Evolving synthetic images for the control of affective experience

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INTRODUCTION

- **Realtime fMRI (rt-fMRI)** is a method of using brain data in real-time to shape an experimental stimulus (Figure 1).
- Previous research in macaques has used intracranial recordings to guide AI image evolution.
- In humans, whole-brain fMRI can be used to evolve images targeting conscious experiences, such as emotions.

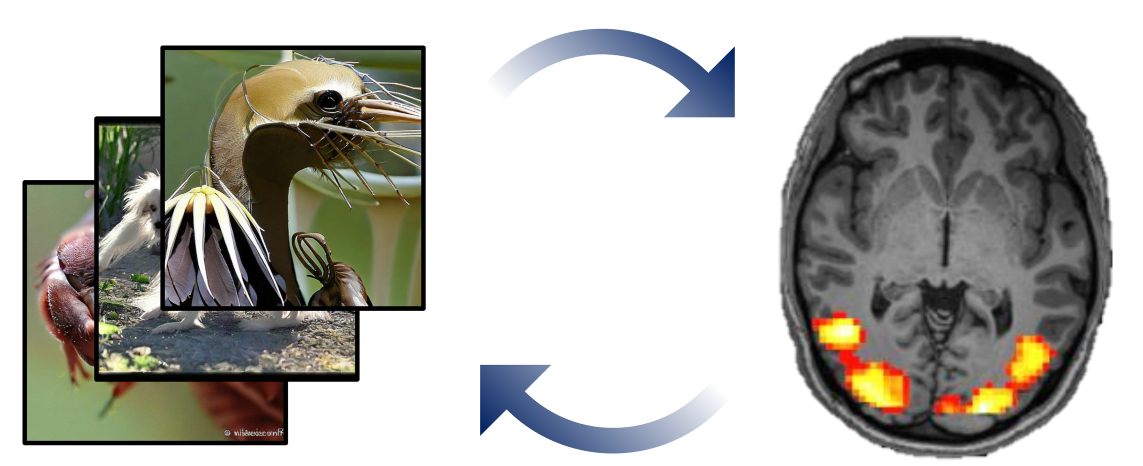

Figure 1. Diagram of a decoded neurofeedback paradigm.

- We developed a Python-based pipeline for evolving fearful animal images in real-time.
- After a pilot study using self-reported fear and skin conductance responses (SCRs), we are preparing an rt-fMRI version.
- This method may allow us to visualize what fMRI brain decoders are responding to, and whether it aligns with the targeted state.

Figure 2. Examples of image evolution using random numbers (control) and skin conductance responses (SCR).

RESULTS

BEHAVIOURAL PILOT STUDY

- Evolving images based on self-reported fear ratings significantly increased the fearfulness of images (Figure 3; $n = 20$, $p < 0.001$).
- Evolving images based on SCRs did not increase fear ratings.
- However, it did tend to converge on similar categories of images as compared to self-report (Figure 5).
- Fear ratings and SCRs did not exhibit significant correlations (p's > 0.05).

