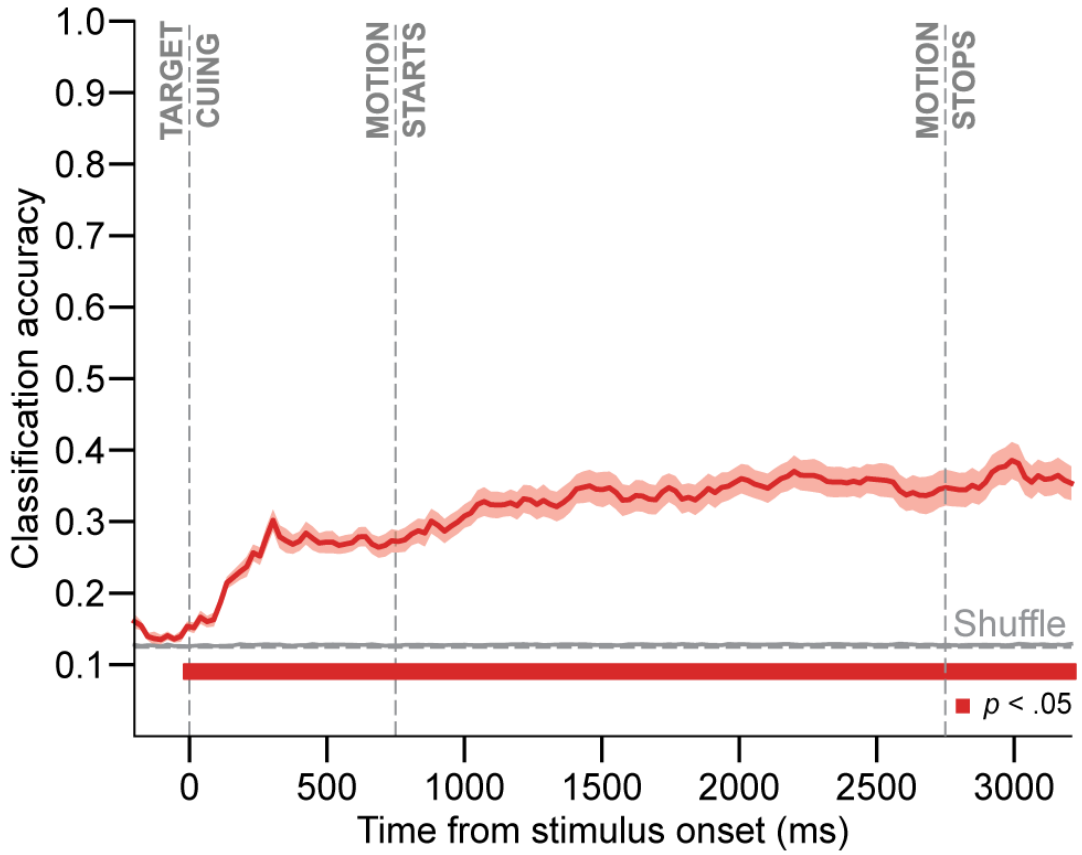
Multivariate classification

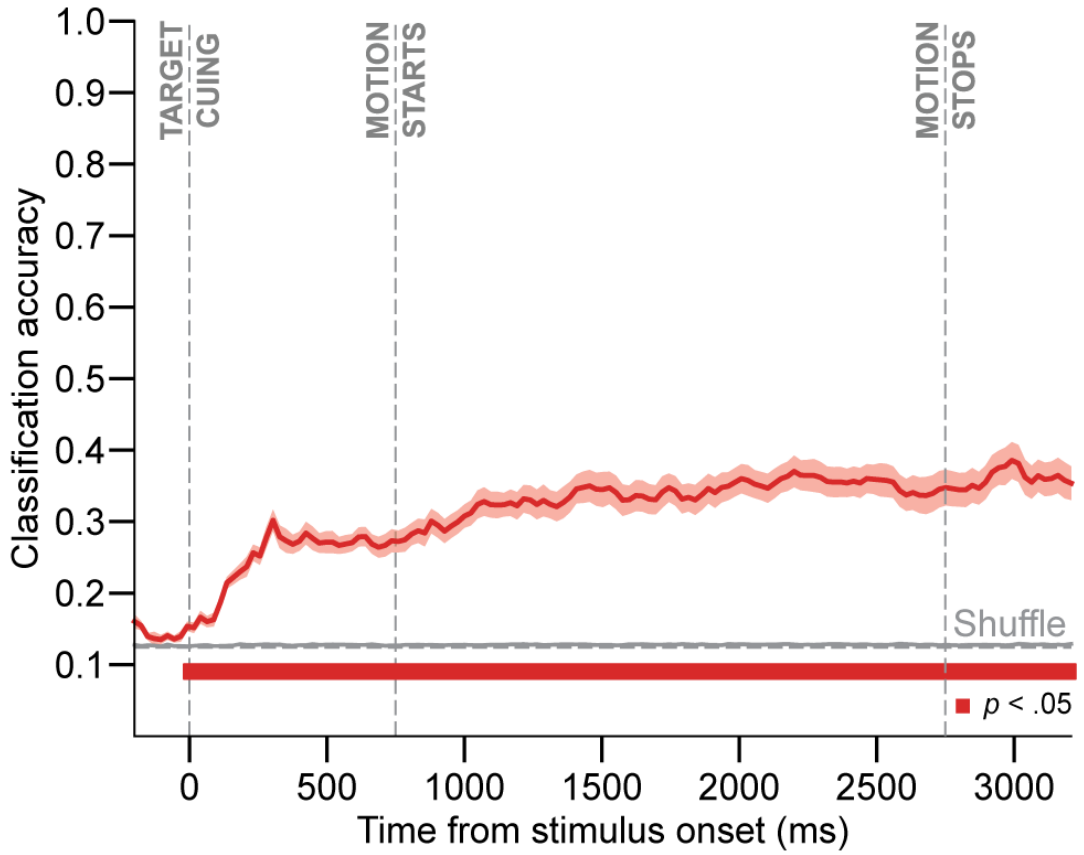
a)



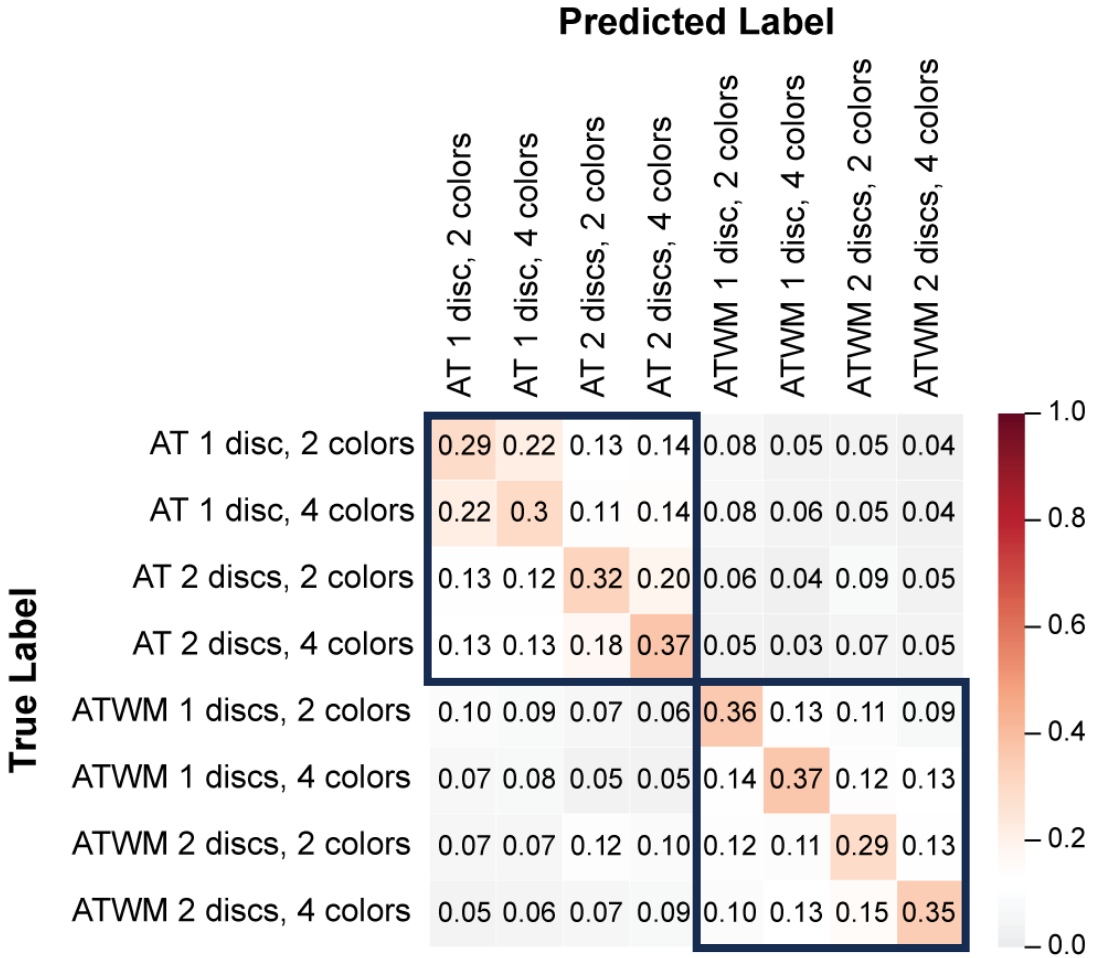
We can accurately decode the conditions!

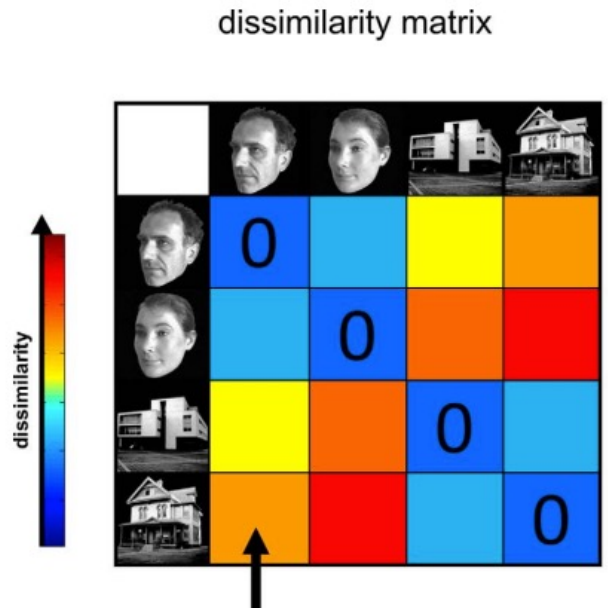
Multivariate classification

a)

