Attention increases representational distance near task-relevant orientations

Melissa Allouche, Angus F. Chapman, & Rachel N. Denison
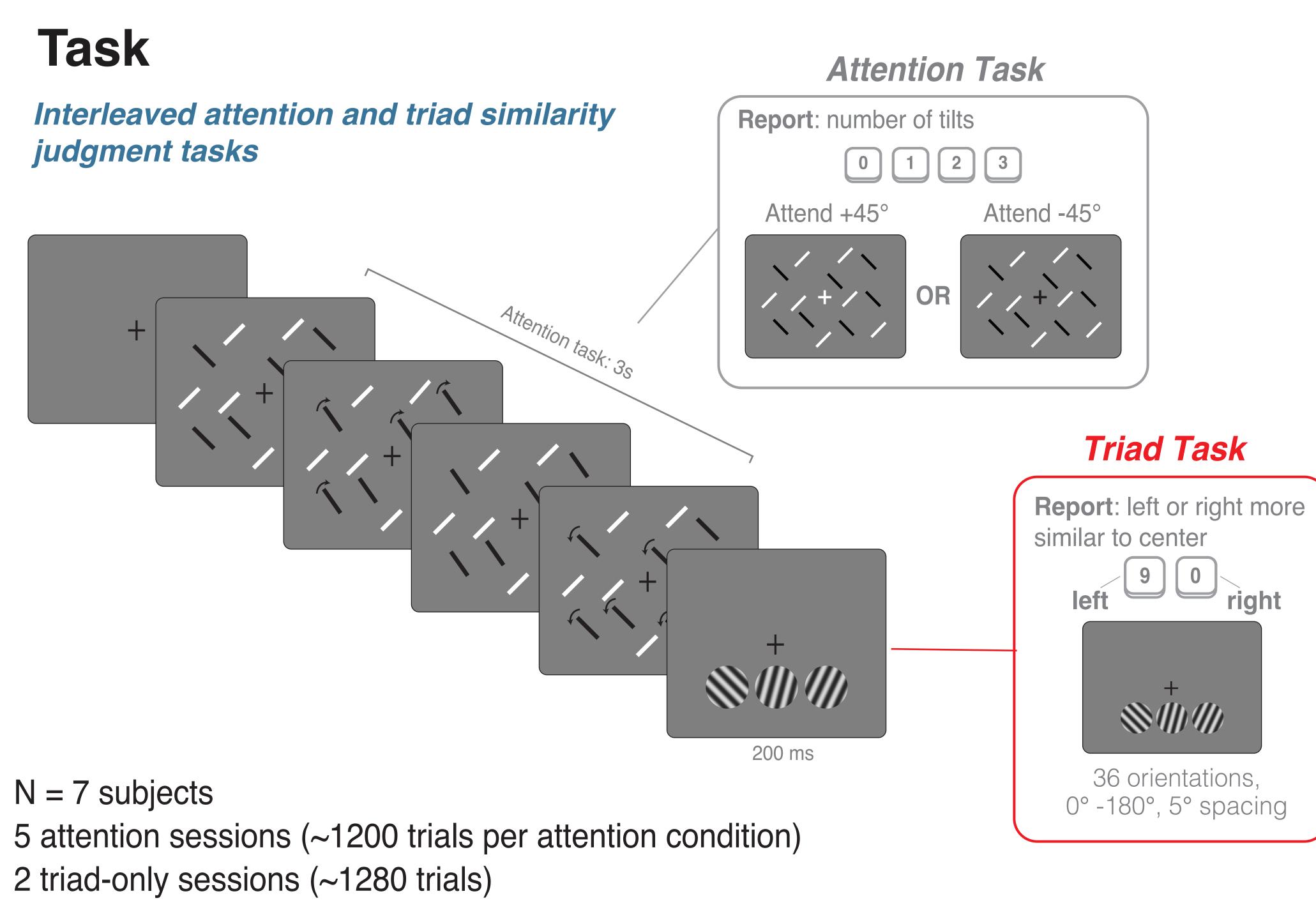
Department of Psychological & Brain Sciences, Boston University

Denison Lab — Psychological & Brain Sciences

BOSTON UNIVERSITY

Background

- Attention enhances the perception of visual information[1], and can alter the appearance of stimuli[2,3,4]

- These effects can be characterized by changes in **representational geometry** [5,6]: a computational framework that quanitifes the structural relationship between different stimuli

