Characterizing the Spatiotemporal Neural Representations of Perceived Similarity Using Implicit and Explicit Tasks.

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Introduction

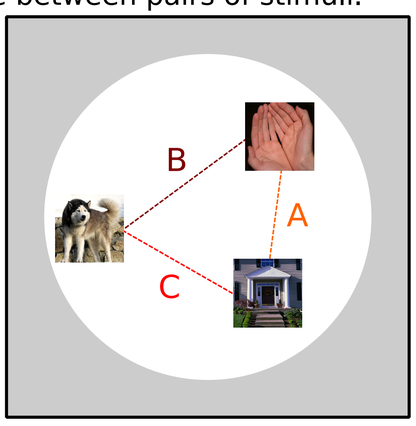
Perceived similarity judgments provid behavioral representations that strongly correlate with visual system activity through representational similarity analysi [1,2]. Many behavioral experiments using this paradigm utilise highly explicit, conscious judgements of similarity, such as the multiple arrangements (MA) task [4], which has been instrumental in successfully relating explicit behavioral information about stimuli to representational geometries of brain activity patterns [5,6,7,8] However, such explicit similarity judgments may not fully reflect representational geometries across the entire visual cortex [9]. Here, we aim to investigate how implicit and explicit similarity judgments capture complementary aspects of brain-behavior relations. By relating data from three tasks with varying levels of processing to recorded neural responses, we explore how they associate with the spatial (fMRI) and temporal (EEG) unfolding of object representations encoded in the ventral stream.

Methods

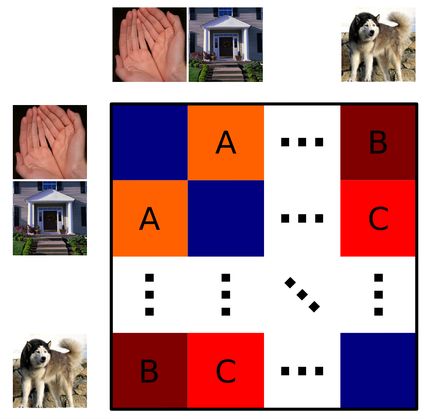
Explicit Pairwise Similarity Judgements: The Multiple Arrangements Task

A) Participants arrange stimuli on a 2D arena according to their percieved similarity.

B) Dissimilarity is measured as the euclidean distance between pairs of stimuli.

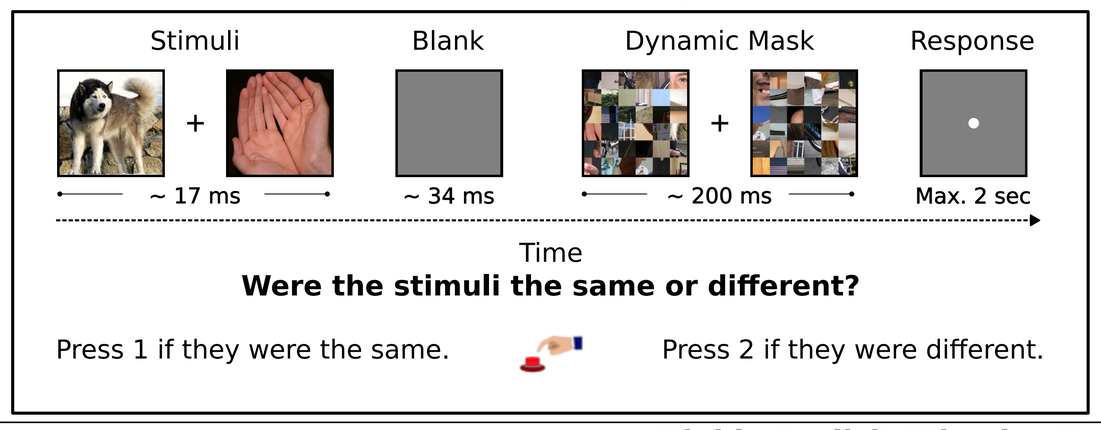


C) All pairwise euclidean distances are stored in an RDM

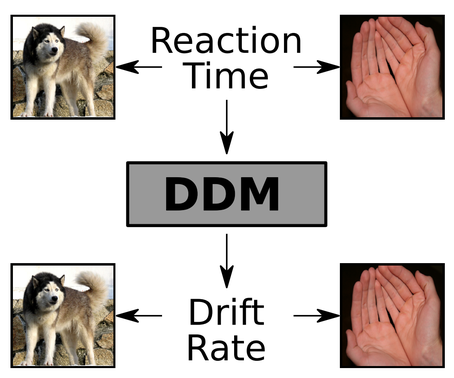


Implicit Pairwise Similarity Judgements: The Discriminability Task

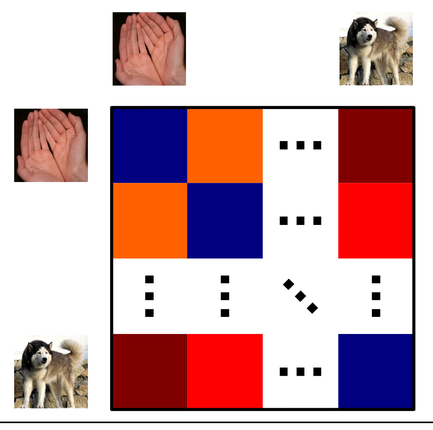
A) Participants are rapidly presented with two imaes in sequence and asked to indicate whether or not they were the same image.