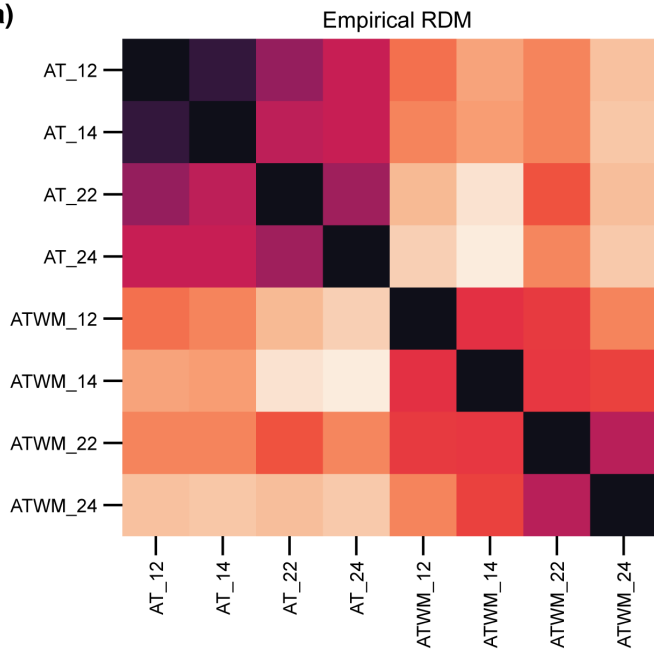


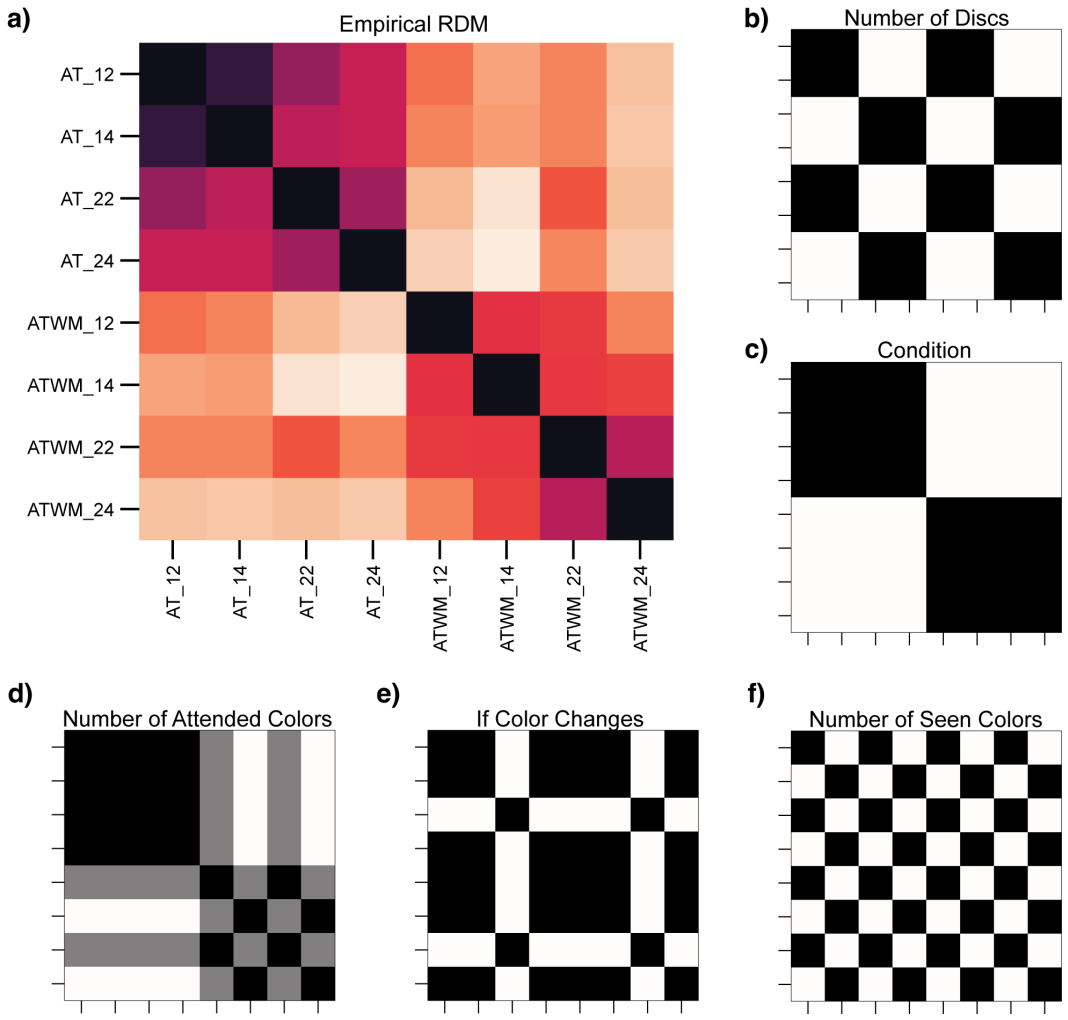
b)

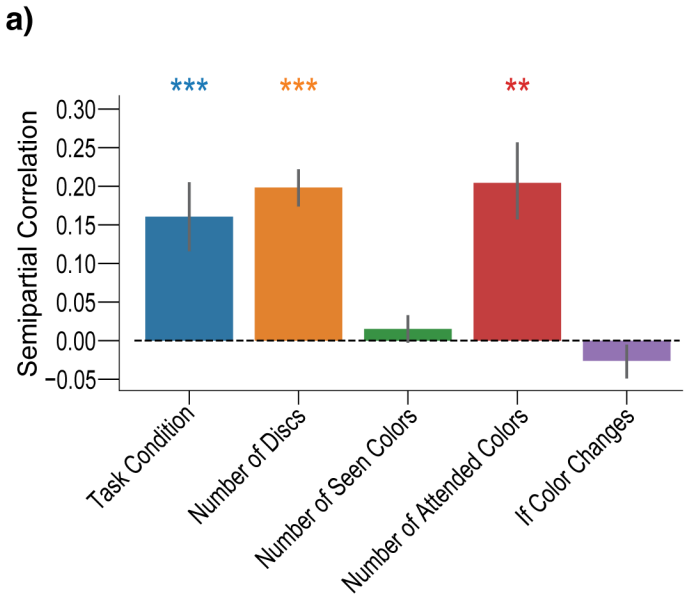


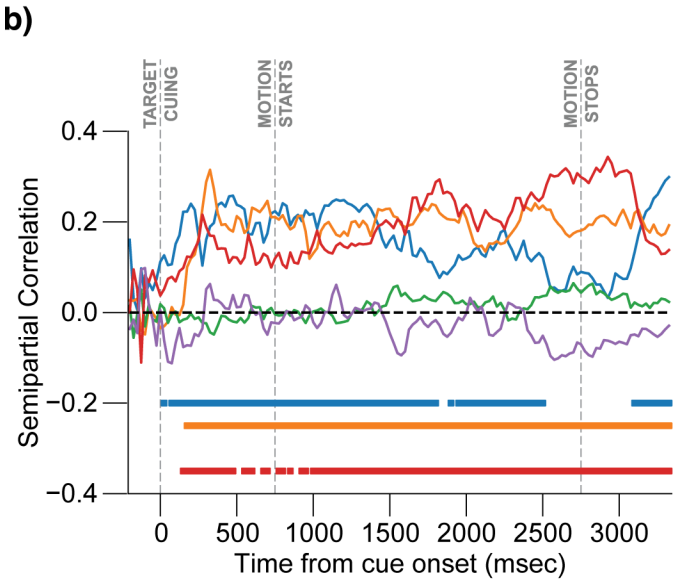

dissimilarity matrix
dissimilarity
0
0
0
0

a)

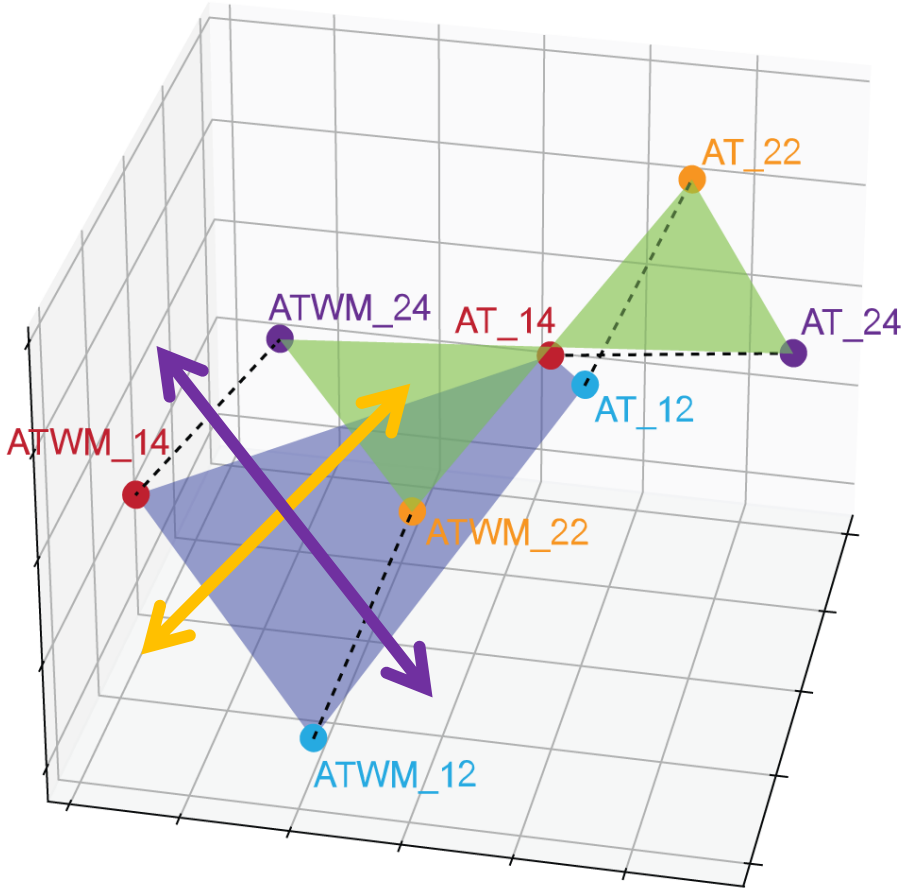

Empirical RDM
AT_12
AT_14
AT_22
AT_24
ATWM_12
ATWM_14
ATWM_22
ATWM_24


a)
Empirical RDM
AT_12
AT_14
AT_22
AT_24
ATWM_12
ATWM_14
ATWM_22
ATWM_24
b)
Number of Discs
c)
Condition
d)
Number of Attended Colors
e)
If Color Changes
f)
Number of Seen Colors

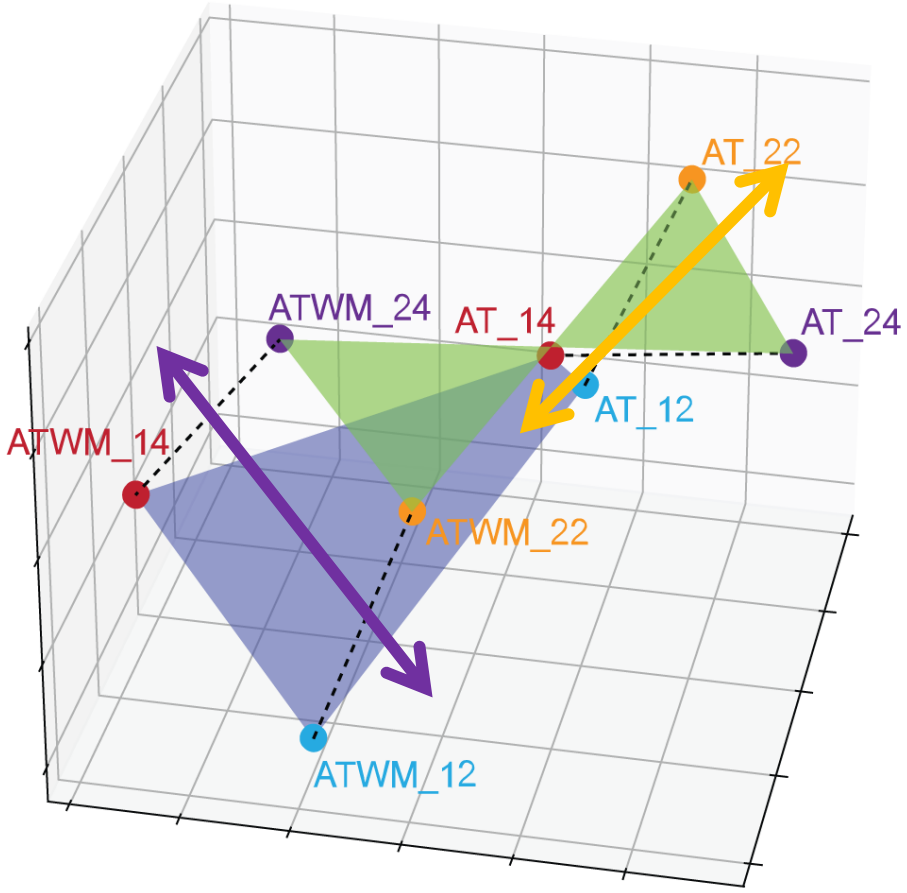

a)
***
***
**
Semipartial Correlation
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
Task Condition
Number of Discs
Number of Seen Colors
Number of Attended Colors
If Color Changes


b)
TARGET CUING
MOTION STARTS
MOTION STOPS
Semipartial Correlation
0.4
0.2
0.0
−0.2
−0.4
0
500
1000
1500
2000
2500
3000
Time from cue onset (msec)

