

Trial-by-trial fMRI-neurofeedback dissociates fusiform and occipital contributions to face detection and recognition

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Introduction

The fusiform face area (FFA) and occipital face area (OFA) are both central to face perception, but their respective roles remain contested. Hierarchical models place OFA first, extracting local features that feed forward to FFA for holistic analysis and identity recognition. Non-hierarchical models reverse this: FFA performs an early, global detection of a face, while OFA is recruited in parallel to supply the local detail needed for recognition. Standard task fMRI struggles to arbitrate between these accounts because the two regions co-activate and correlate during face processing, obscuring their individual contributions. Real-time fMRI neurofeedback (rt-fMRI NFB) offers a way around this. By biasing activity toward one region before a stimulus appears, we can test how that bias shapes behaviour. We trained participants to self-regulate the relative activity of right FFA versus right OFA on a trial-by-trial basis, a state we call ROI dominance, and immediately probed face detection and recognition. The hierarchical model predicts that OFA dominance aids detection and FFA dominance aids recognition. The non-hierarchical model predicts the reverse for detection, with FFA dominance speeding it up.

Methods

Forty-two healthy adults took part: an experimental group (EXP, N=22) receiving veridical feedback and a yoked control group (CONT, N=20) receiving sham feedback copied from an EXP participant. Right FFA and right OFA were localized individually from a functional localizer. Each participant trained on two consecutive days, one session promoting FFA dominance and the other OFA dominance, driven by a differential feedback signal (target minus non-target percent signal change). Each session comprised 7 runs of 7 trials. Every trial ran through four phases (Fig. 1A): a counting baseline, a 25s regulation phase with continuous thermometer feedback of the differential signal, a visual task, and a brief intermittent feedback score. During the task (Fig. 1B) a face (67% of trials) or animal (33%) was revealed gradually across 200 noise-reduced frames; participants pressed to indicate detection (face or animal) and then recognition (old or new), with the frame number of each correct response serving as a latency measure. Imaging used a 3T scanner (TR 800 ms) with real-time processing in a customized version of OpenNFT. We analysed the data with permutation tests on regulation time-courses, linear mixed models linking regulation to task-evoked activity and activity to behaviour, and structural equation path models fitted separately per group.

Results

Only the EXP group learned to bias their target region. Differential activity diverged progressively across runs toward the trained region (Run $\times$ Session $\times$ Group: $\beta = 0.33$, $p < 0.001$), an effect absent in CONT. Regulation was strongest for OFA, while FFA showed a persistent baseline dominance that OFA training gradually offset. Whole-brain analysis confirmed the regulation was face-selective: EXP participants co-activated the core and extended face network, including bilateral FFA, OFA, pSTS, and inferior frontal gyrus, with focal overlap on face-localizer clusters in FFA and pSTS. CONT showed no such activation. Pre-stimulus regulation carried into the task, with upregulation of a region strengthening its own detection and recognition responses. Behaviourally, the two processes dissociated. Face detection was faster with higher FFA ($\beta = -3.92$, $p = 0.016$) and lower OFA activity ($\beta = 10.64$, $p < 0.001$), and their interaction ($\beta = 6.99$, $p < 0.001$) showed the FFA benefit grew as OFA activity fell. Face recognition instead peaked when both regions were active together, each region's contribution amplified by the other (FFA $\times$ OFA: $\beta = -3.19$, $p = 0.002$). Across the board,

higher FFA aided both detection and recognition, whereas OFA hindered detection but supported recognition. Path analysis reproduced this structure in EXP. CONT retained only weak intrinsic links between task activity and behaviour, with no feedback-driven paths.

