Attention locally modulates the discriminability of high-level, task-relevant representations

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Introduction

Selective attention is a mechanism by which the brain prioritizes certain types of information. Electrophysiological work suggests that attention alters neuronal tuning[1] and increases interneuronal decorrelation[2]; however, these effects are difficult to observe across highly distributed neuronal populations are typically characterized using rudimentary visual stimuli. Here we examine how attention reshapes complex, high-dimensional representations grounded in distributed neuronal populations.

Hypothesis: Attentional allocation transiently and selectively reshapes high-dimensional neural representational space such that task-relevant representations become more discriminable, while task-irrelevant representations are collapsed.

Methods

12 right-handed participants (7 female)

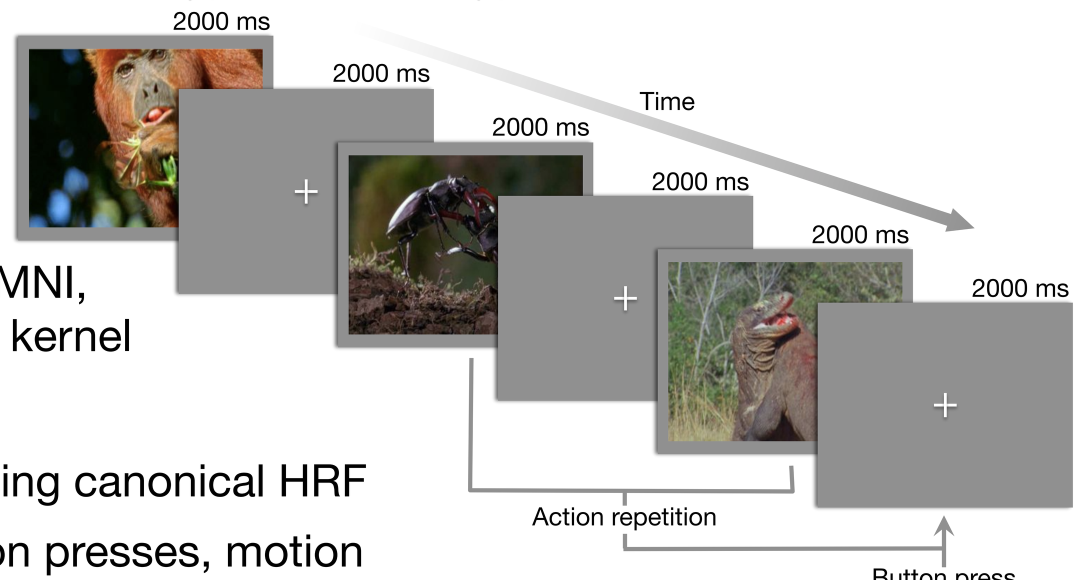
Stimuli: 2000 ms naturalistic video clips of animals performing actions

Rapid event-related design: 2000 ms stimulus + 2000 ms fixation

5 animal types: birds, insects, primates, reptiles, ungulates
4 action types: eating, fighting, running, swimming
20 conditions: 5 (animal type) x 4 (action type) fully crossed design

Attentional task: 1-back repetition detection requiring participants attend to either animal type or action type

Preprocessing:
Despiking,
slice timing correction,
normalization to MNI,
4 mm smoothing kernel