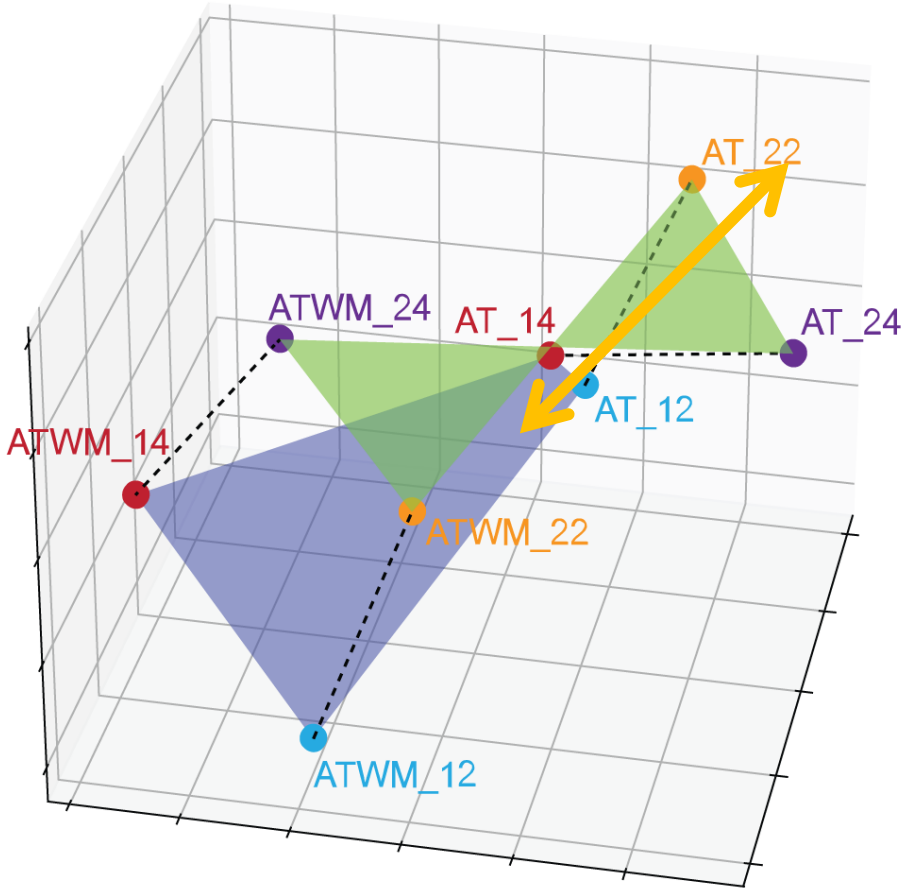
Conclusions



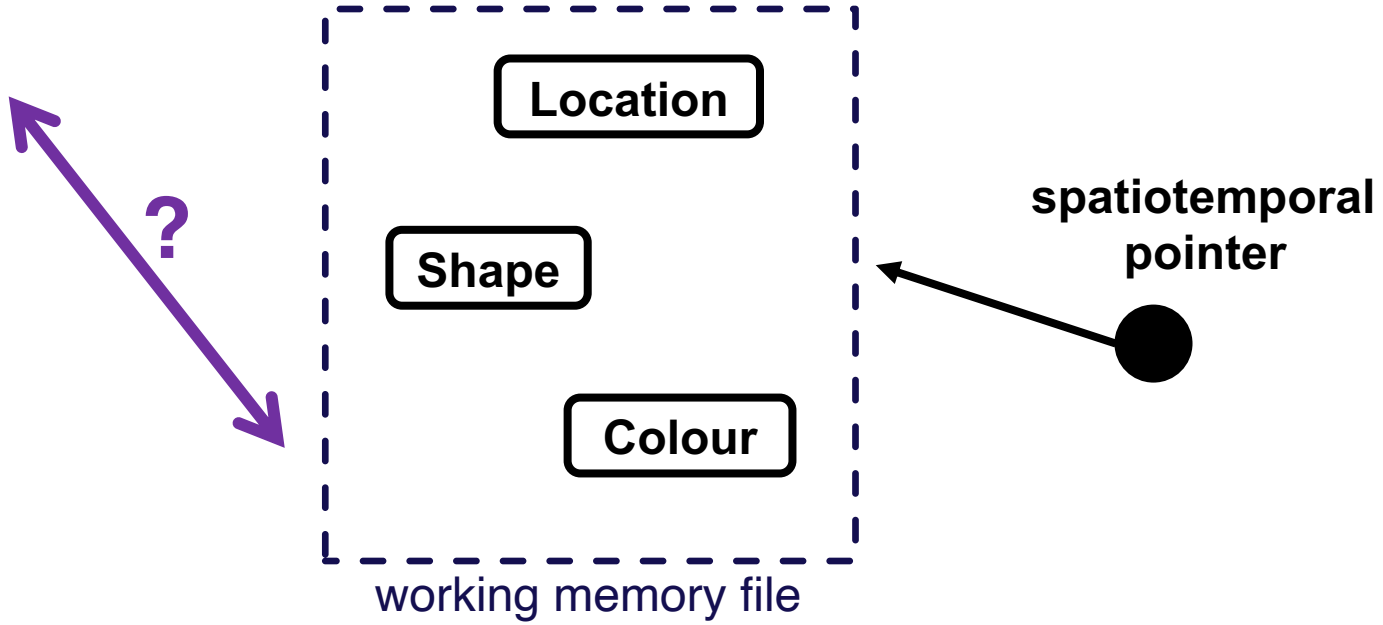
Conclusions



Conclusions



- Distinct neural signals for spatiotemporal attention (tracking) and working memory (remembering)
- Attending is not exactly remembering!



Does learning change working memory?

Will Epstein

Henry Jones

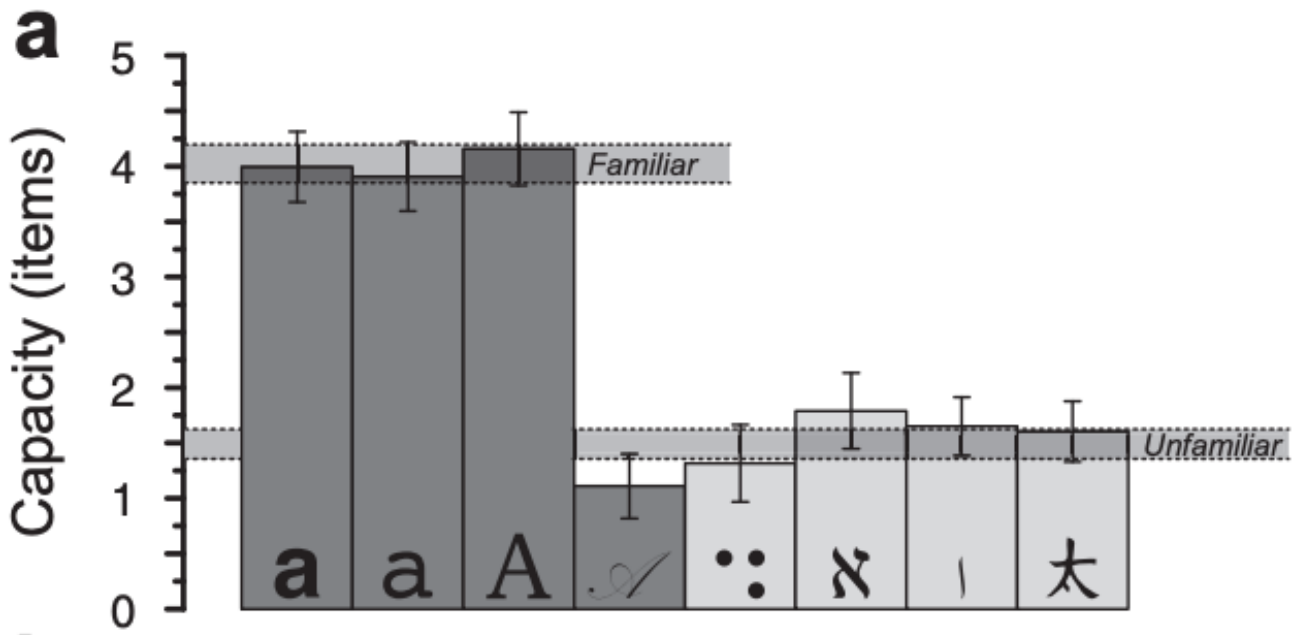
Darius Suplica

William Thyer

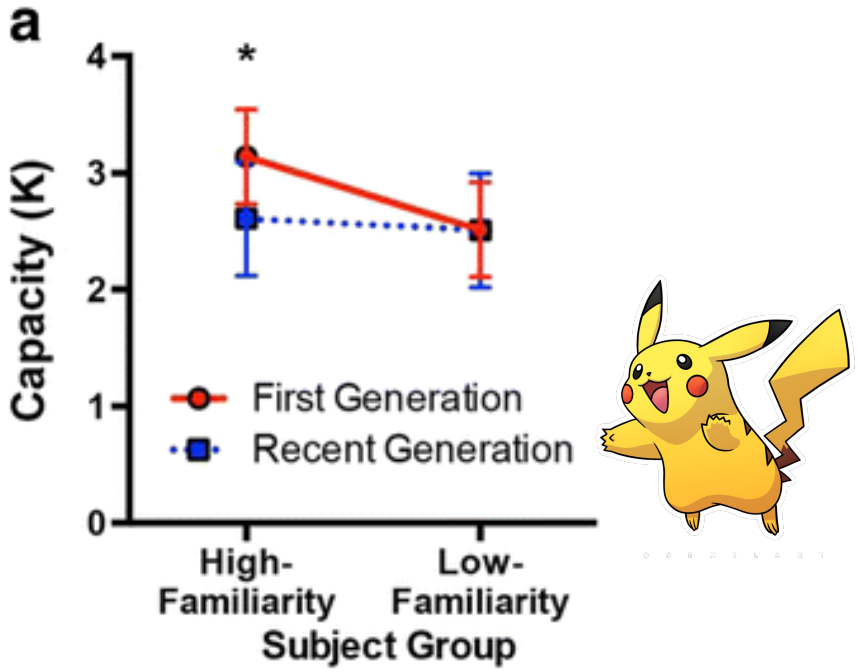
Edward Awh

Working memory is aided by long-term memory

- A hallmark of our visual working memory system is its sharp capacity limit
- But this capacity limit can be overcome with **familiarity:**



