

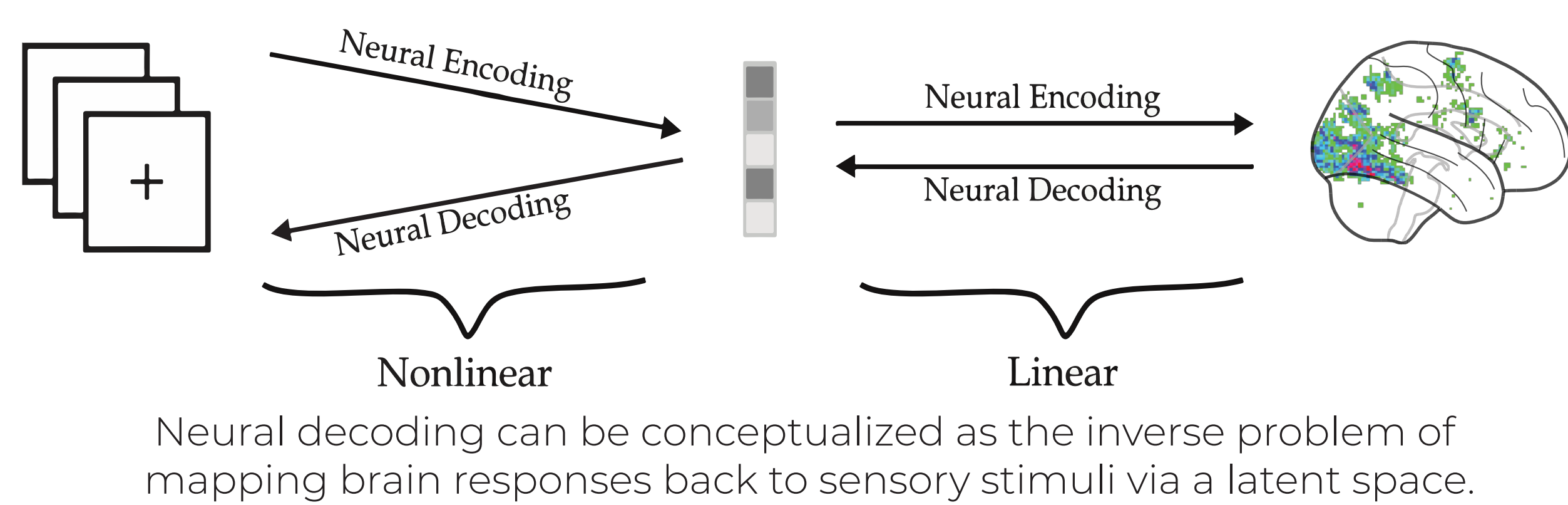
Hyperrealistic neural decoding: Reconstruction of face stimuli from fMRI measurements via the QAN latent space

Thirza Dado, Yağmur Güçlütürk, Luca Ambrogioni, Gabriëlle Ras, Sander Bosch, Marcel van Gerven, Umut Güçlü

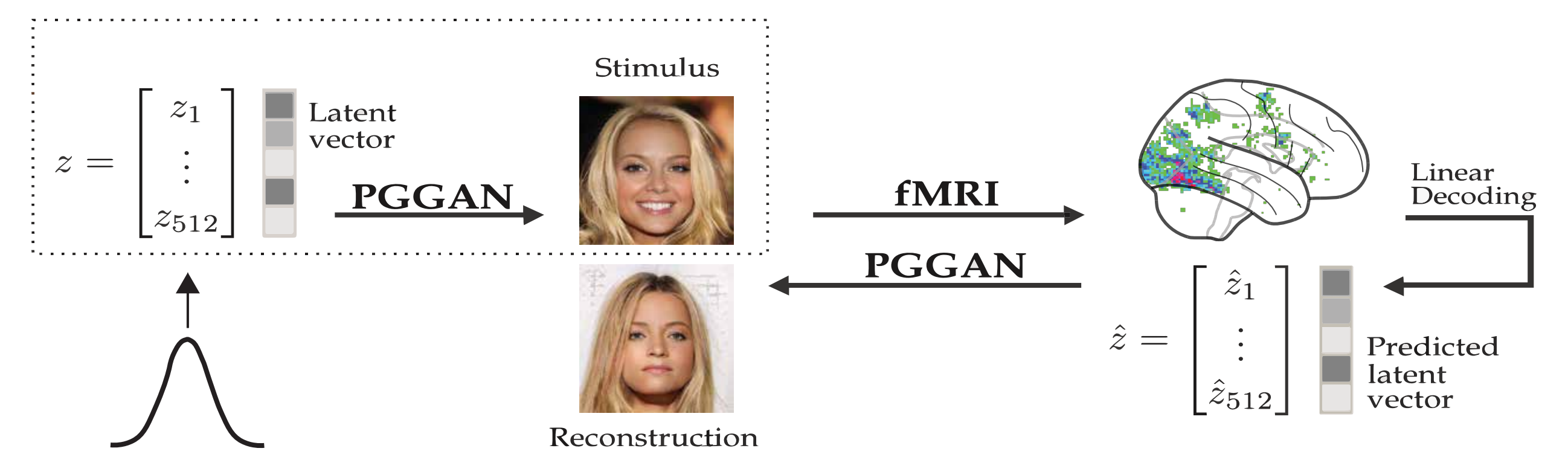
Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, Netherlands

