Hyperrealistic neural decoding of faces

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***Abstract*— We show how generative modeling approximates the neural (face) manifold by obtaining state-of-the-art reconstructions of perceived face images from fMRI activations.**

I. Introduction

Neural decoding can be conceptualized as the problem of mapping brain responses back to the sensory stimuli via a feature space [3]. At present, GANs [1] have emerged as perhaps the most powerful generative models to date. The defining latent features needed for the synthesis of hyperrealistic data potentially overlap with the captured stimulus features in neural representations. However, testing this hypothesis is not directly possible because GANs are unidirectional such that latent vectors of arbitrary stimuli cannot be obtained retrospectively. We circumvent this problem by training a model for HYperrealistic reconstruction of PERception (HYPER) on generated yet highly naturalistic stimuli with known latent vectors.

II. Methods

The HYPER model elegantly integrates GANs in neural decoding by combining the following components:

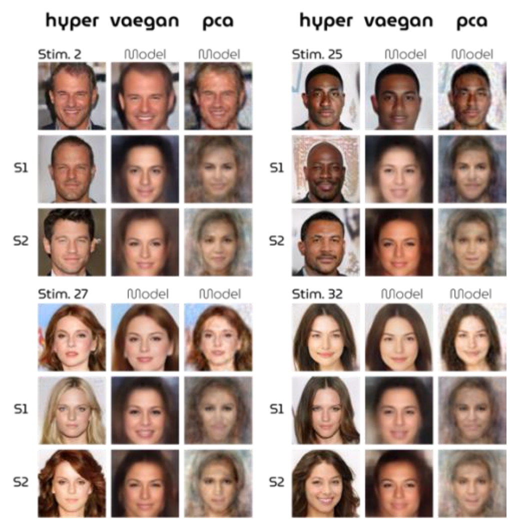
- A pretrained generator network of a progressive growing of GAN (PGGAN) [2] that generates photorealistic face images (1024 × 1024 px) from 512-dim. latents sampled from the std. Gaussian.
- A new fMRI dataset of synthesized face images and whole-brain fMRI activations of two subjects.
- A decoding model that predicts latents from fMRI activations which are fed to the generator for reconstruction. For this, the generator network was adapted by prepending a dense layer.

Stimuli. A training and test set were assembled of 1050 and 36 face images, respectively. Training set images were each presented once to ensure covering a large stimulus space to fit a general face model whereas test set images were each repeated 14 times to increase SNR.

Brain data. An fMRI dataset was collected during perception of face stimuli. The fMRI measurements (TR = 1.5 s, voxel size = $2 \times 2 \times 2$ mm^3, whole-brain coverage) of two subjects were measured while they were fixating a central target superimposed to minimize involuntary eye movements. During preprocessing, the obtained brain volumes were realigned to the first and the mean functional scan, respectively, after which they were normalized to MNI space. A GLM is fit to deconvolve task-related neural activation with the canonical HRF. For each stimulus, we obtained a brain map in terms of the z-statistic. Next, the most-active 4096 voxels were selected from the training set to define a voxel mask which was used for the remainder of the study.

III. Results

HYPER achieved state-of-the-art reconstructions (Fig. 1) while significantly outperforming the baselines in feature and structural similarity ($p < 0.001$; permutation test).



Four representative test set stimuli and reconstructions. Left: HYPER. Middle: (state-of-the-art) pretrained VAE-GAN [4]. Right: (conventional) PCA (i.e., eigenfaces). The *model* image shows the noise ceiling.

IV. Conclusion

Considering the speed of progress in the field of generative modeling, it is likely that neural decoding with synthesized data will soon result in even more impressive reconstructions.

References

[1] Ian Goodfellow, Jean Pouget-Abadie, Mehdi Mirza, Bing Xu, David Warde-Farley, Sherjil Ozair, Aaron Courville, and Yoshua Bengio. Generative adversarial nets. In *Advances in Neural Information Processing Systems*, pages 2672–2680, 2014.

[2] Tero Karras, Timo Aila, Samuli Laine, and Jaakko Lehtinen. Progressive growing of gans for improved quality, stability, and variation. *arXiv preprint arXiv:1710.10196*, 2017.

[3] Marcel AJ van Gerven, Katja Seeliger, Umut Güçlü, and Yağmur Güçlütürk. Current advances in neural decoding. In *Explainable AI: Interpreting, Explaining and Visualizing Deep Learning*, pages 379–394. Springer, 2019.

[4] Rufin VanRullen and Leila Reddy. Reconstructing faces from fmri patterns using deep generative neural networks. *Communications biology*, 2(1):193, 2019.