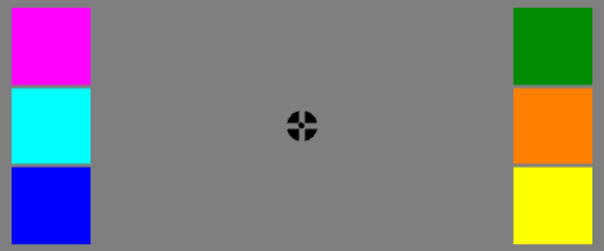
Ngiam et al. (2019) *JEP:G*



Xie and Zhang (2017) *M&C*

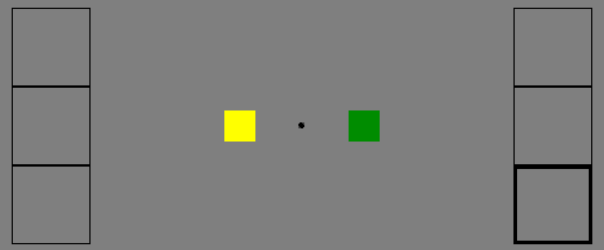
Training

- Trained subjects to learn three color triplets

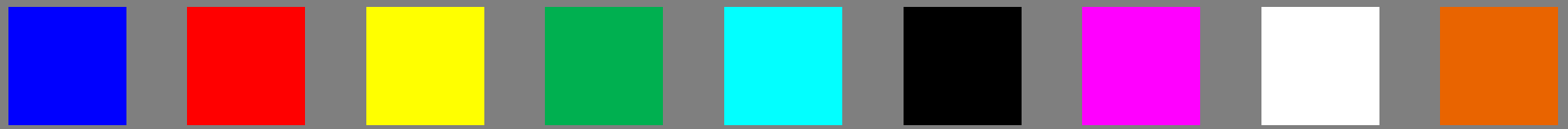


Training

Training

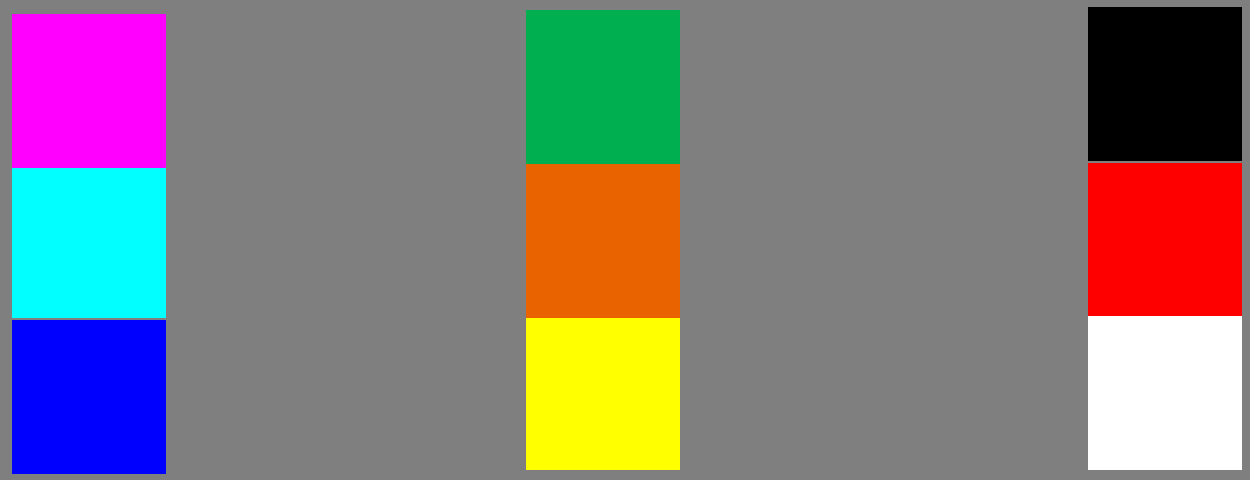


Awareness Test

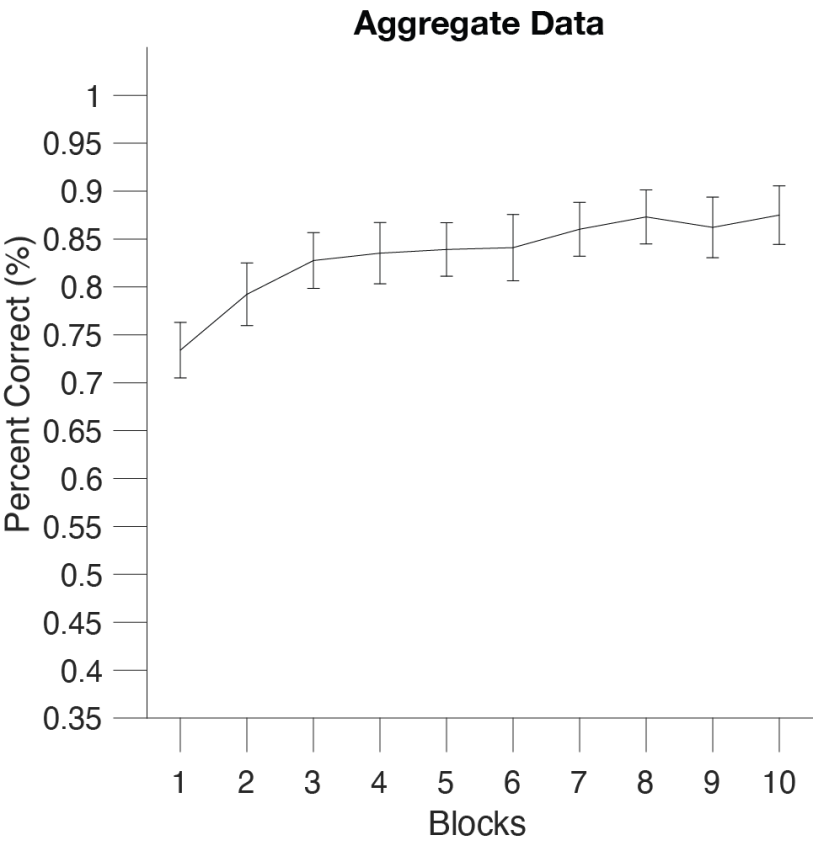


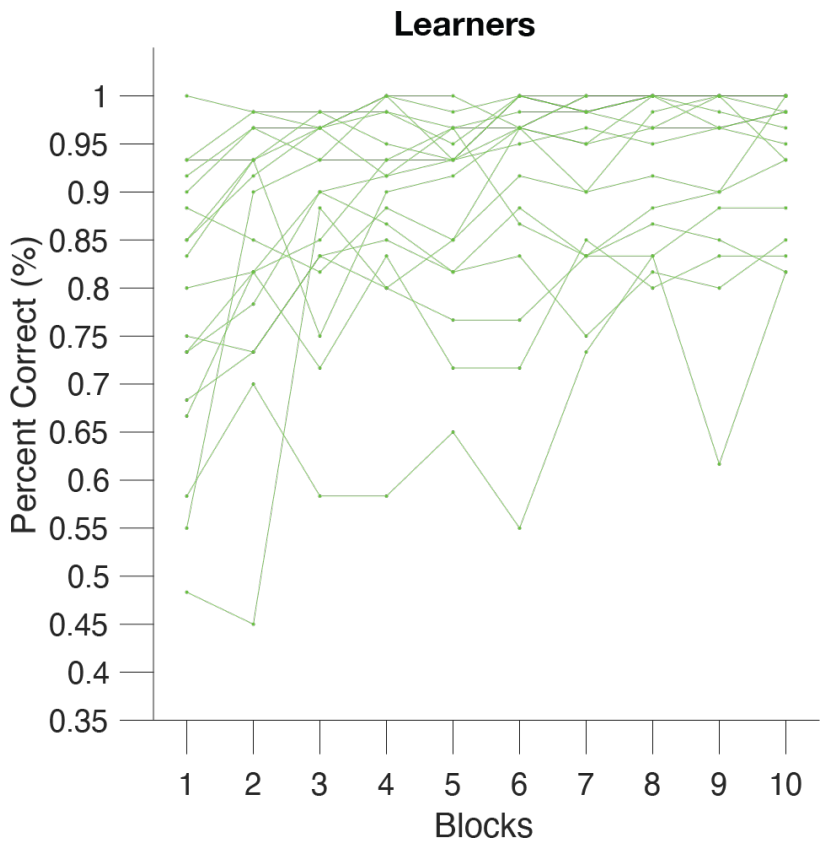
Awareness Test

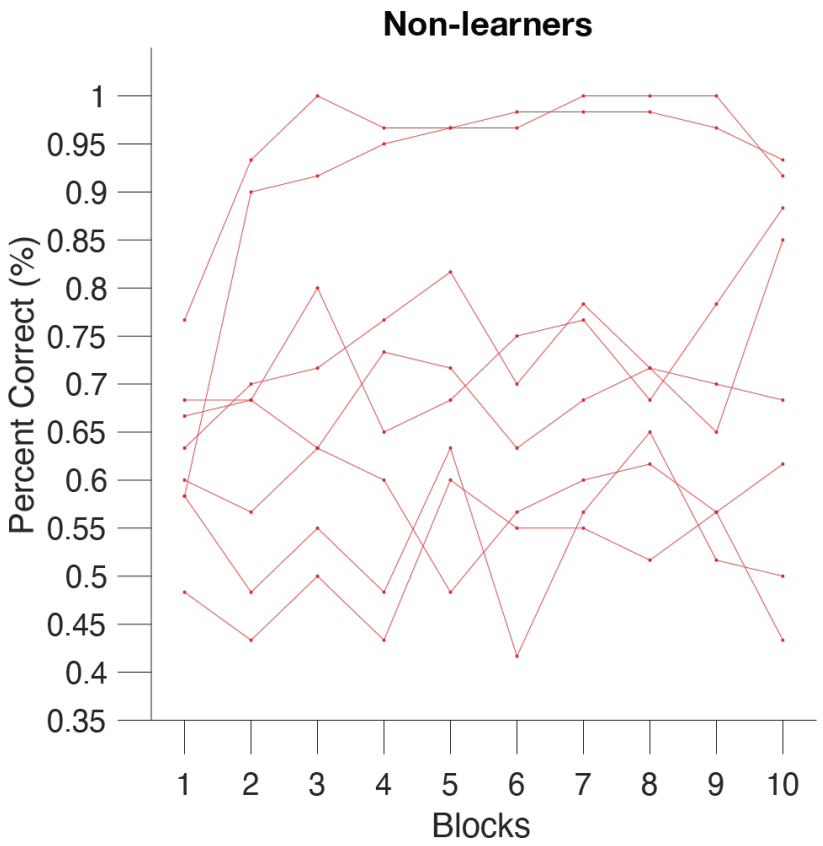
- Only subjects who correctly produced all triplets were considered “learners”