- Attention can alter the representational distances near an attended feature[7], however the effects of attention on the entire representational space are yet to be investigated
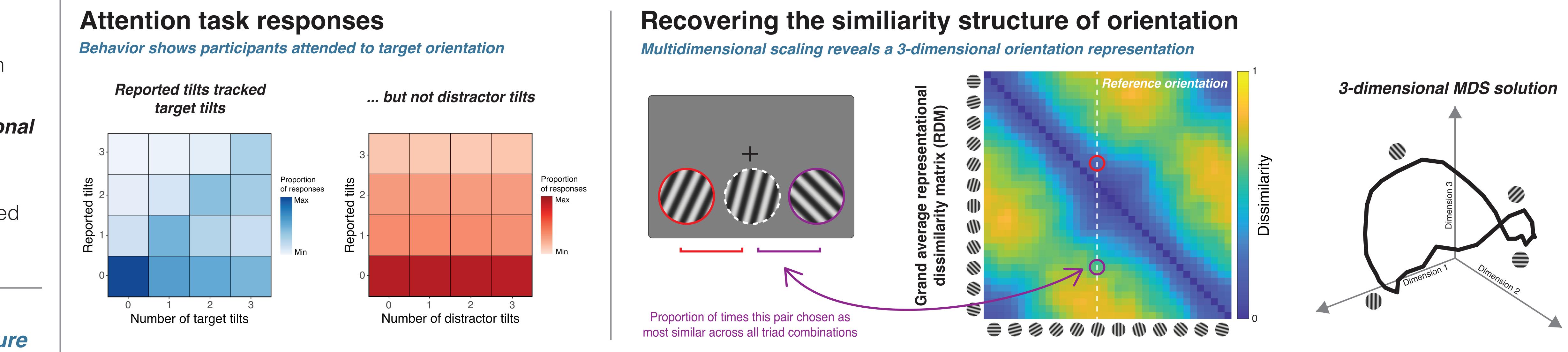
Question

How does attention affect the global representational structure of orientation?

Task

Interleaved attention and triad similarity judgment tasks

Attention Task

Report: number of tilts

0 1 2 3

Attend +45°   Attend -45°

OR

Attention task: 3s

Triad Task

Report: left or right more similar to center

left 9 0 right

36 orientations, 0°-180°, 5° spacing

200 ms

N = 7 subjects
5 attention sessions (~1200 trials per attention condition)
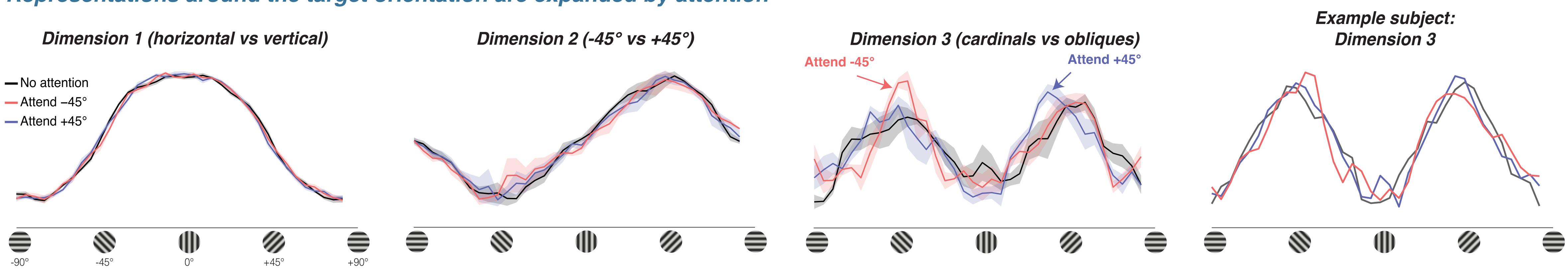2 triad-only sessions (~1280 trials)

References

1. Carrasco, M. (2011). Vis Research, 51, 1484-1525.
2. Carrasco, M., Ling, S., & Read, S. (2004). Nat Neurosci, 7(3), 308-313.
3. Suzuki, S. & Cavanagh, P. (1997). J Exp Psychol: Hum Percept & Perform, 23(2), 443-463.
4. Chapman, A. F., Chunharas, C., & Störmer, V. S. (2023). Sci Rep, 13, 6487.401-412.
5. Kriegeskorte, N. & Kievit, R. A. (2013). TICS, 17(8), 401-412.
6. Kriegeskorte, N. & Wei, X.-X. (2021). Nat Rev Neurosci, 22, 703-718.
7. Chapman, A. F. & Störmer, V. S. (2024). TICS, 28(5), 416-427.