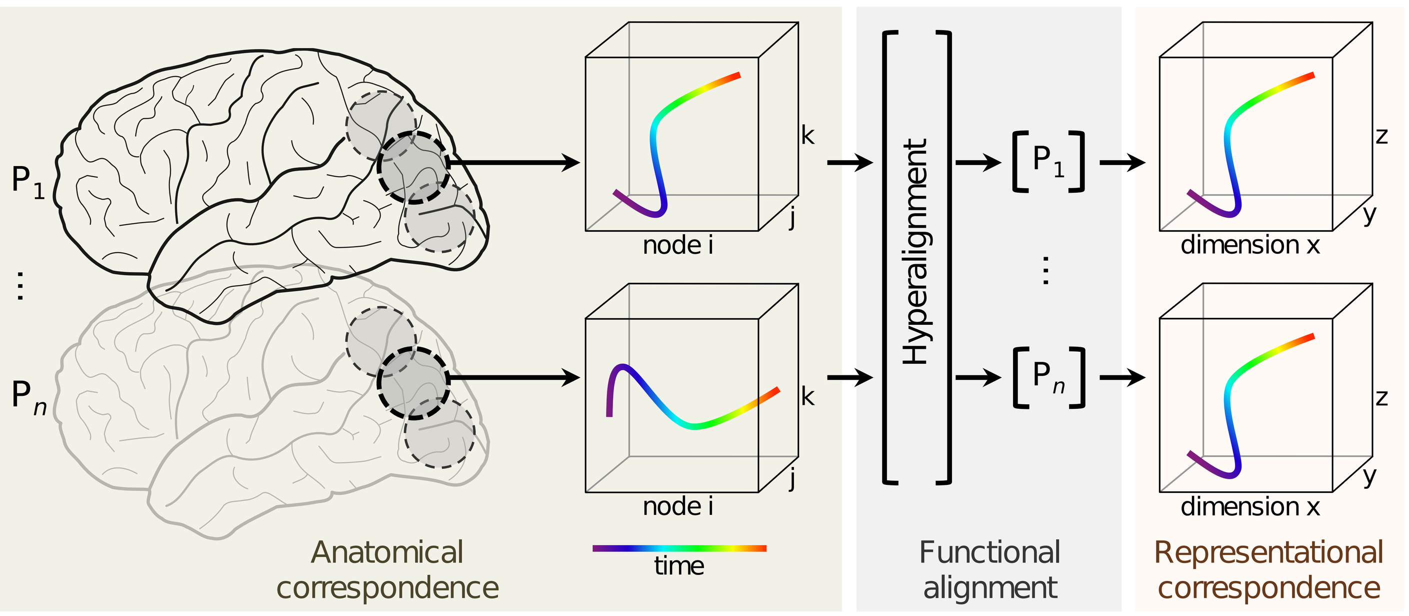
GLM:
Runwise GLM using canonical HRF

Repetitions/button presses, motion parameters included as nuisance regressors

Hyperalignment:
Whole-brain time series hyperalignment using 200-node surface-based searchlights[4]

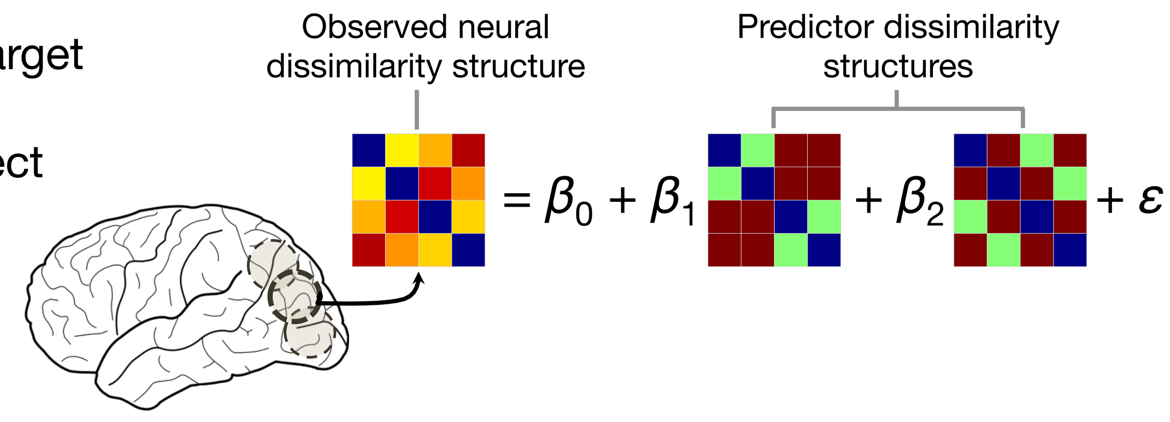
19 participants (including 12 participants from first session)