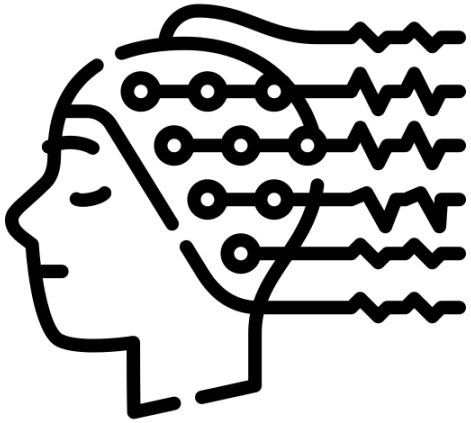
Training Results

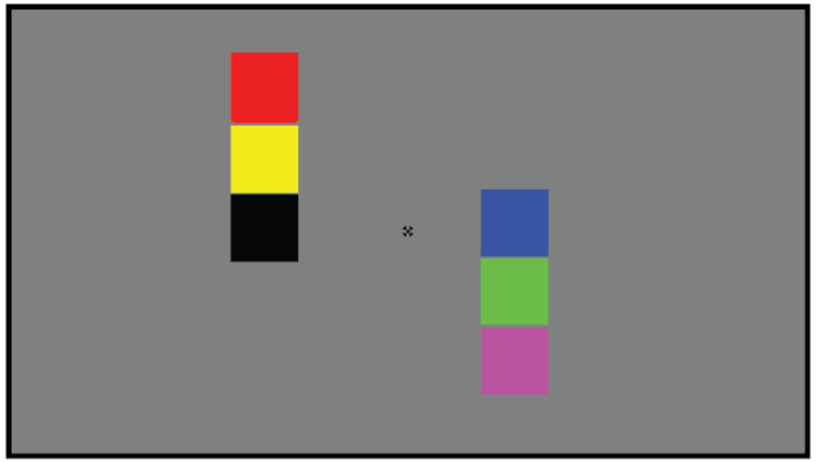


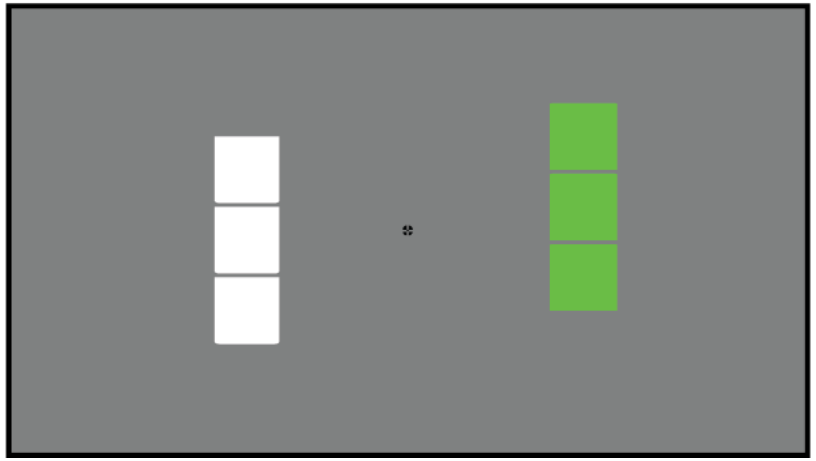




EEG session







Perceptually equivalent

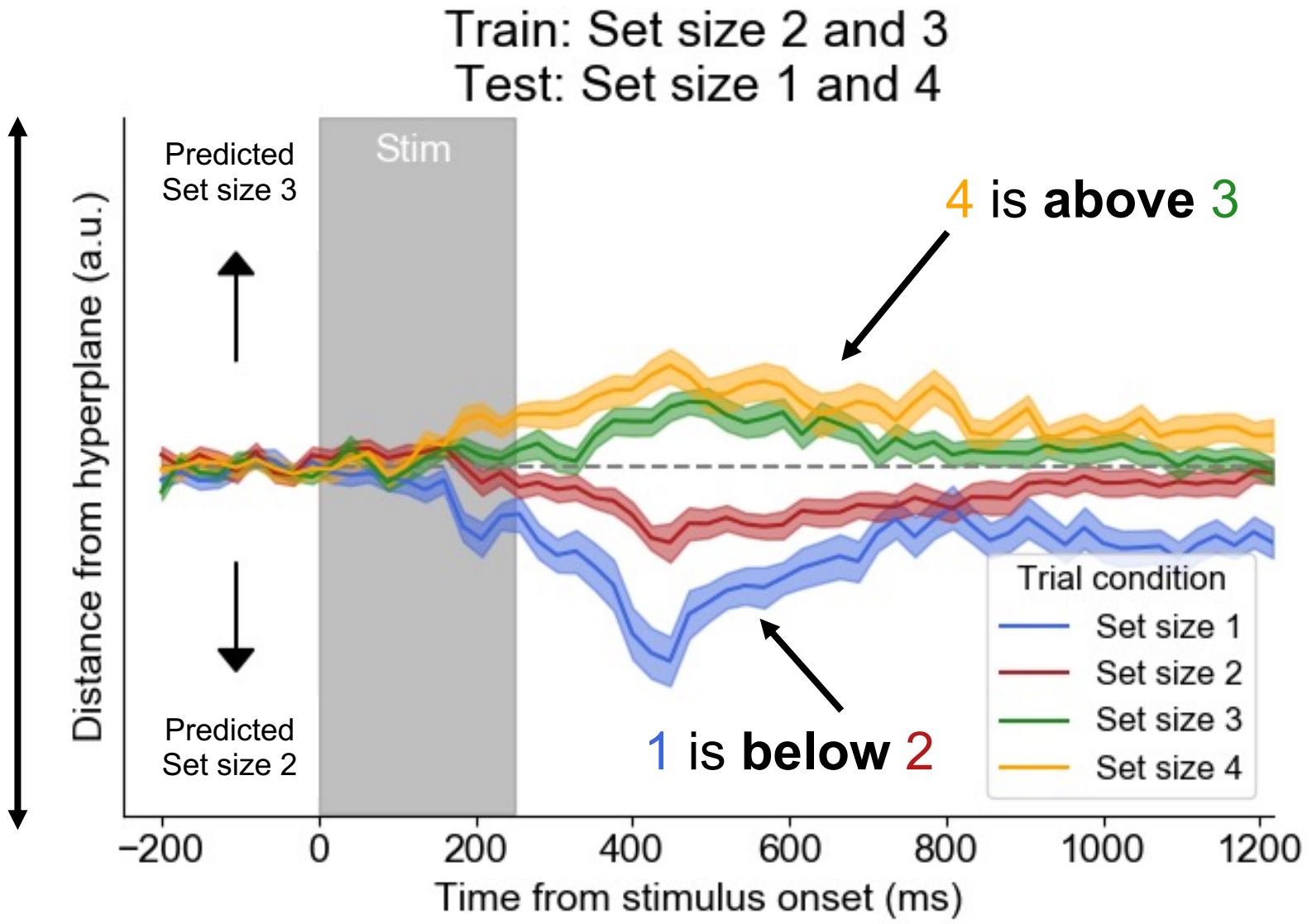
Six random

Six chunked

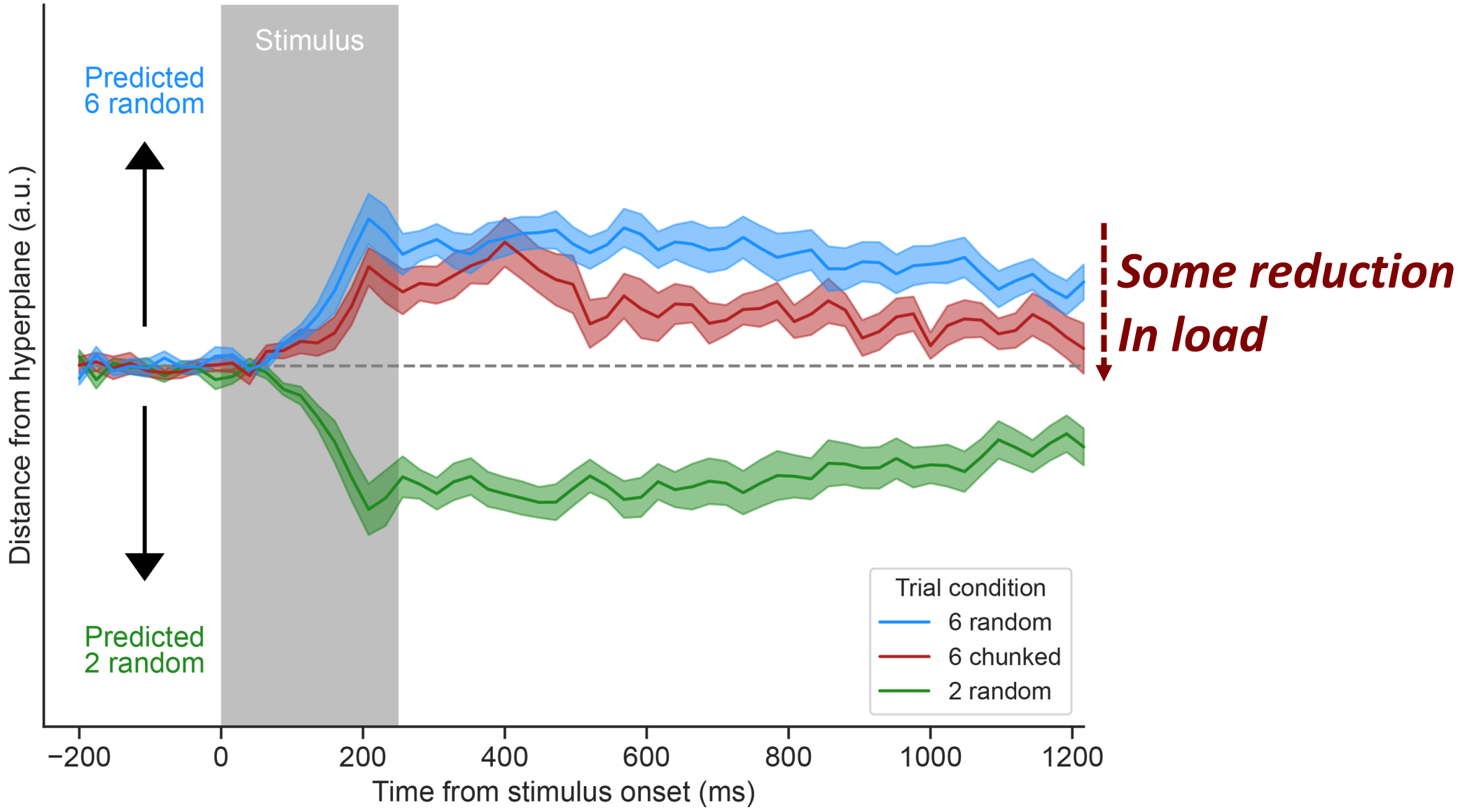
Two random

Multivariate classification of working memory

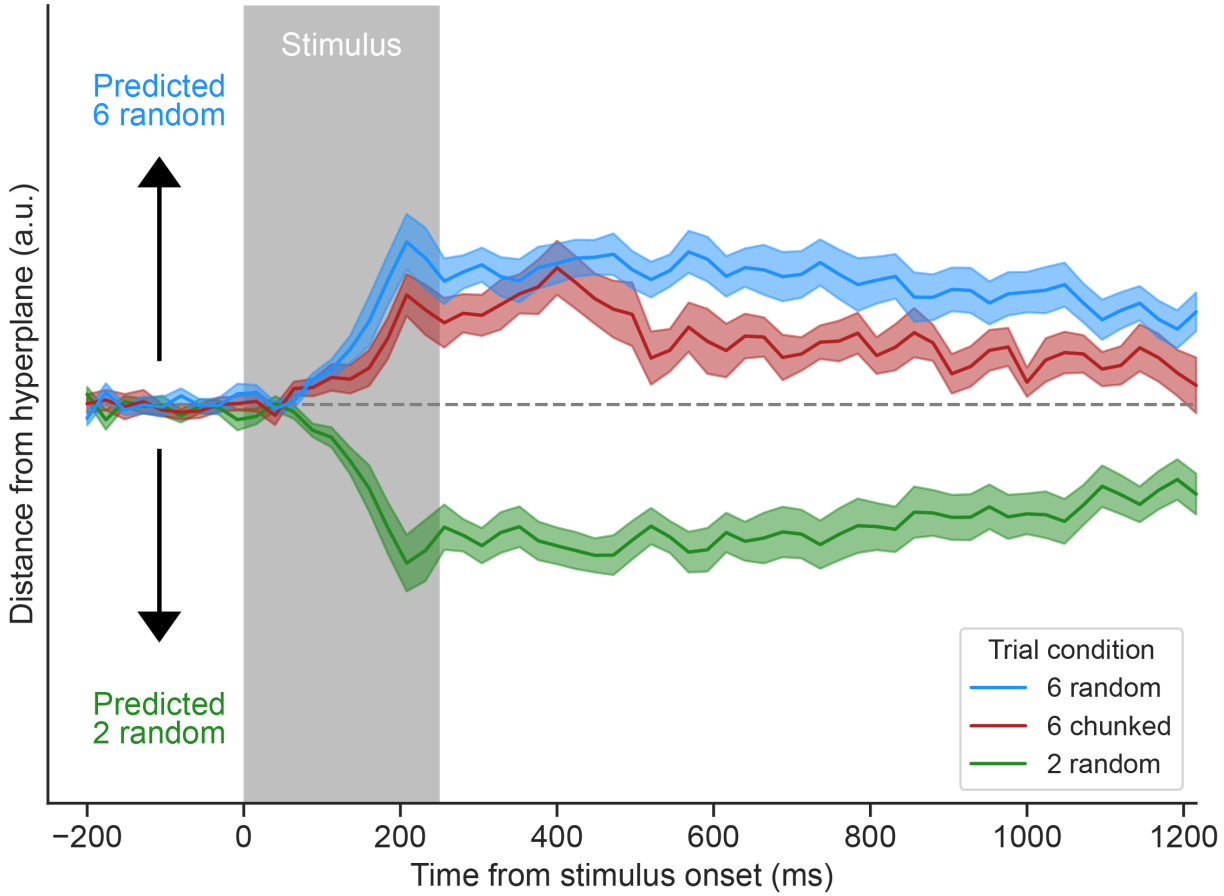
Working memory load signal



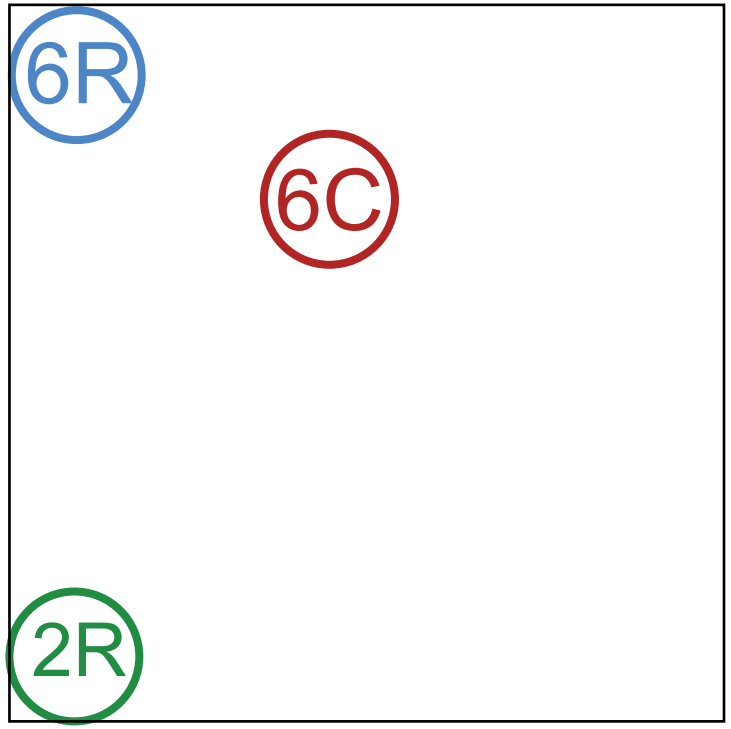
Train 6 random versus 2 random, test 6 chunked