INTRODUCTION

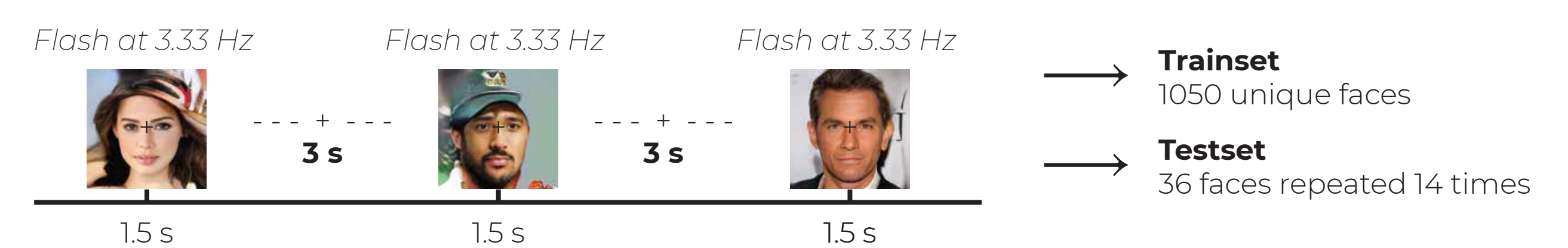
- Unlike their supervised counterparts [1], more biologically plausible unsupervised deep neural networks (DNNs) have paradoxically been unsuccessful in modeling neural representations [2].
- At the same time, generative adversarial networks (GANs) have become one of the most powerful unsupervised DNNs in modeling image representations.
- Problem:** GANs have high potential in modeling neural representations, but testing this hypothesis is not directly possible because latent representations cannot be obtained retrospectively [3].
- Solution:** A novel experimental paradigm for well-controlled yet naturalistic stimuli with known latent representations, and a GAN-based neural decoding model for HYperrealistic reconstruction of PERception (HYPER) with unprecedented accuracy to date.