B) Dissimilarity is measured as the inverse of the response time, passed to a drift diffusion model.

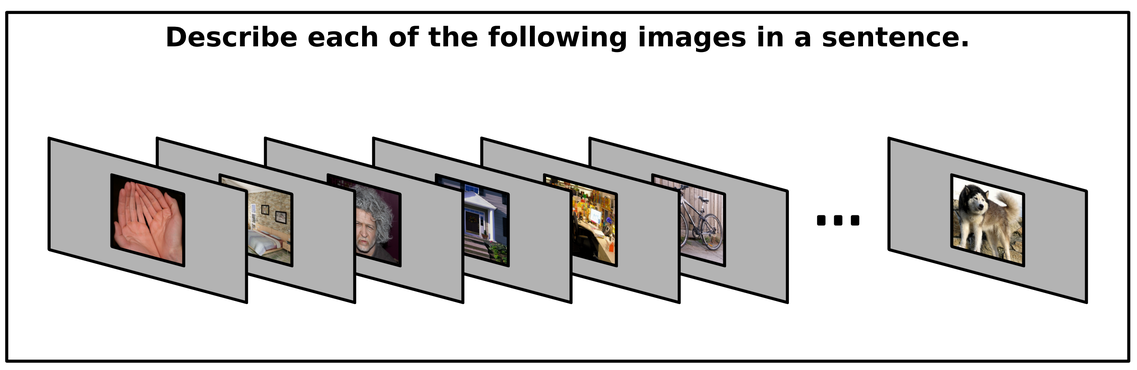


C) All pairwise drift rates are stored in an RDM

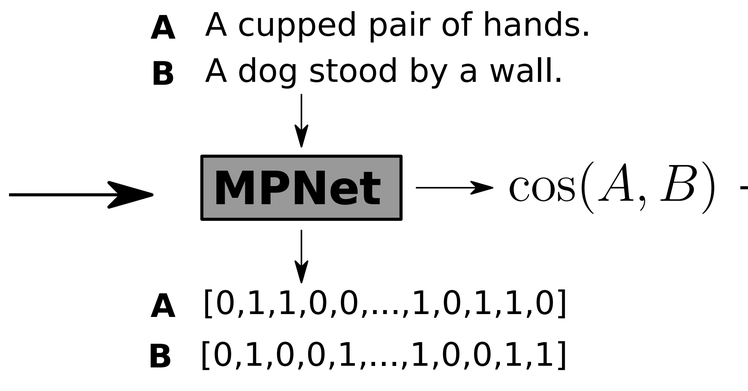


Highly Explicit Stimulus Descriptions: The Image Captioning Task

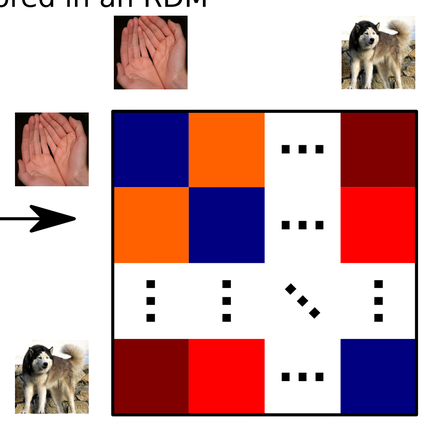
A) Participants are shown a series of images and asked to describe each one in a sentence.



B) Dissimilarity is measured as the cosine distance between sentence embeddings.