Train 6 random versus 2 random, test 6 chunked

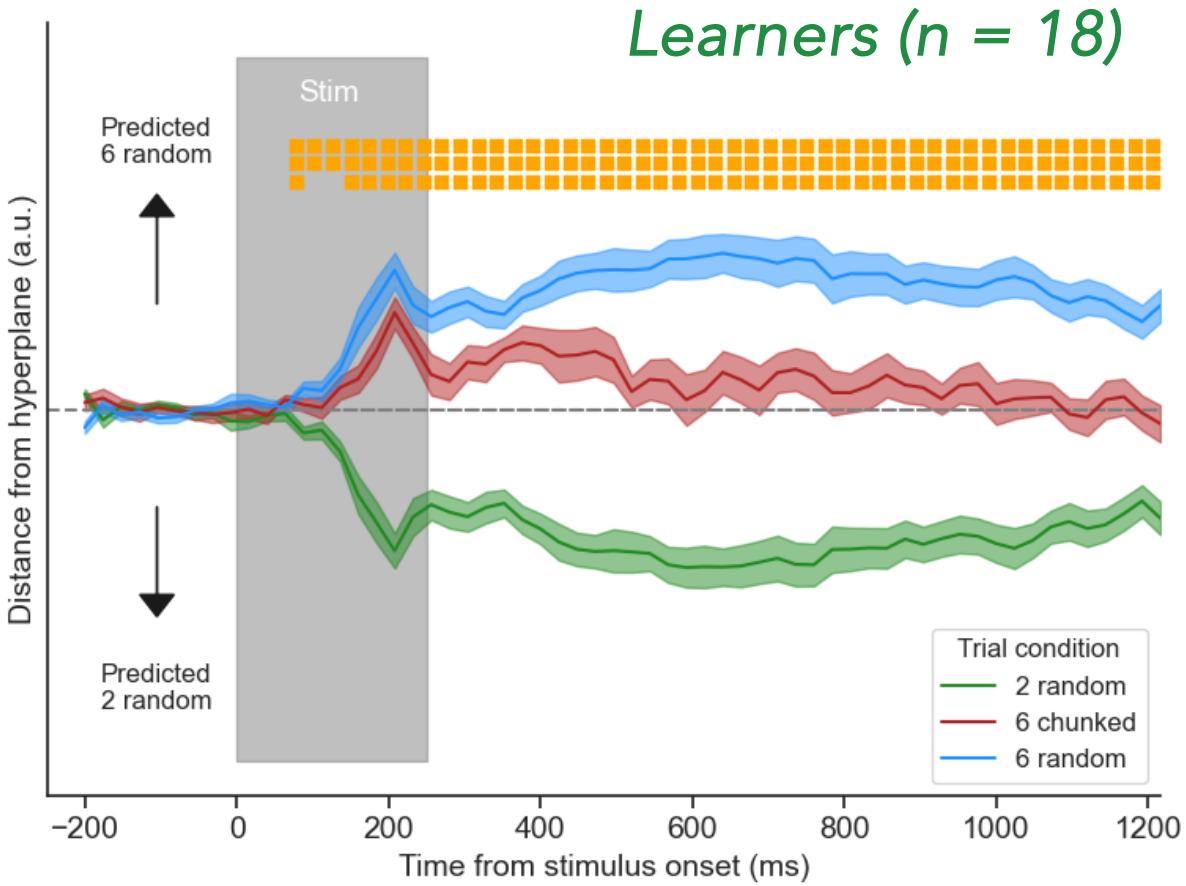


Multidimensional scaling

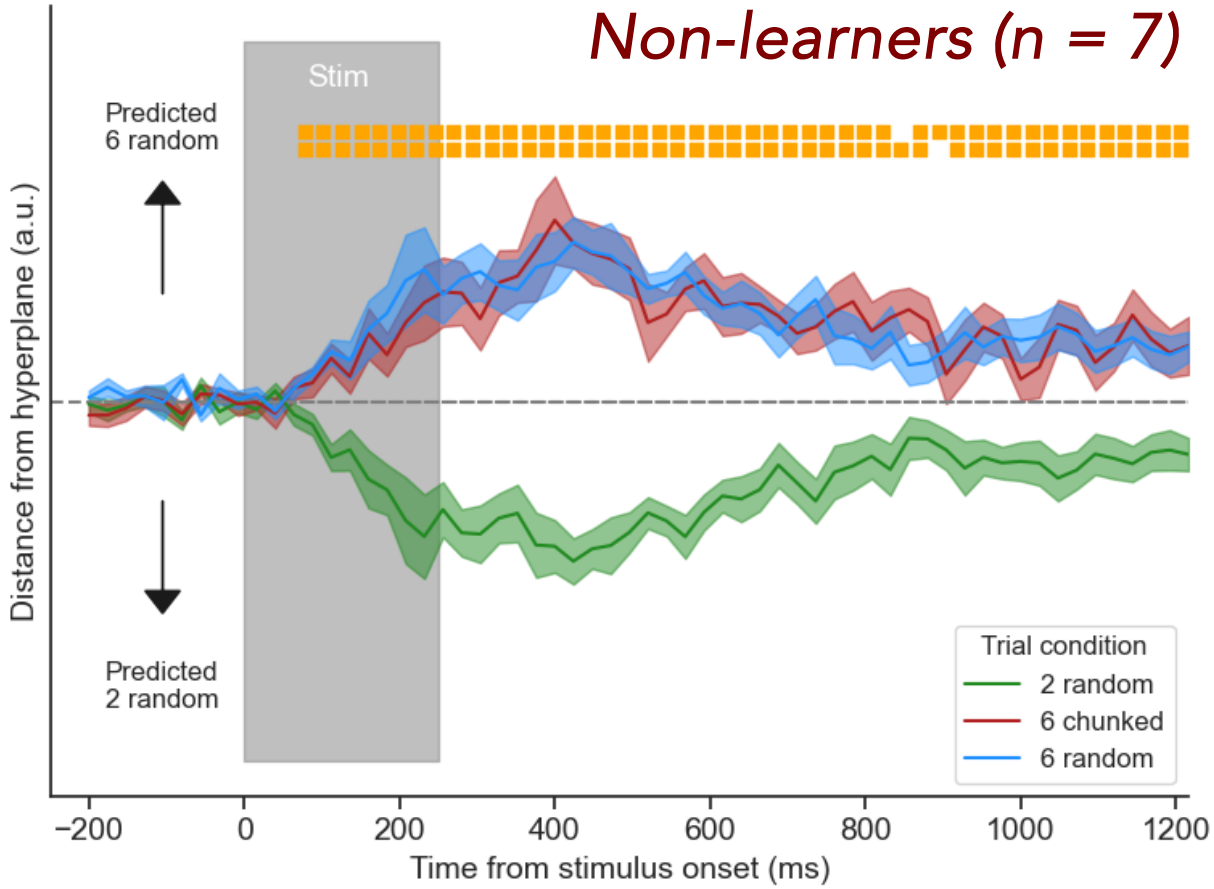


Learners vs non-learners

Learners (n = 18)

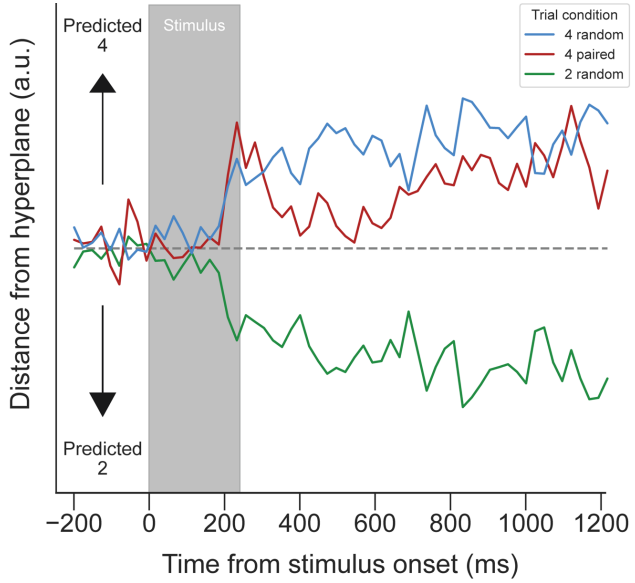


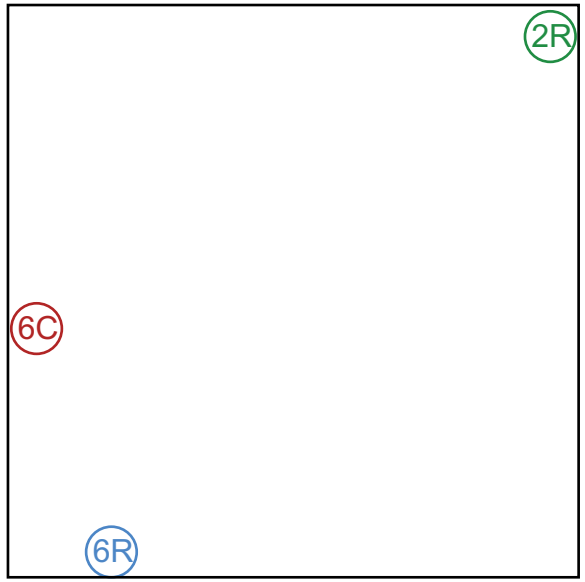
Non-learners (n = 7)



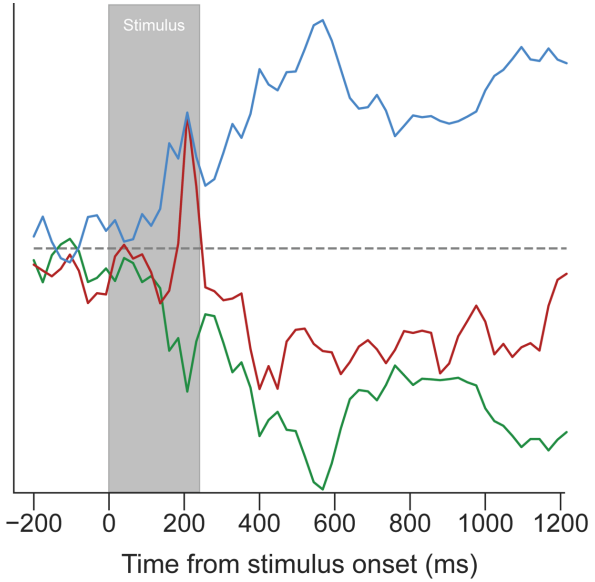
Individual differences

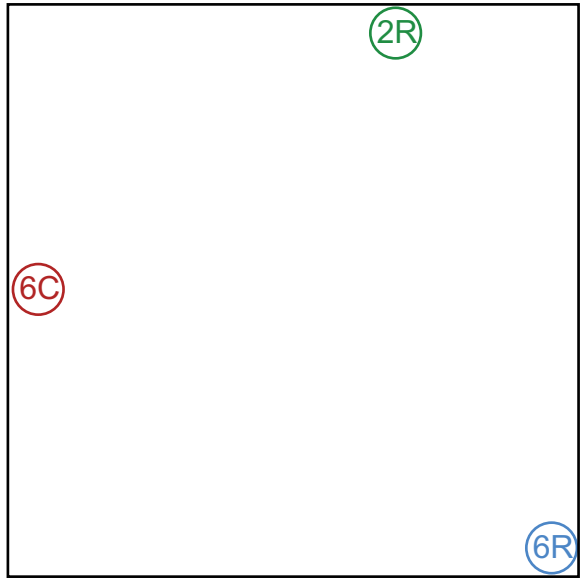
"Weak chunking"





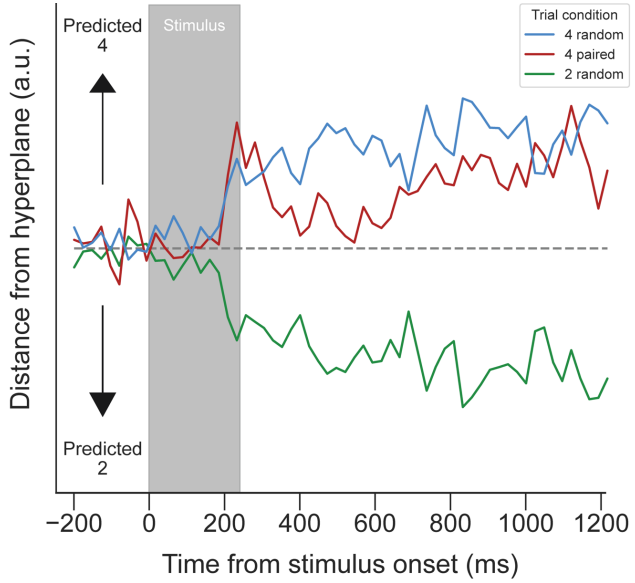
"Strong chunking"

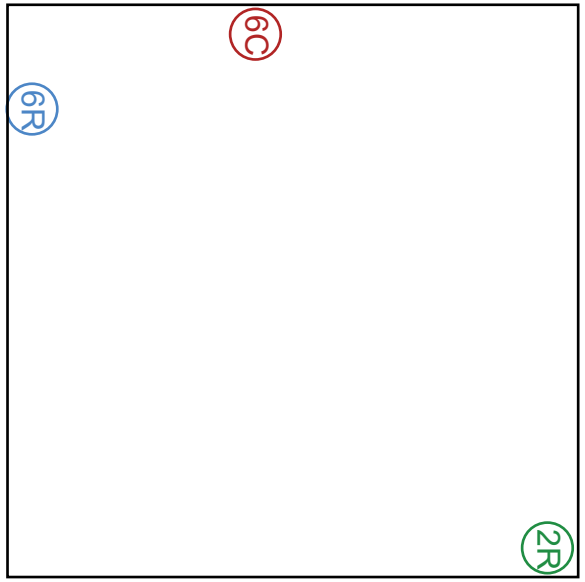




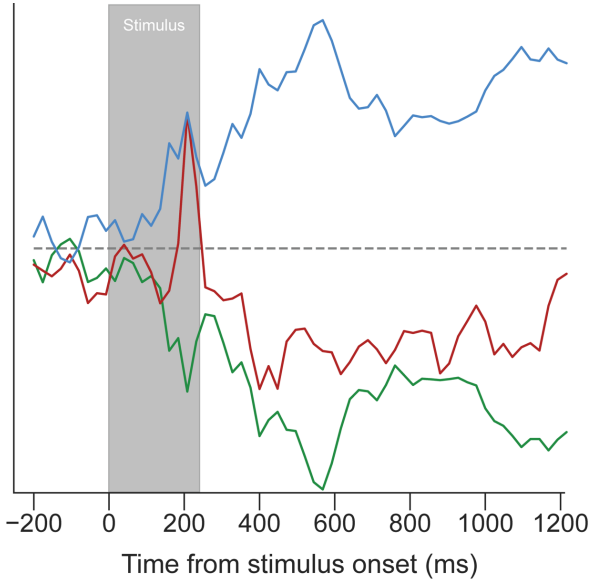
Individual differences

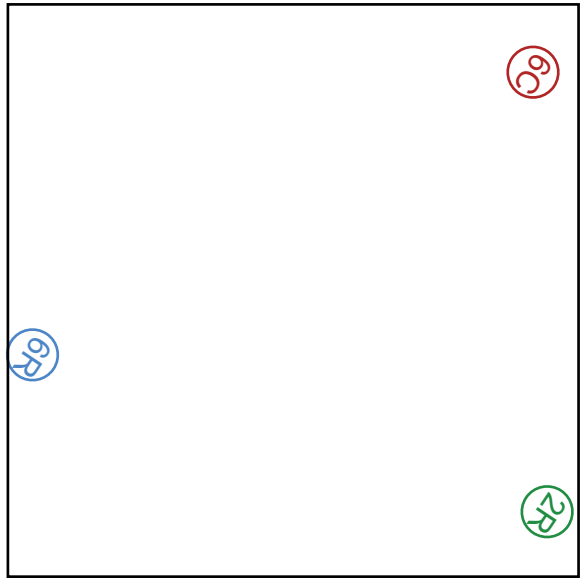
"Weak chunking"