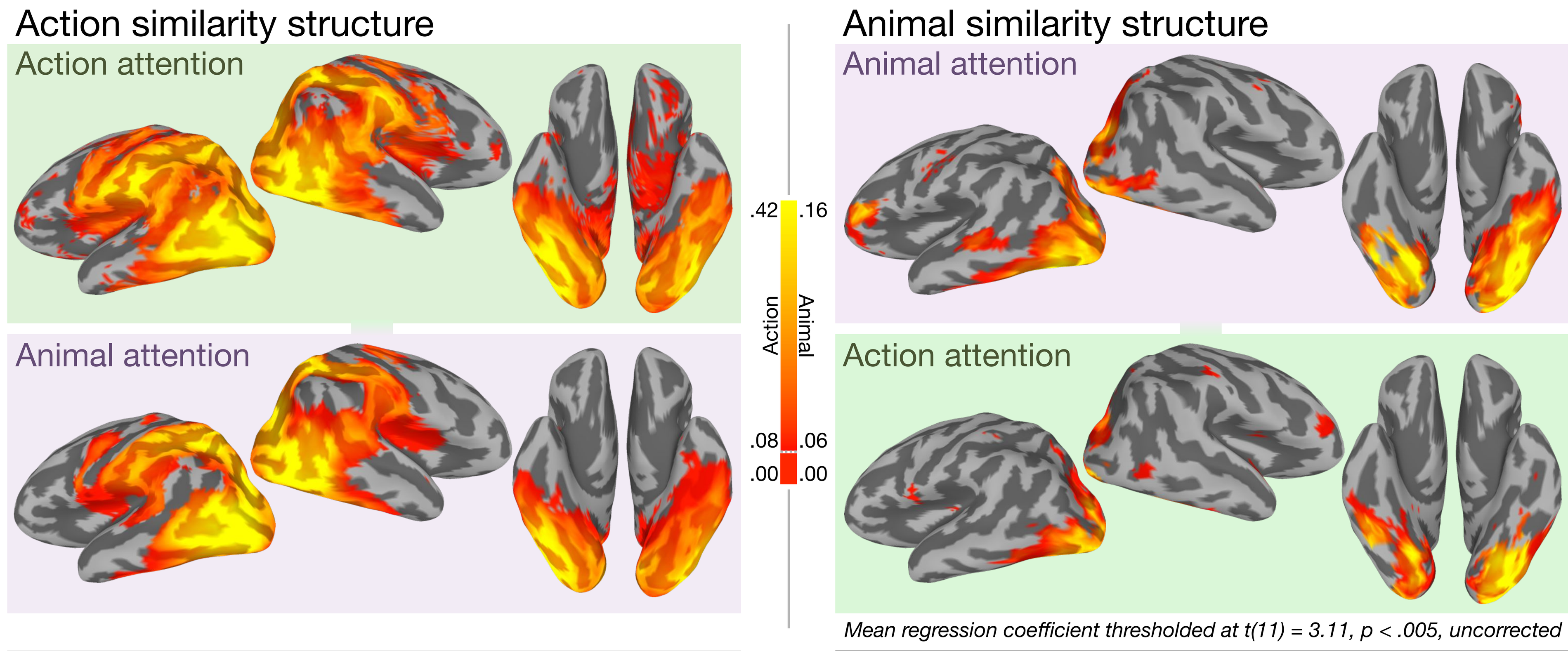
Stimulus: 1 hr freely viewed naturalistic movie (*Life* nature documentary, narrated by David Attenborough)



Representational similarity regression searchlight

Multiple regression per 100-node searchlight using two categorical target similarity structures as predictors. Regression coefficients (β_1, β_2) reflect how well each target similarity structure predicts observed neural similarity structure.

