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

Peter Brotherwood[1], Simon Faghel-Soubeyrand[2], Jasper van den Bosch[1], Ian Charest[1,]

1 - cerebrUM, Département de Psychologie, Université de Montréal;
2 - Department of Experimental Psychology, University of Oxford

Contact: peter.brotherwood@umontreal.ca

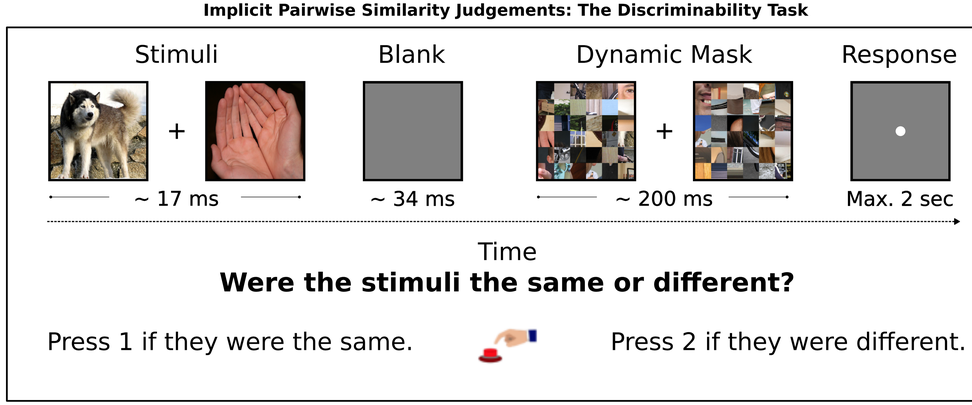
Introduction

Linking neural and behavioral activity is crucial for understanding and replicating the mechanisms behind visual stimulus recognition. Perceived similarity judgments have become increasingly popular in visual experiments, providing behavioral representations that strongly correlate with visual system activity [1,2]. Representational similarity analysis (RSA) facilitates identification of commonalities between neural and behavioral activity representations by comparing dissimilarity between all pairwise combinations of stimuli [3]. For large stimulus sets, the multiple arrangements (MA) task [4] has been instrumental in successfully relating explicit behavioral information about stimuli to representational geometries of brain activity patterns [5,6,7,8] in both space and time [5,7], owing to its efficiency in collecting pairwise similarity judgments. 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.

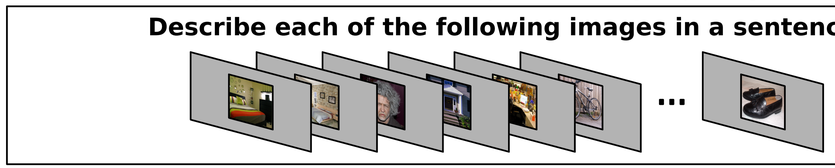
Methods

Explicit Pairwise Similarity Judgements: The Multiple Arrangements Task

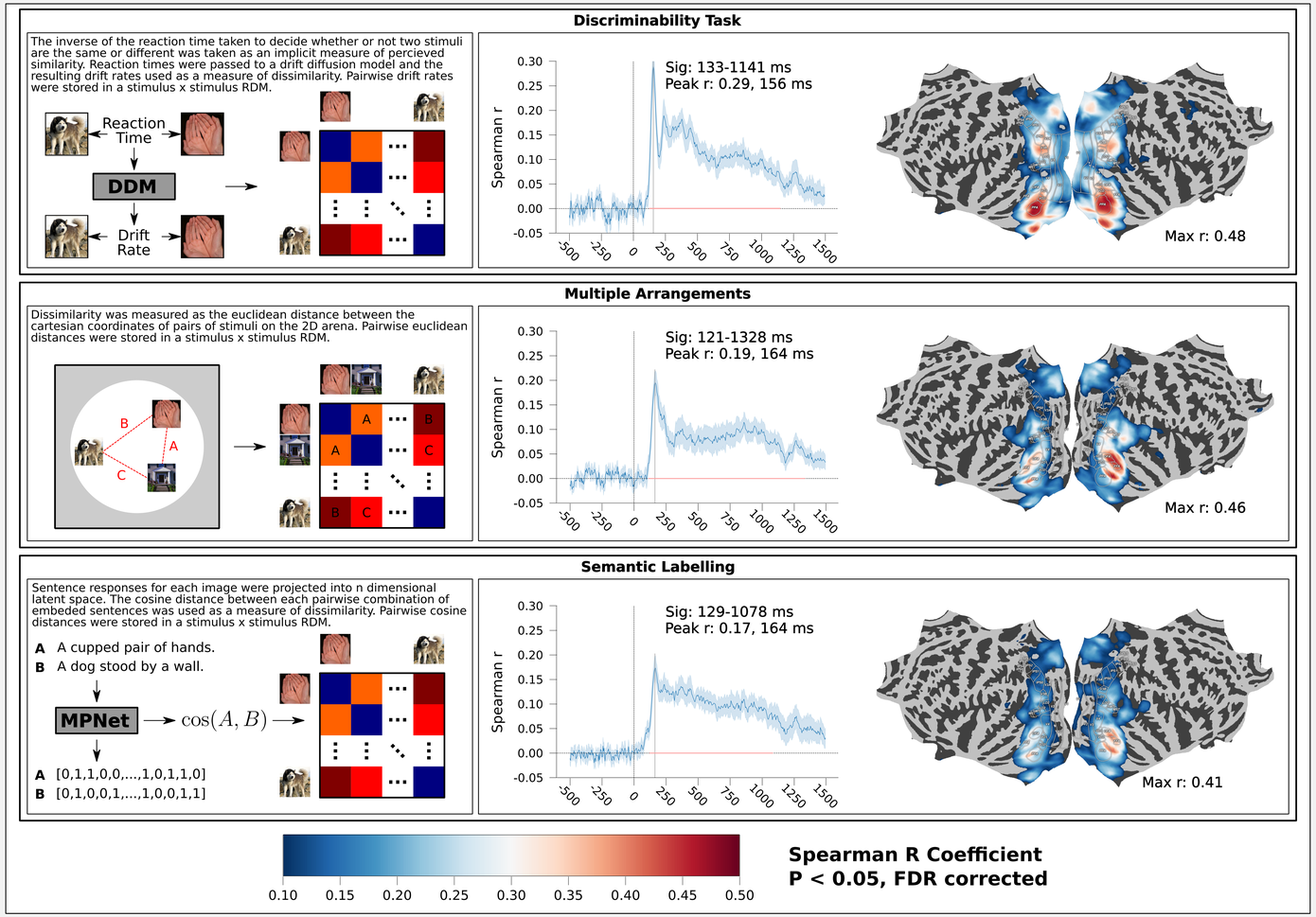
Implicit Pairwise Similarity Judgements: The Discriminability Task



Highly Explicit Stimulus Descriptions: The Image Captioning Task



Results



Discussion

This study compared how behavioural experiments designed to capture explicit, implicit and high-level semantic similarity judgments can explain the spatio-temporal unfolding of object representations in the visual ventral stream. Our results showed that an implicit task, 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.

While implicit judgments have been used in the past[1,10], the same-different task is not constrained by the need to combine similarity judgments across many participants, allowing single-subject analyses. Indeed, this task has been used previously to investigate idiosyncratic brain and behavioural relationships[6], something to which spatio-temporal characterisation could be extended. Altogether, our results highlight how 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
10. Magri C, Konkle T. Comparing facets of behavioral object representation: Implicit perceptual similarity matches brains and Models. 2019 Conference on Cognitive Computational Neuroscience. 2019; doi:10.32470/ccn.2019.1395-0