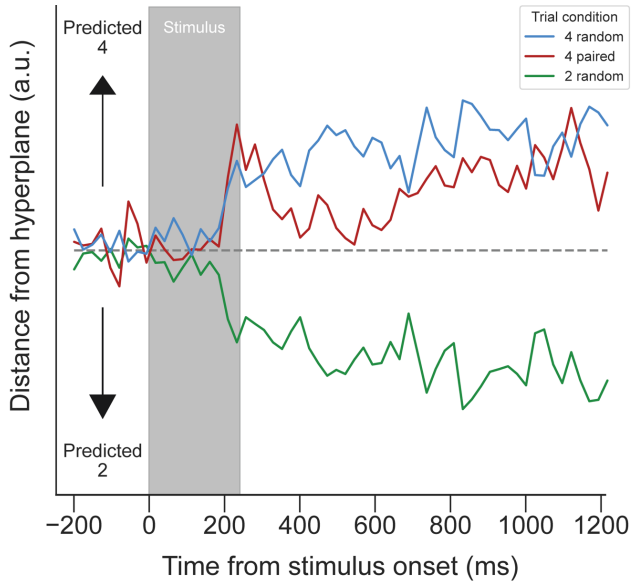
"Strong chunking"

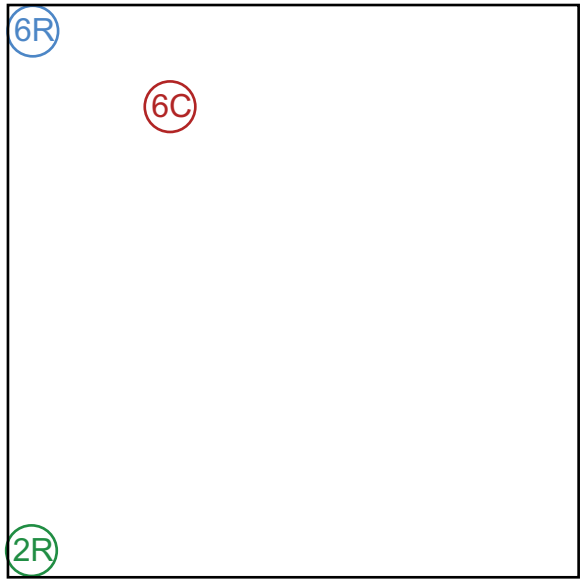




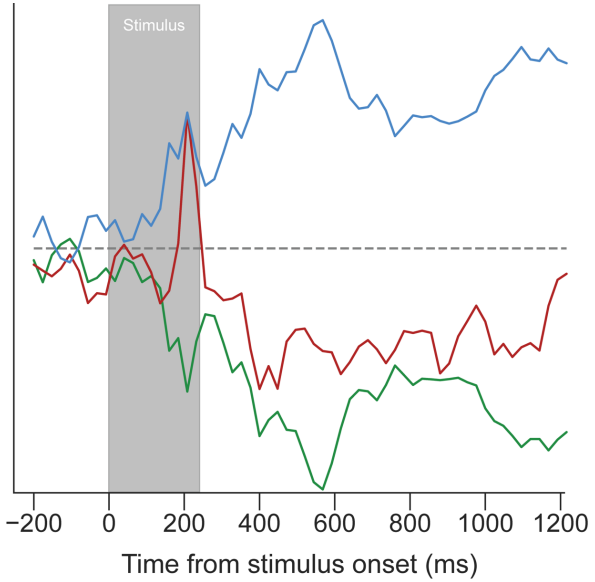
Individual differences

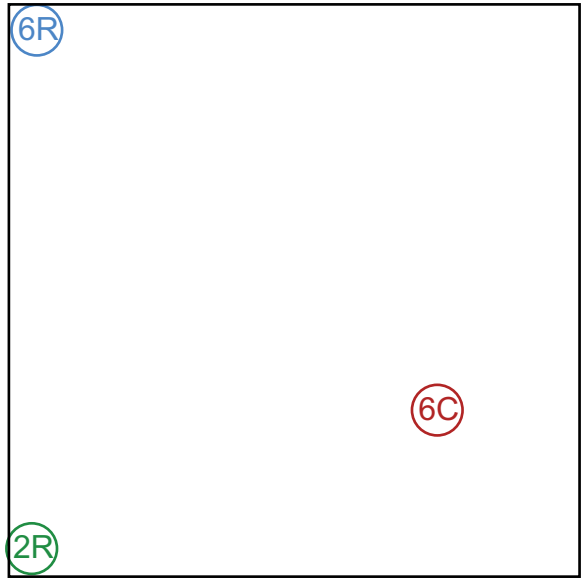
"Weak chunking"





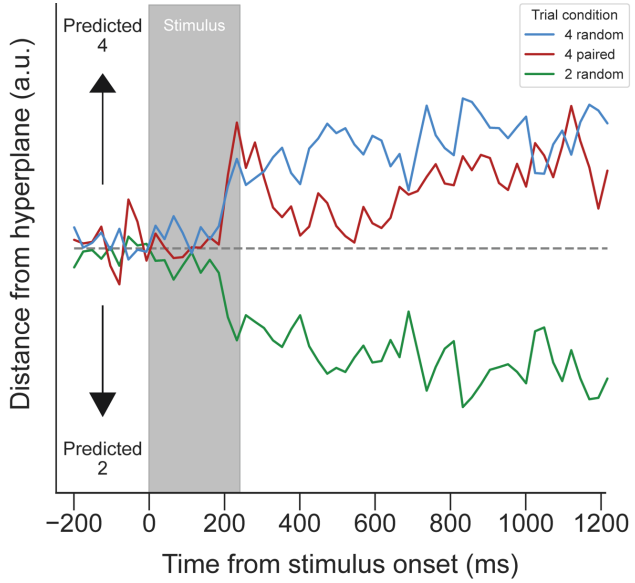
"Strong chunking"



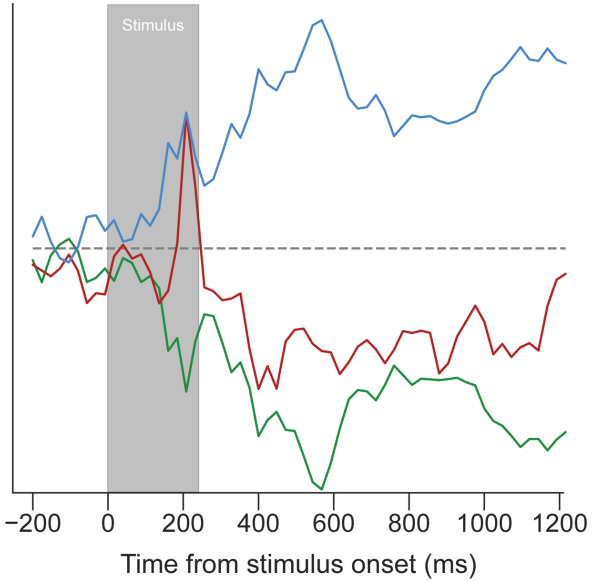


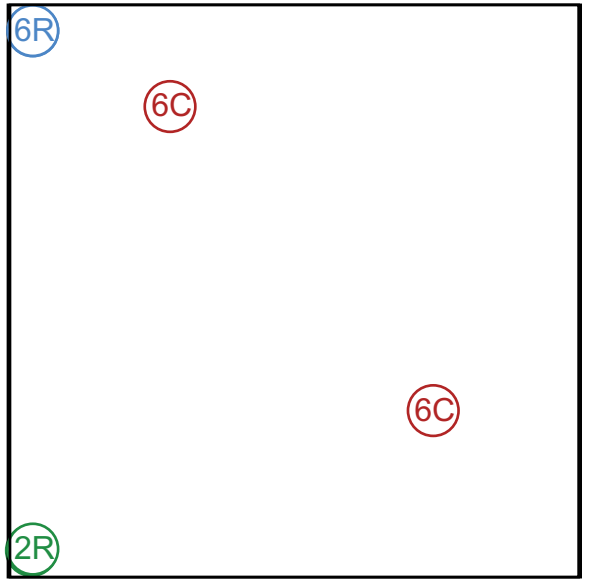
Individual differences

"Weak chunking"

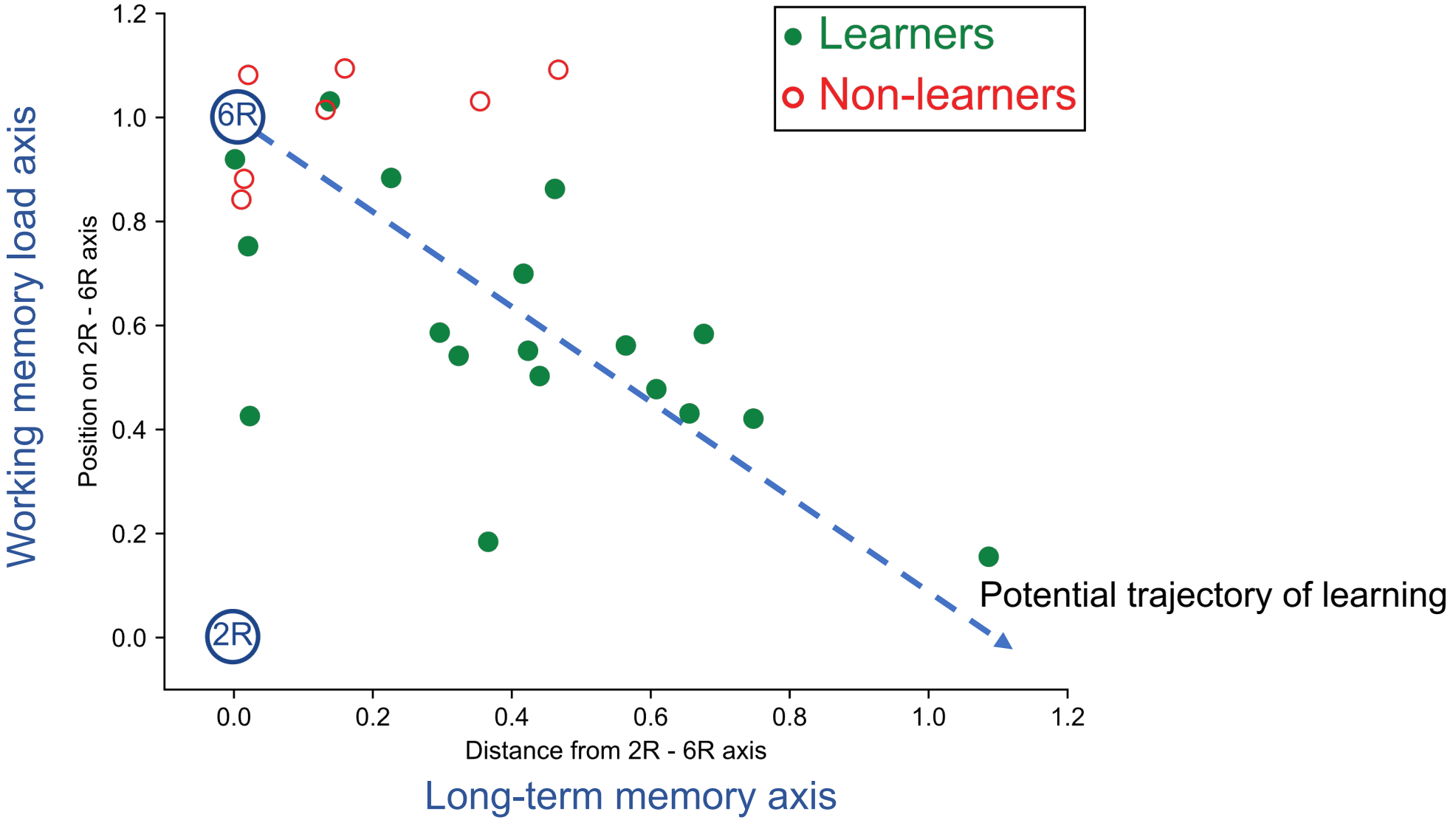


"Strong chunking"