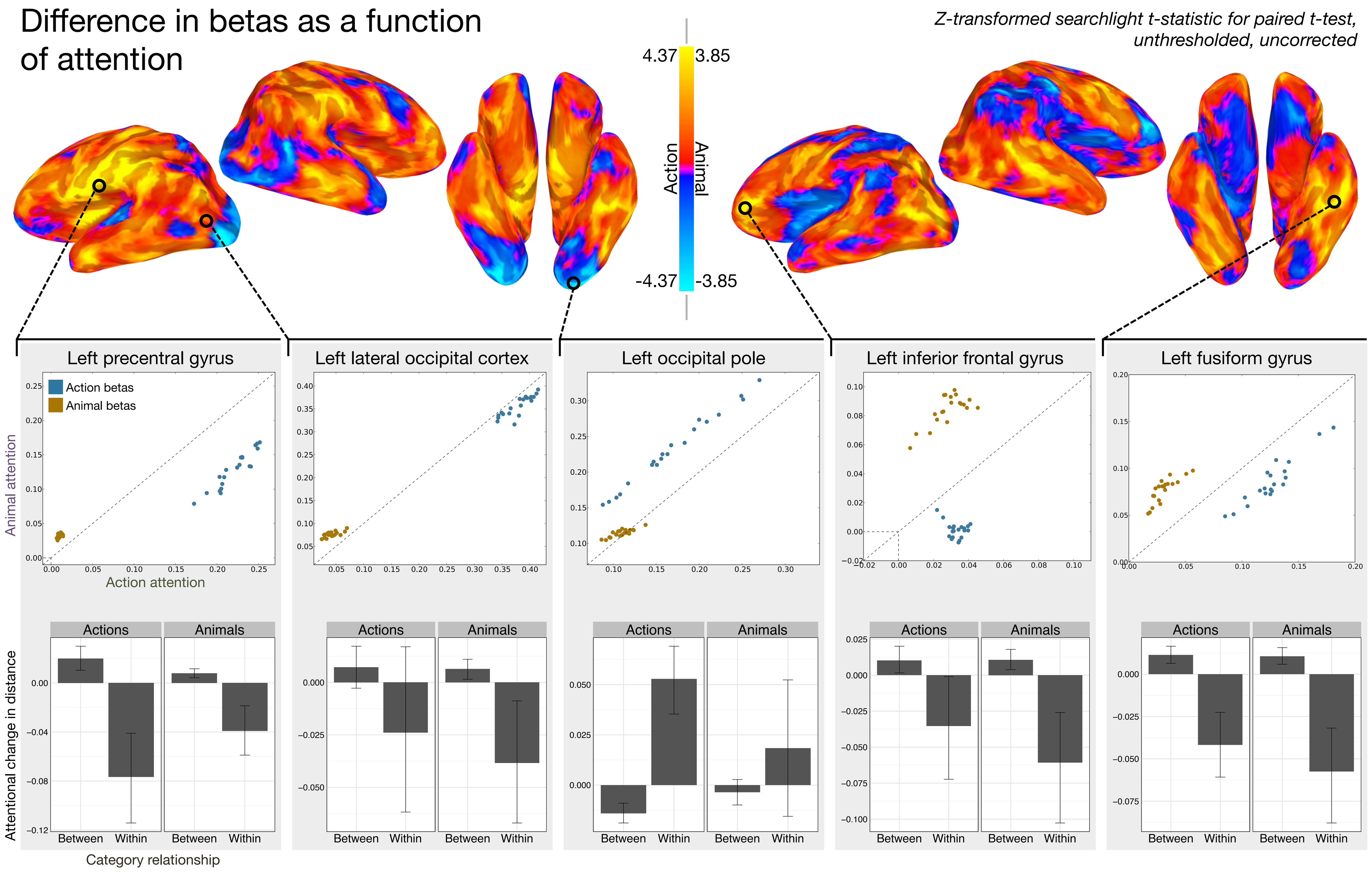




Mean regression coefficient thresholded at $t(11) = 3.11$, $p < .005$, uncorrected

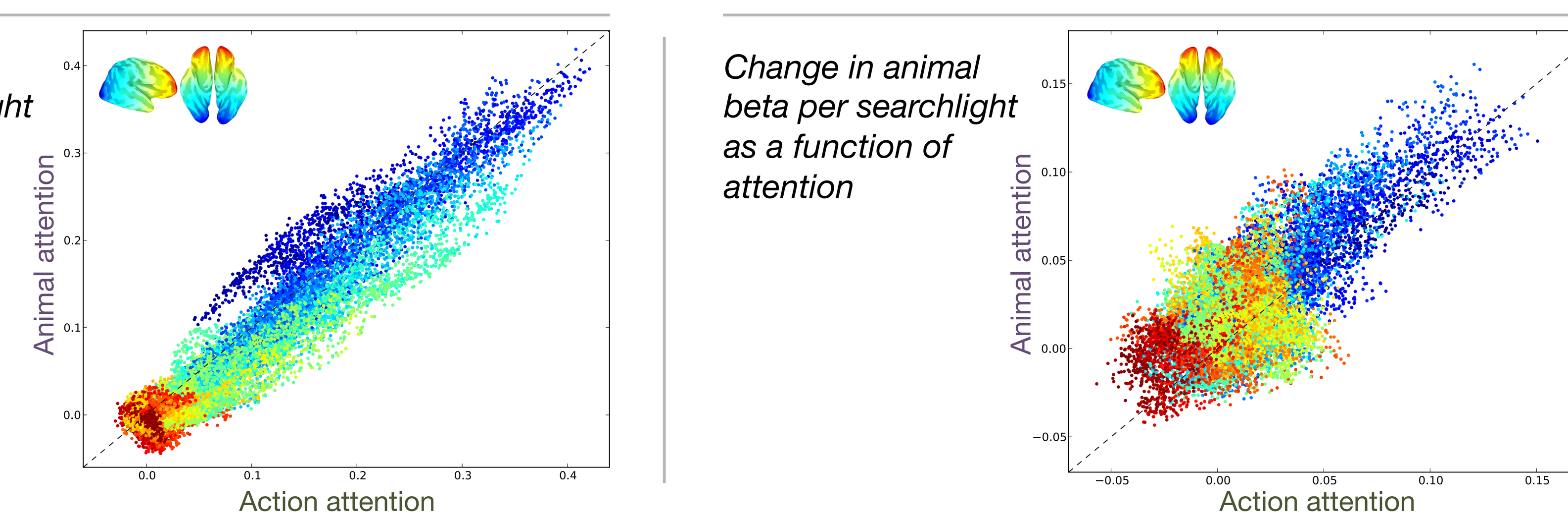
Difference in betas as a function of attention