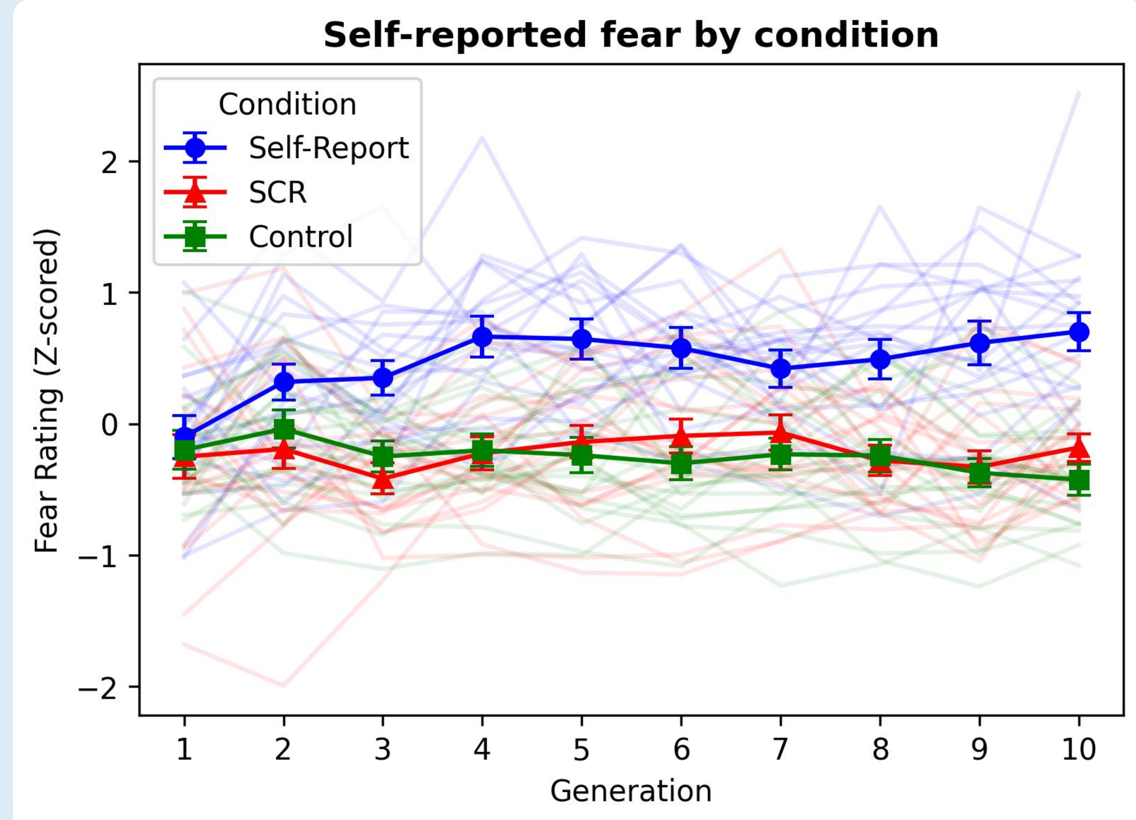

Figure 3. Results of a behavioural pilot with n=20 participants. Each generation contains 8 synthetic images. Error bars = 95% CI.

REALTIME FMRI STUDY

- Our PCR model successfully decoded fear ratings in a pilot subject ($r^2 = 0.1$, $r = 0.3$).
- Our Python-based realtime pipeline could process fMRI frames with a sub-1s TR and present new images every 4s.
- First pilot results were recently acquired and demonstrate the functioning of the pipeline (n=1; Figure 4) . More data is needed for conclusions.

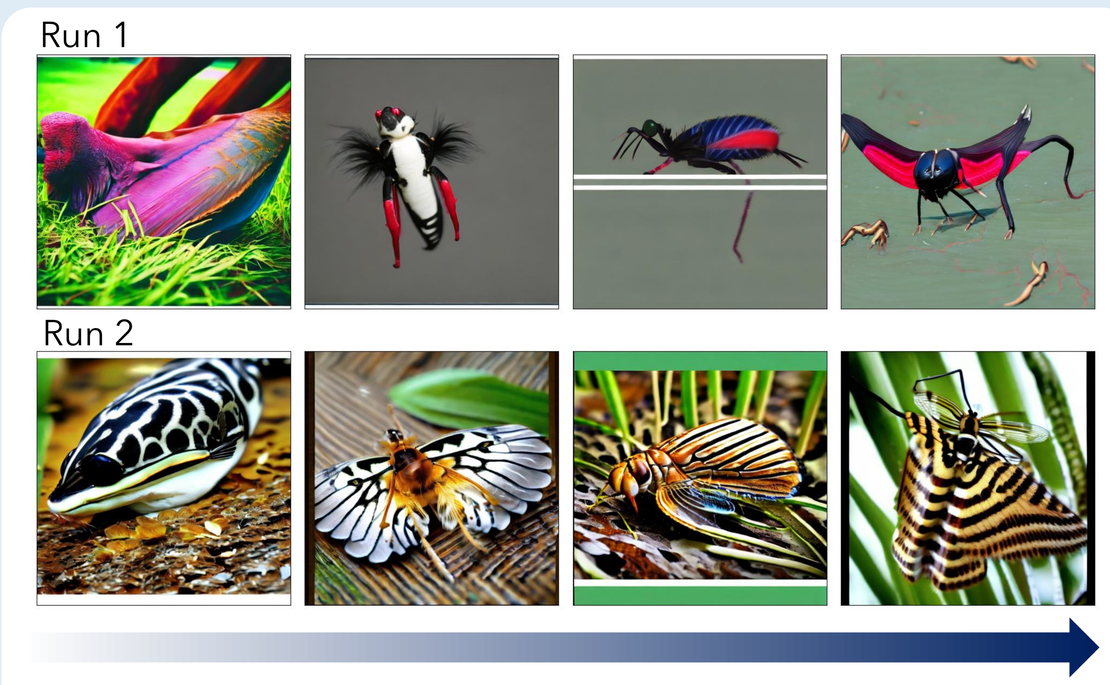

Figure 4. Pilot results for the decoded neurofeedback paradigm. The top scoring images across several generations are shown.