Multidimensional scaling on each subject



Conclusions

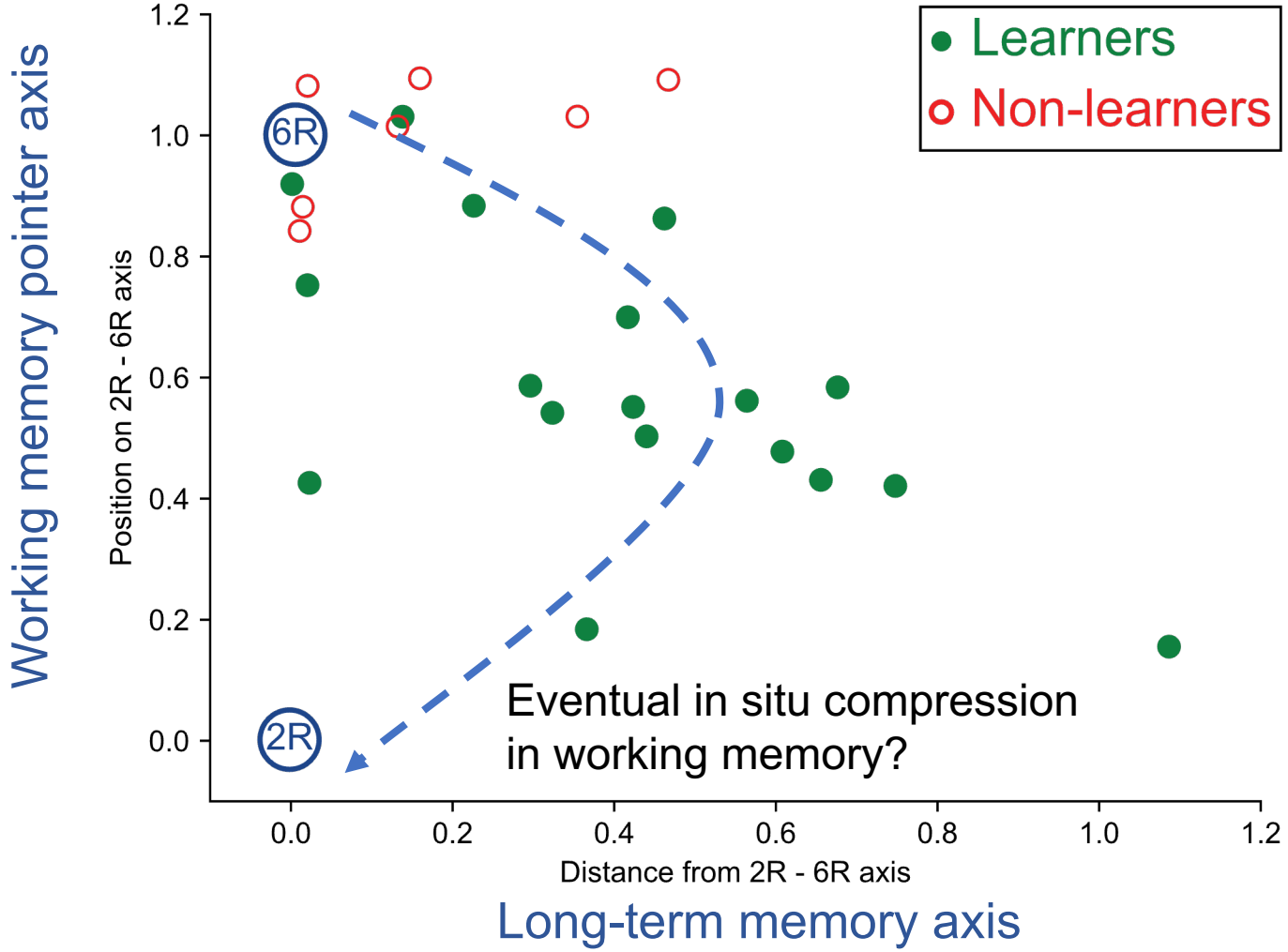
- A multivariate neural signal for items in working memory shows associative learning ***reduces*** the number of items stored in working memory

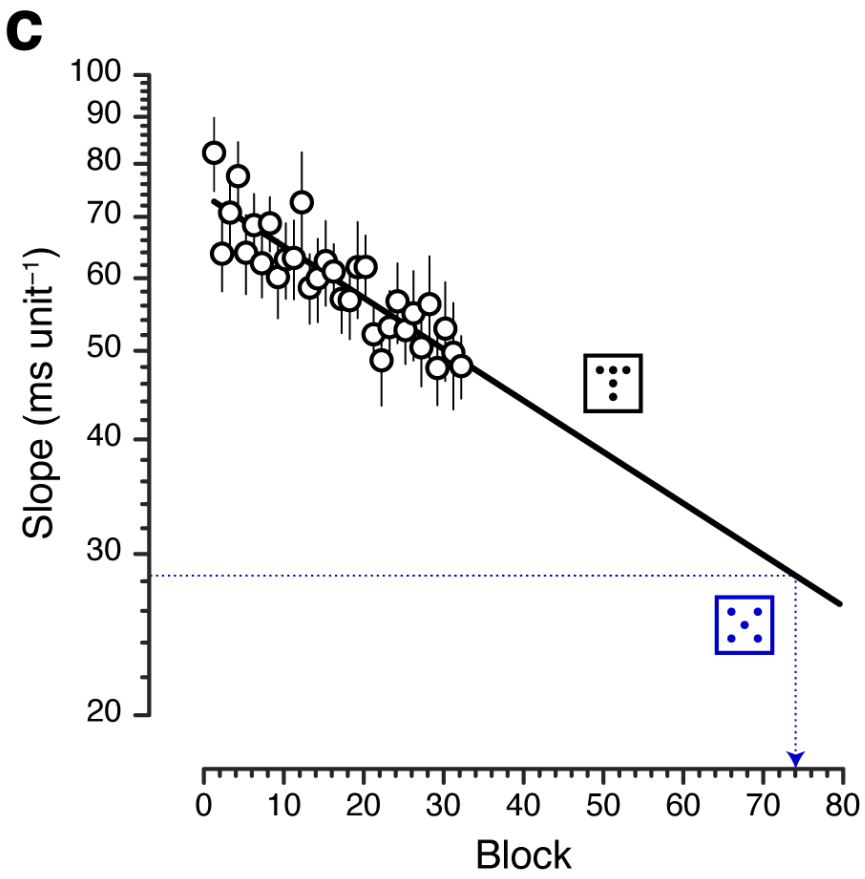
- Furthermore, neural signatures of associative learning showed the reduction only in those that **successfully learnt the associations**

- This is consistent with a ***chunking*** account – associative learning may not allow one to circumvent item pointer limits

Thank you for your attention!

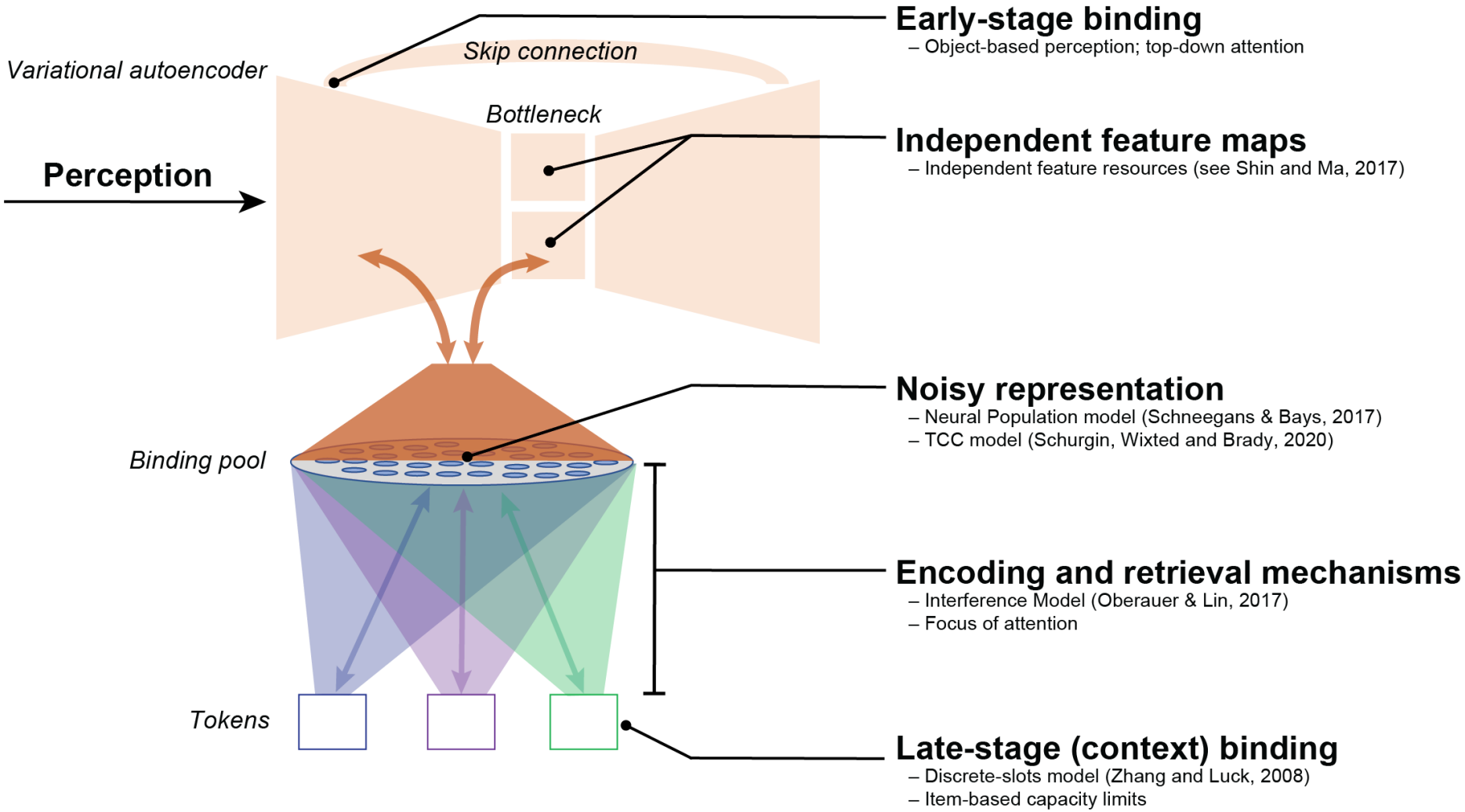
Bonus slide: why does learning fully reduce load // learned condition not cross the hyperplane?



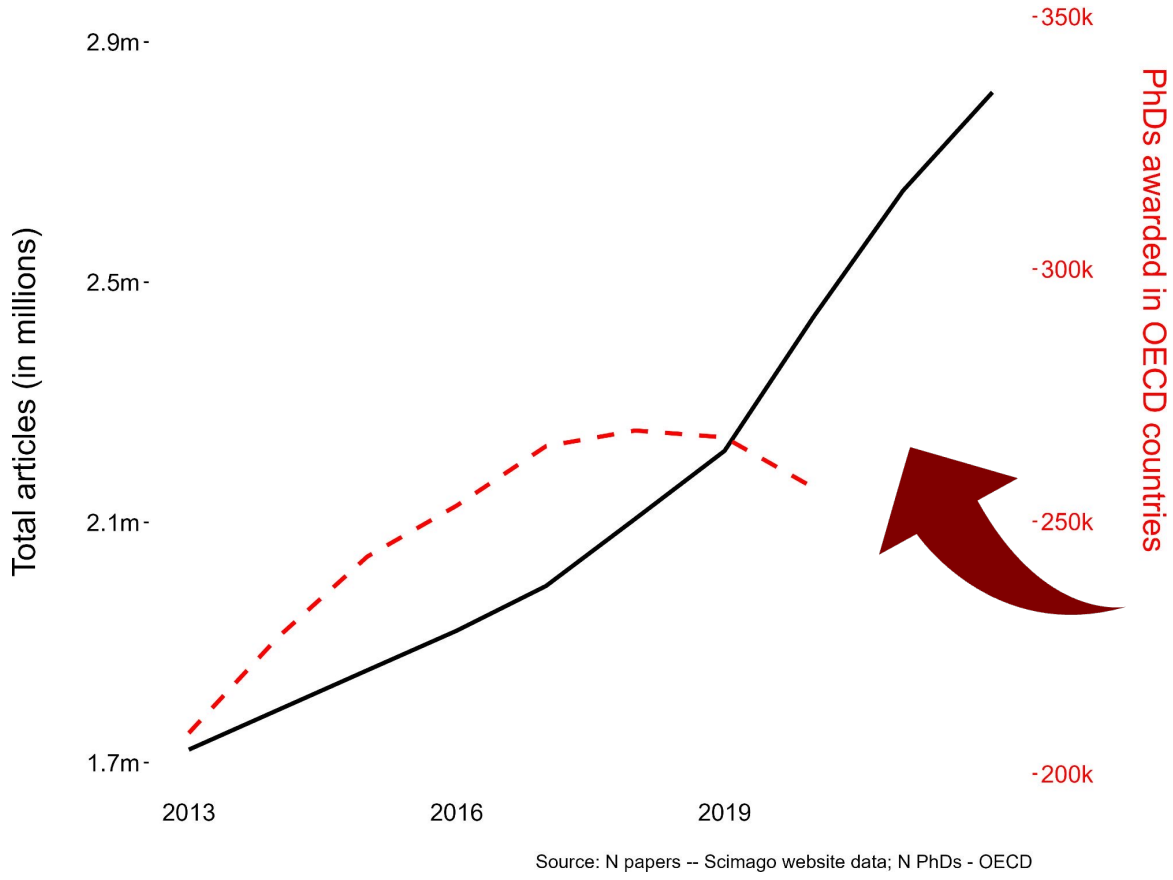


https://osf.io/preprints/psyarxiv/gh5ps

Bonus slide: what actually are pointers?



Bonus slide: are scientists (we) attending to the right things?



Increasing strain on scientists to read, review and co-ordinate.

Magnifying an "attention economy" where scientists compete for their work to be noticed and have impact.