Supplementary Materials List:

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Supplementary Methods

Learning Effect across Rt-fMRI Neurofeedback Training

The learning effect measures the change in BOLD activation in trained brain region/s across the neurofeedback training sessions. The mean percentage signal change (PSC) for each training run and ROI was calculated and plotted (seeFigure2B in main paper, and compare with S1, S2).

Supplementary Results

Results - Behaviour

Binocular Rivalry – Durations:

See main paper.

Results – Imaging

Strategy-related and Strategy-unrelated ROIs:

We first determined if the differential signal significantly changed over days across participants (see main paper, Result Section). We additionally examined the changes in the two ROIs used to produce the differential signal; the strategy-related ROI and the strategy-unrelated ROI (see Figure 2, main paper).

A one-way ANOVA (with 3 levels corresponding to the 3 training days) revealed a significant reduction in activation in the strategy-unrelated ROI over the 3 days of training ($F(2,16)= 8.71$, $p= 0.003$). On the other hand, a one-way ANOVA for the strategy-related ROI revealed no significant change ($F(2,16)= 0.33$, $p= 0.72$).

Sub-groups:

To assess whether there was any difference between the face and house group during training, an ANOVA was performed on the differential training signal across the 3 training days, with a between-subjects factor with two levels (for the two sub-groups, ‘Face’ and ‘House’). This did not reveal a significant interaction ($F(2,14)=0.064$, $p=0.94$) between the two factors.

For neurofeedback training graphs for the two groups (mean percentage signal change over 9 sessions), please see Figures S2 and S3.

Supplementary Discussion

Levelt's Second Proposition, 1966

Levelt's second proposition(Levelt, 1966), as applied to stimulus perception was based on the physical properties of visual stimuli and states: *"Variation of the stimulus strength in one eye will only influence the mean dominance duration of the contralateral eye and not the mean dominance duration of the ipsilateral eye".*

Known Influences on Visual Perception

The role of 'priming' and 'cueing' might also be invoked as possible causes for the perceptual changes observed following neurofeedback training in this study. Prior presentation of a specific orientation grating can cause an increase in the perception of the identical grating during BR. However, dominance durations were unchanged(Denison et al., 2011). Similarly, exogenous cueing prior to BR can increase the probability of the predominant percept being linked to the cue. For example prior to BR, hearing sentences with the word 'face', results in FFA activation(Pelekanos et al., 2011). Nonetheless, no significant change in stimulus dominance between faces and houses on rivalry trials were observed when participants were cued with a word linked to one of the rivalrous stimuli. Dominance durations have also been demonstrated as being immune to the effects of volitional attention(Jung et al., 2016), and reflective of true differences in sensory processing(Dieter et al., 2016). It is therefore unlikely that the perceptual changes produced by neurofeedback training could be ascribed to participant expectation. Evidently, neither altering the level of activity in higher order brain regions involved in perception, nor applying known influences on visual perception, provide a comprehensive explanation for the lasting shifts in perceptual bistability observed following neurofeedback training in this study.

Controlling the Neurofeedback Signal

With regards to the neurofeedback training signal itself (i.e. differential brain activation between two ROIs), there were five potential activation states which could increase the difference between the two brain regions (*strategy-related ROI minus strategy-unrelated ROI*), leading to upregulation of the training signal: These could be: (1) an increase in *strategy-related ROI*; (2) a decrease in *strategy-unrelated ROI*; (3) a combination of the two; (4) a relatively greater increase in *strategy-related ROI* as compared to *strategy-unrelated ROI*; and (5) a relatively greater decrease in the *strategy-unrelated ROI*. Based on our results (Figure 1B in main paper), the mechanism for the upregulation of the differential signal across groups during neurofeedback training appeared to be produced by maintenance of activation in the strategy-related ROI, and a reduction of activation in the strategy-unrelated ROI.