Z-transformed searchlight t-statistic for paired t-test, unthresholded, uncorrected



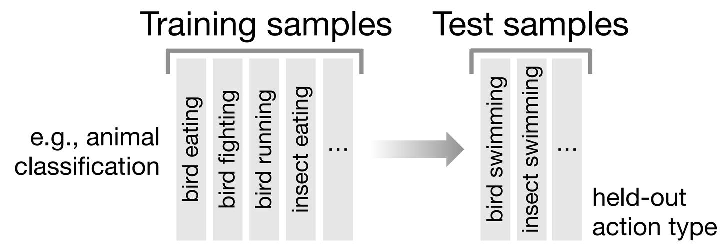
Change in action beta per searchlight as a function of attention

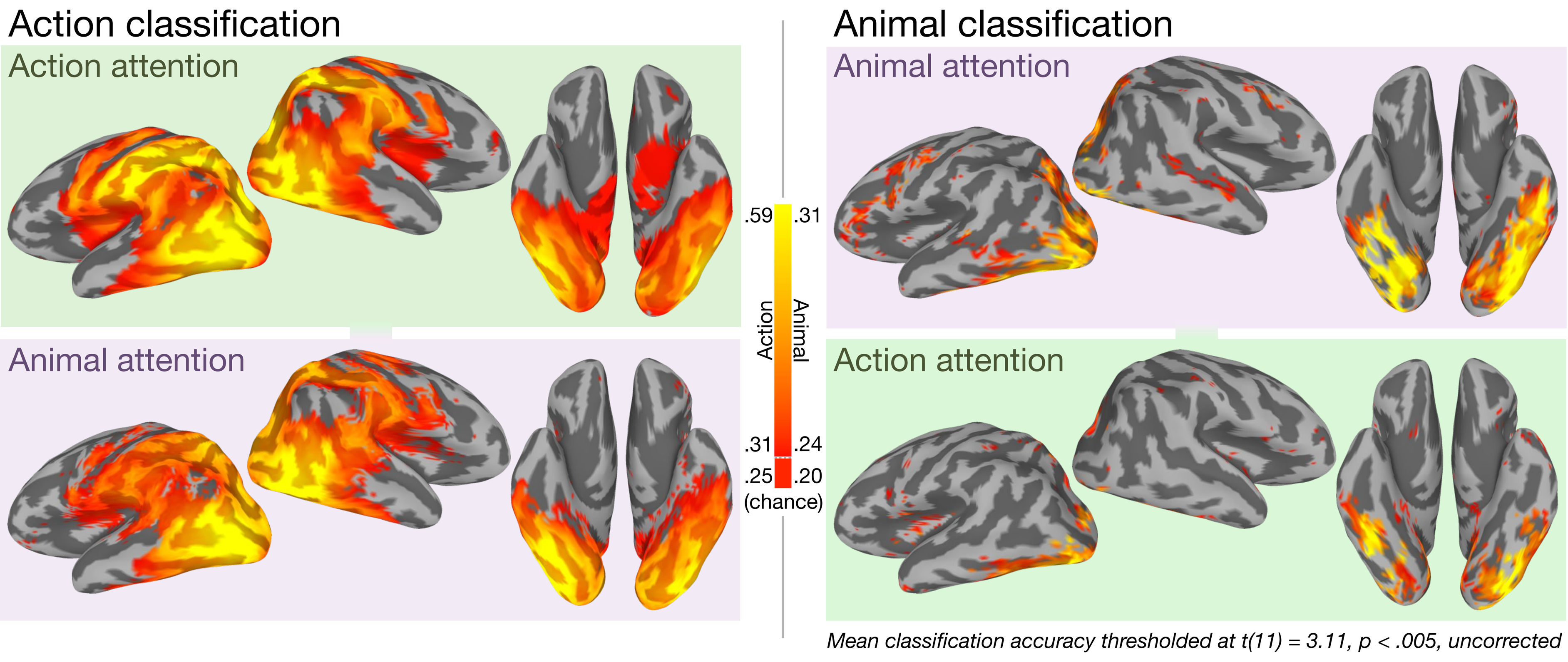
Change in animal beta per searchlight as a function of attention