Attention task responses

Behavior shows participants attended to target orientation

Reported tilts tracked target tilts

Reported tilts (y-axis) vs Number of target tilts (x-axis). Proportion of responses Max–Min.

... but not distractor tilts

Reported tilts (y-axis) vs Number of distractor tilts (x-axis). Proportion of responses Max–Min.

Recovering the similarity structure of orientation

Multidimensional scaling reveals a 3-dimensional orientation representation

Reference orientation

Grand average representational dissimilarity matrix (RDM)

Dissimilarity 0–1

Proportion of times this pair chosen as most similar across all triad combinations

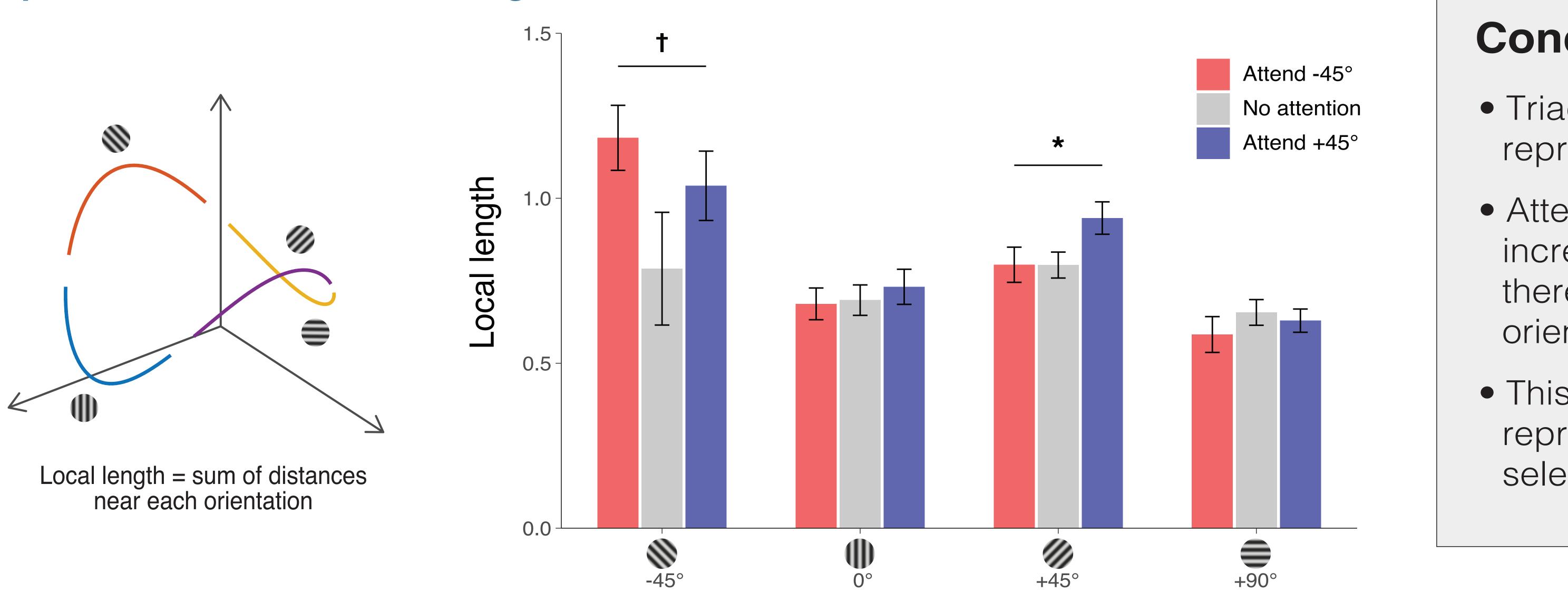**3-dimensional MDS solution**

Dimension 1, Dimension 2, Dimension 3

Attention affects the representational geometry of target orientations

Representations around the target orientation are expanded by attention

Dimension 1 (horizontal vs vertical)

Dimension 2 (-45° vs +45°)

Dimension 3 (cardinals vs obliques)

— No attention
— Attend -45°
— Attend +45°

Attend -45°   Attend +45°

-90° -45° 0° +45° +90°

Example subject: Dimension 3

Representational distance changed near but not far from attended orientation

Local length = sum of distances near each orientation

Local length (y-axis) 0.0–1.5

† ... *

Attend -45°
No attention
Attend +45°

-45° 0° +45° +90°

Conclusions

- Triad task responses revealed a 3-dimensional representation of orientation

- Attention modulated this representation, resulting in increased length around attended orientations, however there was no evidence for changes around unattended orientations

- This suggests that attention acts to expand the representation around relevant features to enable efficient selection