Supplementary figures

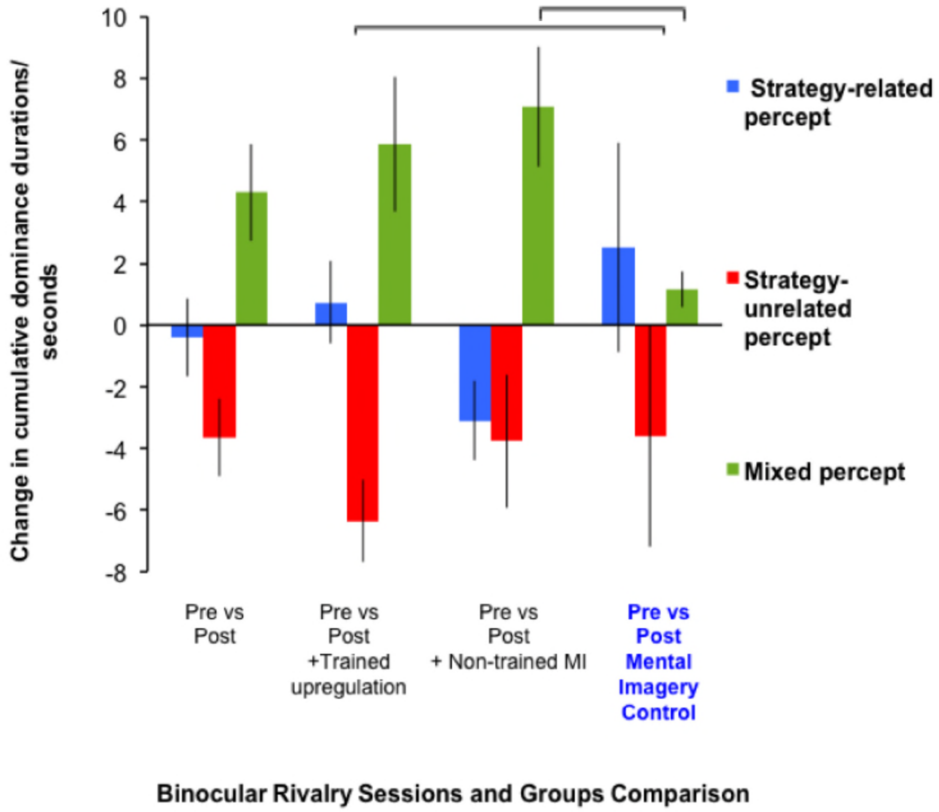

Figure S1. Changes in cumulative dominance durations for binocular rivalry sessions, showing comparisons before and after neurofeedback training. This figure is the analogous to Figure 3B in the main paper, but additionally shows changes in dominance durations for the 'Mental Imagery' control group. Error bars indicate ±1SEM. Horizontal brackets show significant between group comparisons for percepts ($p<0.05$).