Linear SVM classification searchlight

Surface-based searchlight classification using leave-one-sample-out cross-validation to control for low-level visual similarity and cross-modal information. All searchlight analyses performed on hyperaligned data using 100-node searchlights.

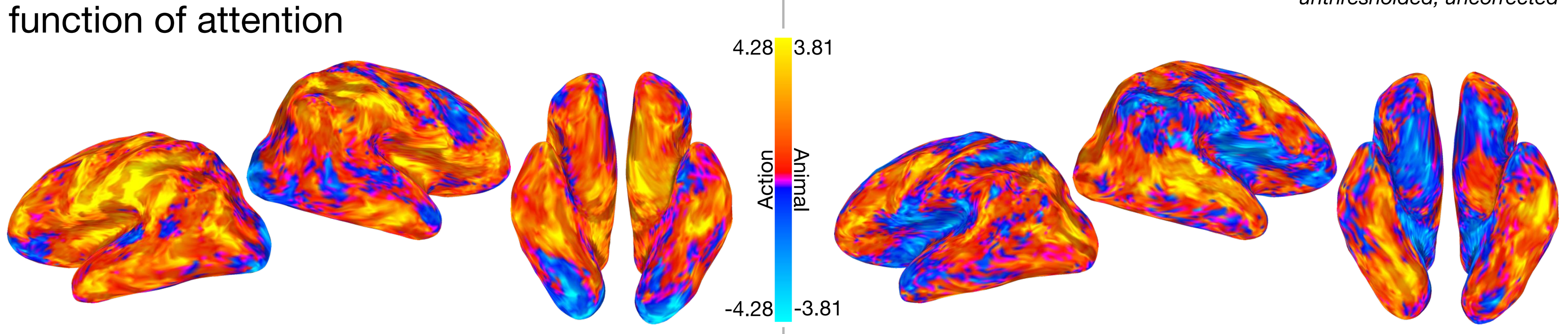




Mean classification accuracy thresholded at $t(11) = 3.11$, $p < .005$, uncorrected

Difference in classification accuracy as a function of attention

Z-transformed search-light t-statistic for paired t-test, unthresholded, uncorrected



Conclusions

Representational similarity regression and linear SVM classification yielded convergent searchlight maps.

Robust action representation was found in lateral occipitotemporal and posterior parietal cortices, and pre- and postcentral gyri. Animal representation was greatest in lateral occipital, posterior parietal, left inferior frontal, and ventral temporal cortices.

Attending to actions increased action discriminability in premotor cortex, and pre- and postcentral gyri, while decreasing discriminability in early visual cortex. Attending to animals increased animal discriminability in left inferior frontal gyrus and ventral temporal cortex.

Attentional effects were characterized by both decreased within-category representational distance and increased between-category distance.

Task-based changes in representational structure generalized across participants aligned to a common space via whole-brain hyperalignment.

Attentional effects on distributed representation adhere to the functional topography of cortex and are localized to areas representing task-relevant category information.

References:
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3. Oosterhof, N. N., Wiggett, A. J., Diedrichsen, J., Tipper, S. P., & Downing, P. E. (2010). Surface-based information mapping reveals cross-modal vision–action representations in human parietal and occipitotemporal cortex. *Journal of Neurophysiology, 104*(2), 1077-1089.
4. Haxby, J. V., Guntupalli, J. S., Connolly, A. C., Halchenko, Y. O., Conroy, B. R., Gobbini, M. I., Hanke, M., & Ramadge, P. J. (2011). A common, high-dimensional model of the representational space in human ventral temporal cortex. *Neuron, 72*(2), 404-416.