Conclusions

Using real-time fMRI neurofeedback to bias the balance of activity between FFA and OFA, we show that the two regions play distinct and, for detection, opposing roles in face perception. Detecting that a stimulus is a face was helped by FFA activity but hindered by OFA, consistent with OFA's focus on fine local detail working against the fast, holistic processing that separates a face from a non-face. Recognizing whose face it is required both regions together: their co-activation benefited performance beyond either region alone, pointing to an integration of detailed feature analysis with a broader structural representation of the face. These results support a non-hierarchical account in which FFA and OFA are not sequential stages in a feedforward chain but distinct, interacting systems with complementary functions, contrary to the classic model routing information from occipital to temporal cortex. To our knowledge this is also the first demonstration that people can self-regulate two functionally interconnected regions, biasing the balance of activity within a network with measurable consequences for perception.

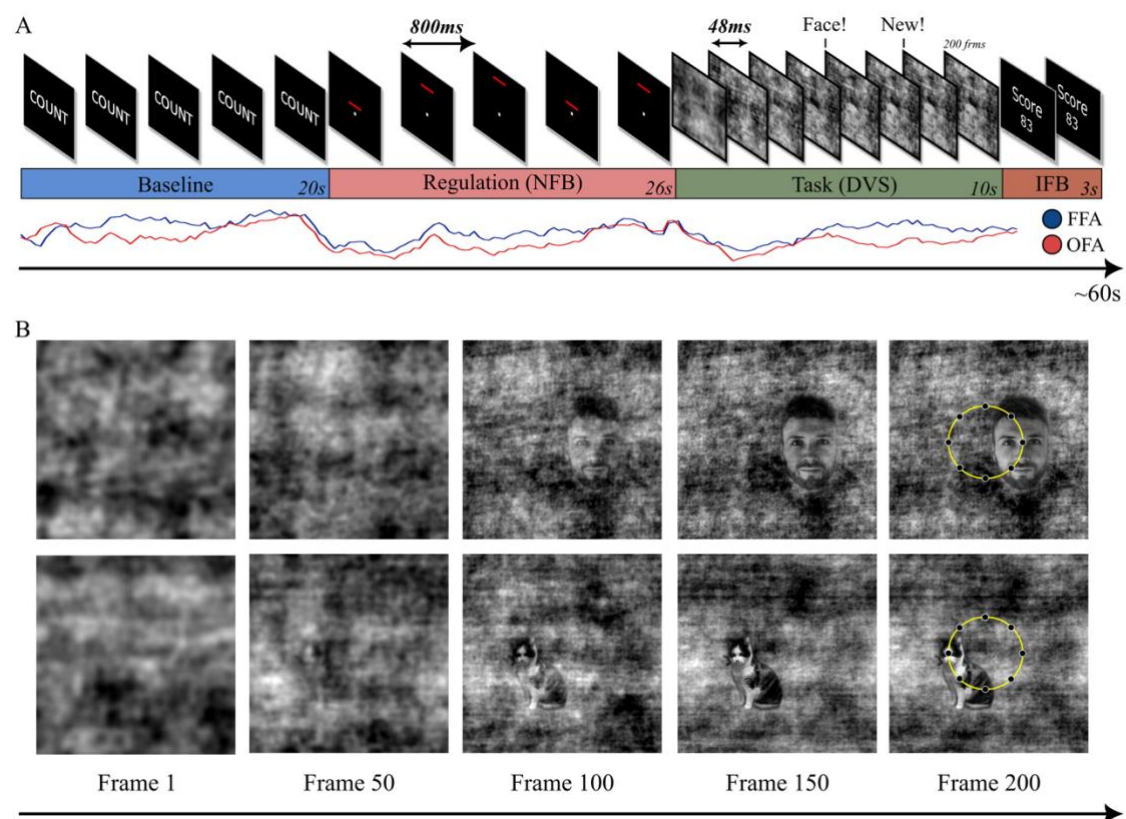


Figure 1. Single neurofeedback trial. (A) Each trial ran through four phases: a baseline count-down (blue), a regulation phase (red) with continuous thermometer feedback of the differential FFA/OFA signal, a visual task (green), and a brief performance score (IFB, dark red). (B) During the task, a face (top) or animal (bottom) emerged from noise over 200 frames. Participants reported detection (face or animal) and then recognition (old or new). Yellow circles mark the possible stimulus positions.

References

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