A. Pre vs. Post-training BR comparison

B. Pre vs. Post-training BR with concurrent training up-regulation

C. Pre vs. Post-training BR with concurrent non-trained mental imagery

D. Pre vs. Post training BR comparison for Mental Imagery Control group

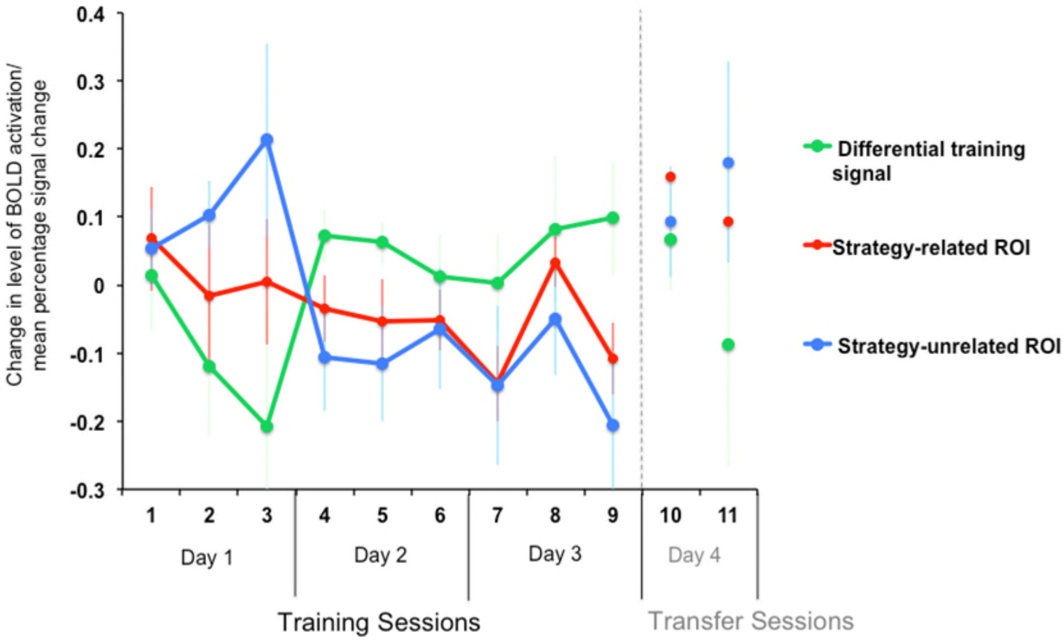

Figure S2. Mean BOLD signal changes across the House group, in the strategy-related brain region (red) and the strategy-unrelated brain region (blue), for each of the nine training sessions. The green line shows the difference in mean BOLD activation between the two brain regions and corresponds to the neurofeedback training signal. Error bars show ±1SEM.

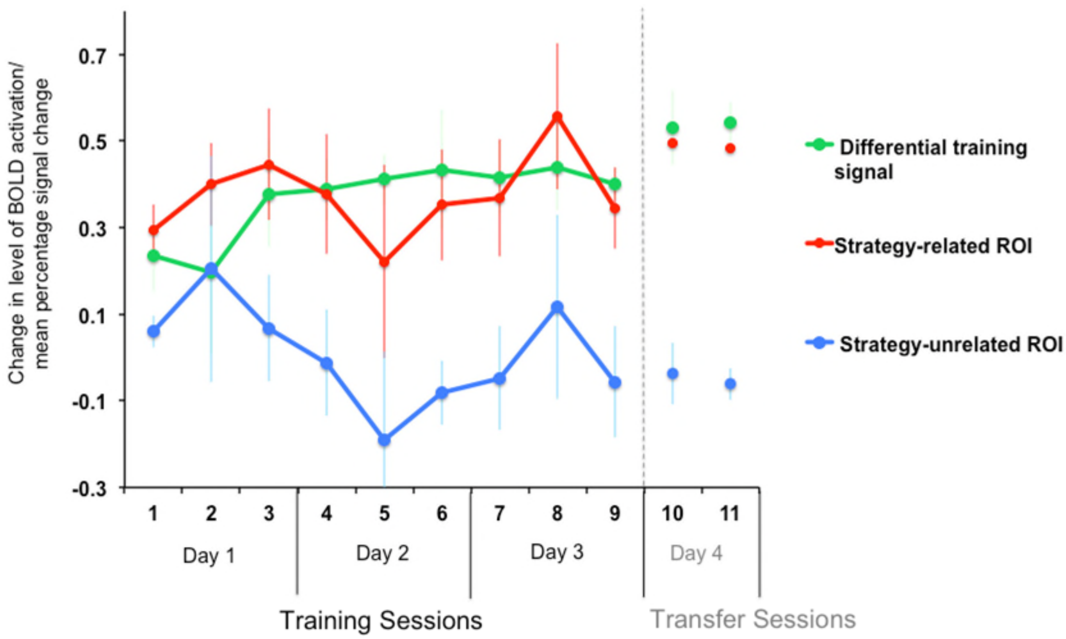

Figure S3. Mean BOLD signal changes across the Face group, in the strategy-related brain region (red) and the strategy-unrelated brain region (blue), for each of the nine training sessions. The green line shows the difference in mean BOLD activation between the two brain regions and corresponds to the neurofeedback training signal. Error bars show ±1SEM.