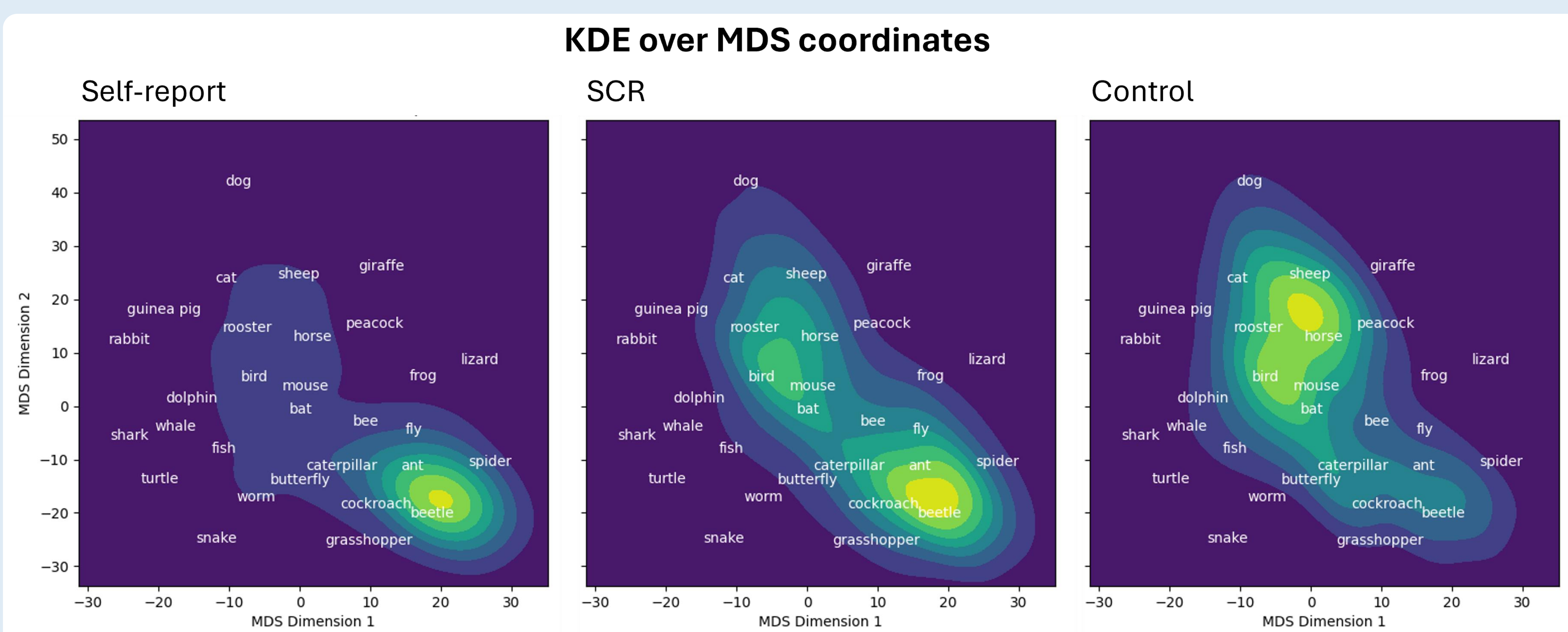

Figure 5. Regions of a multi-dimensional scaling (MDS) space occupied by images at the end of evolution using three fitness criteria.

METHODOLOGY

- Stable unCLIP was used to generate images from latent space embeddings.
- A PCA over 2,700 animal image embeddings was used to define a subdomain of CLIP.
- Image evolution used a simplified version of Covariance Matrix Adaptation (CMA-ES).
- Self-reported ratings and skin conductance responses were used in a pilot study.
- For training brain decoders, we created a Creative Commons stimulus library of 400 naturalistic animal videos.
- We developed a Python-based principal component regression (PCR) pipeline to predict fear from fMRI data in real-time.

CONCLUSION

- Image evolution is a viable method for creating affective stimuli in humans.
- A 100% Python-based image evolution pipeline, along with a Creative Commons library of animal videos, is publicly available.
- This method may help us understand the link between felt emotions and biometric models.

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