METHODS



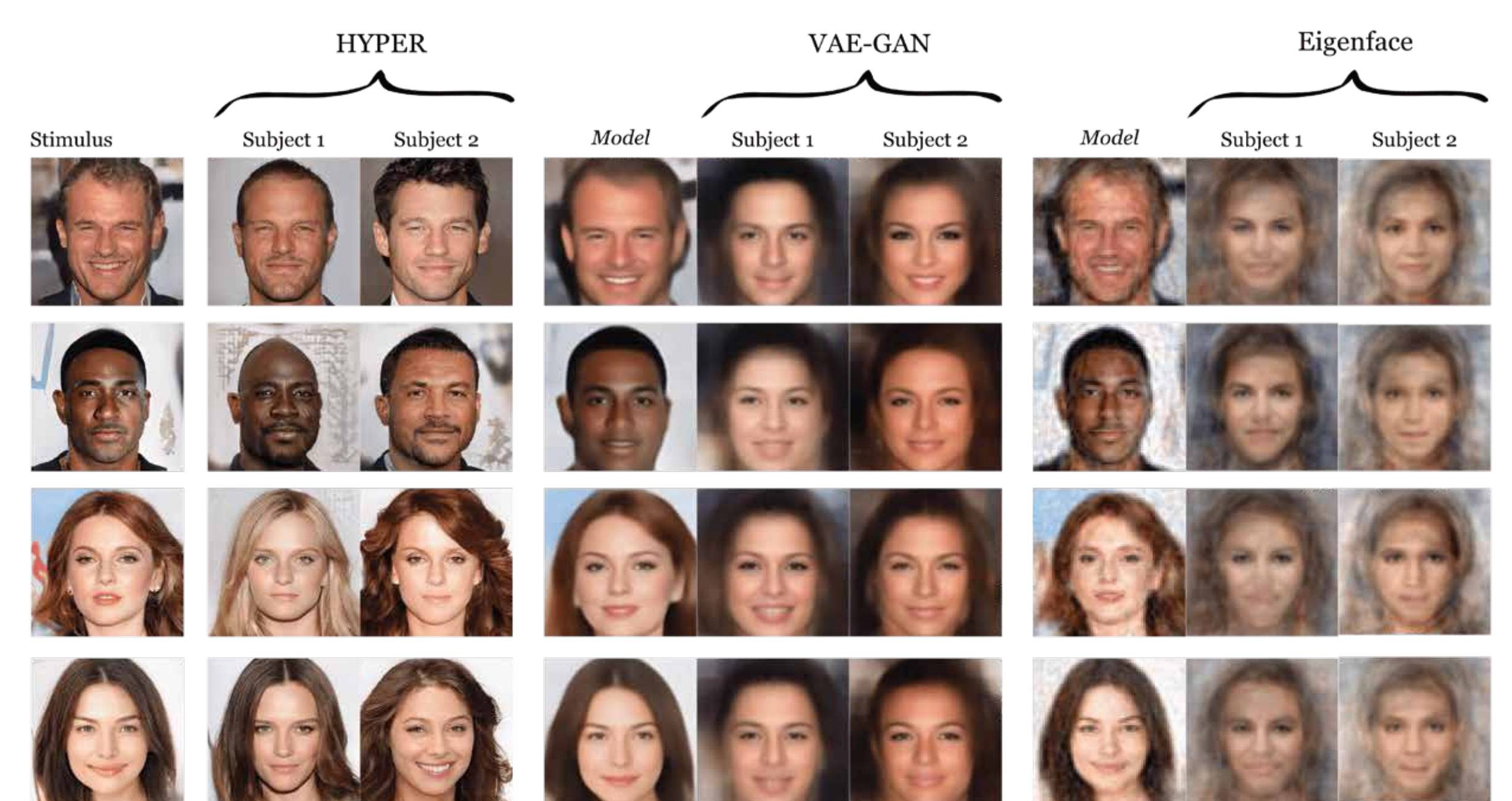
- The progressive growing of GANs (PGGAN) model** [4] generates photo-realistic faces (1024 x 1024 pixels) that resemble celebrities from randomly sampled latent vectors (512 dims).
- Blood-oxygen-level dependent hemodynamic responses** (TR = 1.5 s, voxel size = 2 x 2 x 2 mm³, whole brain) of two subjects were measured during presentation of faces.
- Linear decoding** by a dense layer at the beginning of PGGAN to transform brain data into latent vectors.