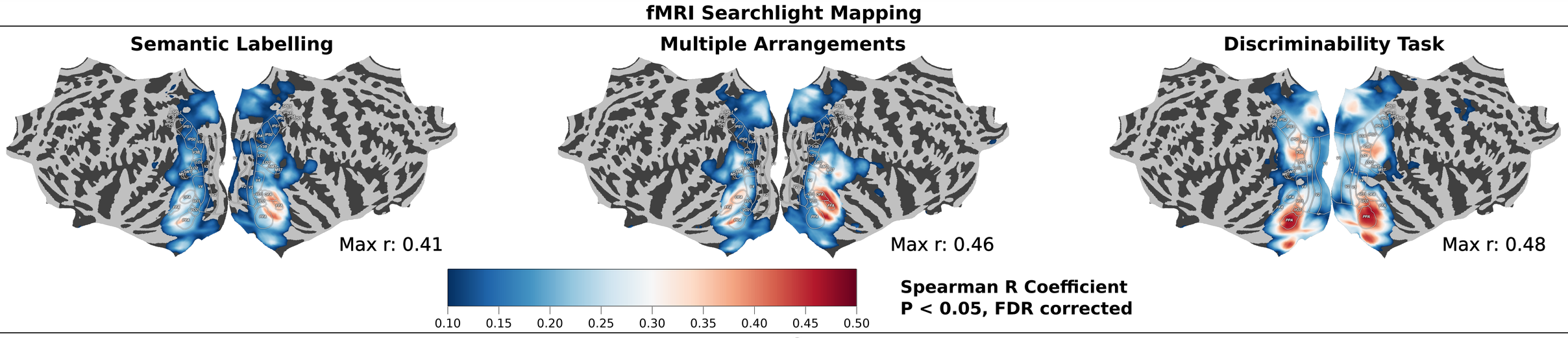


C) All pairwise cosine distances are stored in an RDM

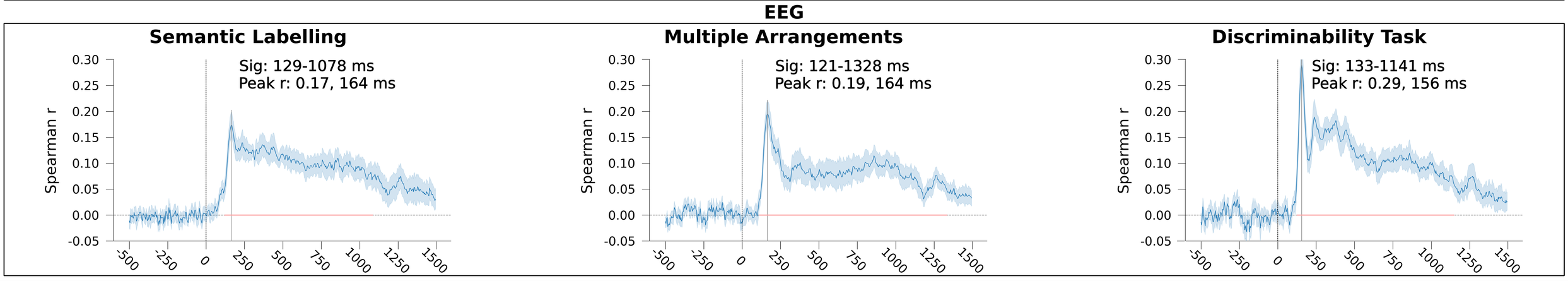


Results

fMRI Searchlight Mapping



EEG



Discussion

Implicit tasks, in which conscious decisions about similarity are absent, is a strong behavioural predictor of the neural representational geometry of the visual cortex in both space and time. Compared with explicit similarity judgements, this implicit task is able to explain representational geometries along the visual ventral stream in both more posterior regions and high-level anterior regions. Combining behavioural experiments that capture complementary features underlying similarity judgements can provide a more comprehensive spatiotemporal map of neural object representations than either could alone, and provide novel insights about behaviourally relevant brain representational similarities at different stages of information processing along the visual ventral stream.

References

1. Hebart MN, Zheng CY, Pereira F, Baker CI. Revealing the multidimensional mental representations of natural objects underlying human similarity judgements. Nature Human Behaviour. 2020;4(11):1173–85. doi:10.1038/s41562-020-00951-3 **2.** Waraich SA, Victor JD. A psychophysics paradigm for the collection and analysis of Similarity judgments. Journal of Visualized Experiments. 2022;(181). doi:10.3791/63461 **3.** Kriegeskorte N. Representational similarity analysis – connecting the branches of Systems Neuroscience. Frontiers in Systems Neuroscience. 2008; doi:10.3389/neuro.06.004.2008 **4.** Kriegeskorte N, Mur M. Inverse MDS: Inferring dissimilarity structure from multiple item arrangements. Frontiers in Psychology. 2012;3. doi:10.3389/fpsyg.2012.00245 **5.** Bankson BB, Hebart MN, Groen IIA, Baker CI. The temporal evolution of conceptual object representations revealed through models of behavior, semantics and Deep Neural Networks. NeuroImage. 2018;178:172–82. doi: 10.1016/j.neuroimage.2018.05.037 **6.** Charest I, Kievit RA, Schmitz TW, Deca D, Kriegeskorte N. Unique semantic space in the brain of each beholder predicts perceived similarity. Proceedings of the National Academy of Sciences. 2014;111(40):14565–70. doi:10.1073/pnas.1402594111 **7.** Cichy RM, Kriegeskorte N, Jozwik KM, van den Bosch JJF, Charest I. The spatiotemporal neural dynamics underlying perceived similarity for real-world objects. NeuroImage. 2019;194:12–24. doi:10.1016/j.neuroimage.2019.03.031 **8.** Mur M, Meys M, Bodurka J, Goebel R, Bandettini PA, Kriegeskorte N. Human object-similarity judgments reflect and transcend the primate-it object representation. Frontiers in Psychology. 2013;4. doi:10.3389/fpsyg.2013.00128 **9.** King ML, Groen IIA, Steel A, Kravitz DJ, Baker CI. Similarity judgments and cortical visual responses reflect different properties of object and scene categories in naturalistic images. NeuroImage. 2019;197:368–82. doi:10.1016/j.neuroimage.2019.04.079

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