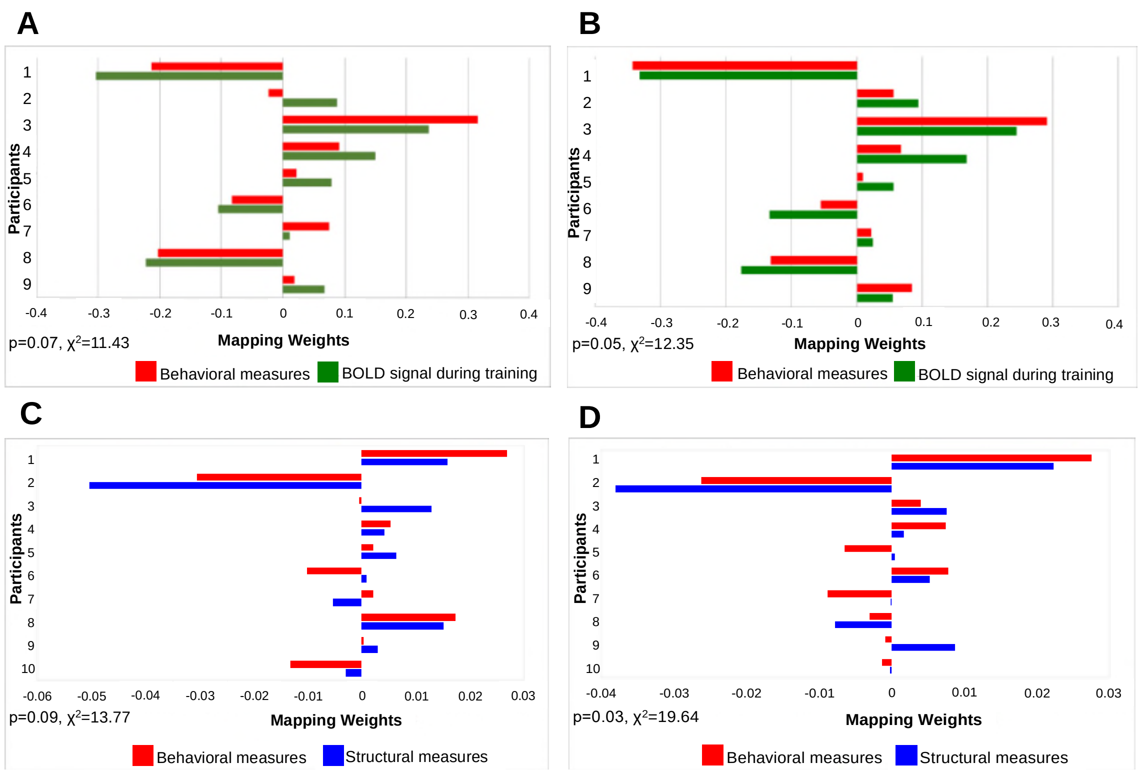

Figure S4. Canonical variate analysis illustrating the correlation between individual behaviour and physiological measures. For each participant mapping weights are shown for pairs of predictor and outcome variables. This approach aims to reveal relationships that may exist between multiple outcome variables following neurofeedback training.

A,B: Comparison of BR behavioural measures (i.e. durations of mixed, strategy-related and strategy-unrelated percepts), and functional BOLD signal changes across training (i.e. differential signal). Nine of the ten participants were included, as one of the participants did not complete all nine training sessions. Participants 1-5 are Face Group, Participants 6-9 are House Group. A shows a non-significant relationship (p= 0.07) between individual participant BR measures (pre vs. post training) and functional BOLD signal changes across training. B shows a non-

significant relationship (p= 0.05) between individual participant BR measures (pre vs. post-training with concurrent trained upregulation) and functional BOLD signal changes across training.

C,D: Comparison of BR behaviour measures (i.e. durations of mixed, strategy-related and strategy-unrelated percepts), and structural measures from FFA and PPA (pre vs. post training). Participants 1-5 are 'Face Group', Participants 6-10 are 'House Group'. C shows a non-significant relationship (p= 0.09) between individual participant BR measures (pre vs. post training) and structural measures from FFA, and PPA (pre vs. post training). D shows a significant relationship (p= 0.03) between individual participant BR measures (pre vs. post-training with concurrent trained upregulation) and structural measures from FFAand PPA (pre vs. post training).

Supplementary References

Denison, R.N., Piazza, E. a, Silver, M. a, 2011. Predictive Context Influences Perceptual Selection during Binocular Rivalry. Front. Hum. Neurosci. 5, 166. doi:10.3389/fnhum.2011.00166

Dieter, K.C., Sy, J.L., Blake, R., 2016. Individual differences in sensory eye dominance reflected in the dynamics of binocular rivalry. Vision Res. doi:10.1016/j.visres.2016.09.014

Jung, Y., Kang, M.-S., Chong, S.C., 2016. Effect of Attention on the Initiation of Binocular Rivalry. Perception 45, 492–504. doi:10.1177/0301006615622324

Levelt, W.J.M., 1966. The alternation process in binocular rivalry. Br. J. Psychol. 57, 225–238.

Pelekanos, V., Roumani, D., Moutoussis, K., 2011. The effects of categorical and linguistic adaptation on binocular rivalry initial dominance. Front. Hum. Neurosci. 5, 187. doi:10.3389/fnhum.2011.00187