RESULTS

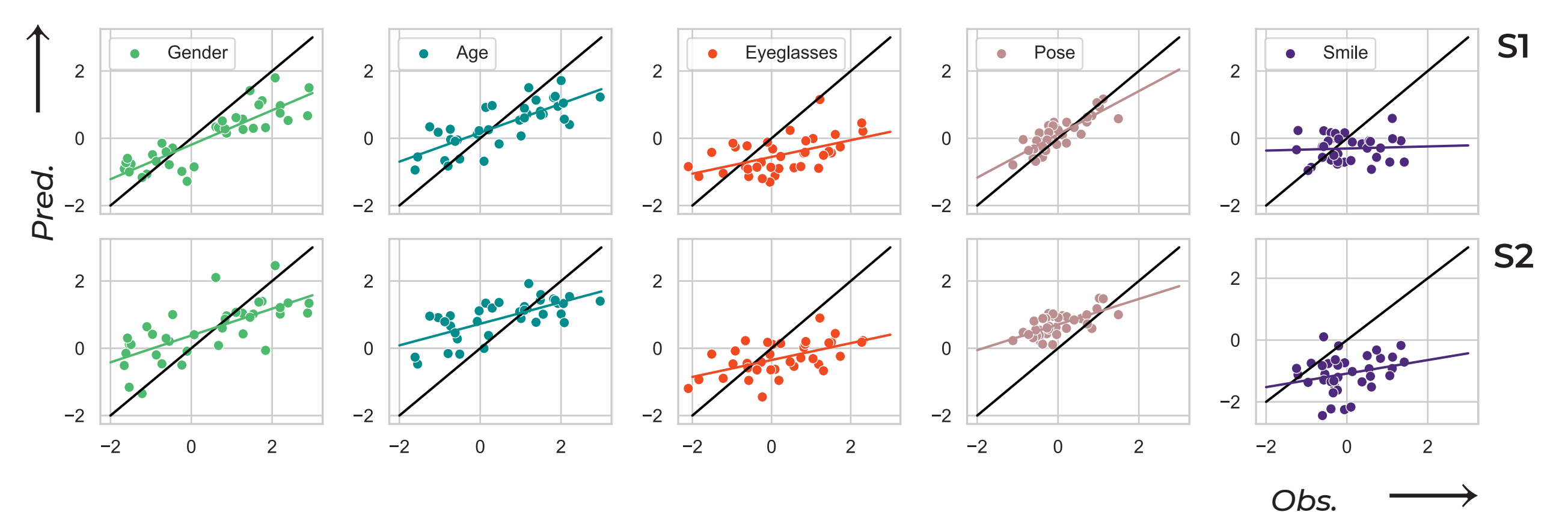


QUALITATIVE RESULTS



QUANTITATIVE RESULTS

		Lat. sim.	Feat. sim.	Struct. sim.
S1	HYPER	0.4521 ± 0.0026 (p < 0.001; perm.test)	0.1745 ± 0.0038 (p < 0.001; perm.test)	0.6663 ± 0.0115 (p < 0.001; perm.test)
	VAE-GAN	-	0.1416 ± 0.0025	0.5598 ± 0.0151
	Eigenface	-	0.1319 ± 0.0016	0.5877 ± 0.0115
S2	HYPER	0.4447 ± 0.0020 (p < 0.001; perm.test)	0.1715 ± 0.0049 (p < 0.001; perm.test)	0.6035 ± 0.0128 (p < 0.001; perm.test)
	VAE-GAN	-	0.1461 ± 0.0022	0.5832 ± 0.0141
	Eigenface	-	0.1261 ± 0.0019	0.5616 ± 0.0097



CONCLUSIONS

With the introduced paradigm and model we:

- Showed that unsupervised deep neural networks can successfully model neural representations of naturalistic stimuli
- Showed that the GAN latent space approximates the neural face manifold
- Obtained state-of-the-art reconstructions of perceived faces from brain activations

Considering the speed of progress in the field of generative modeling, the HYPER framework will likely result in even more impressive reconstructions of perception in the near future.

REFERENCES

- Güçlü, U., & van Gerven, M. A. (2015). Deep neural networks reveal a gradient in the complexity of neural representations across the ventral stream. *Journal of Neuroscience*, 35(27), 10005-10014. Chicago
- Khaligh-Razavi, S. M., & Kriegeskorte, N. (2014). Deep supervised, but not unsupervised, models may explain IT cortical representation. *PLoS computational biology*, 10(11), e1003915.
- Seeliger, K., Güçlü, U., Ambrogioni, L., Güçlütürk, Y., & van Gerven, M. A. (2018). Generative adversarial networks for reconstructing natural images from brain activity. *NeuroImage*, 181, 775-785.
- Karras, T., Aila, T., Laine, S., & Lehtinen, J. (2017). Progressive growing of gans for improved quality, stability, and variation. *arXiv preprint arXiv:1710.10196*.
- Shen, Y., Gu, J., Tang, X., & Zhou, B. (2020). Interpreting the latent space of gans for semantic face editing. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 9243-9252).