Effects of category-specific costs on perceptual decisions in the human brain

Stephen M. Fleming, Louise Whiteley, Oliver J. Hulme, Maneesh Sahani and Raymond J. Dolan

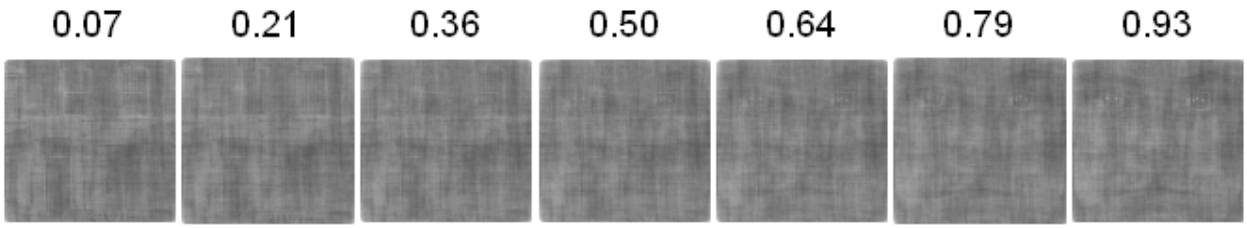
SUPPLEMENTARY MATERIAL

Supplementary Figures 1 – 5

Supplementary Tables 1 – 2

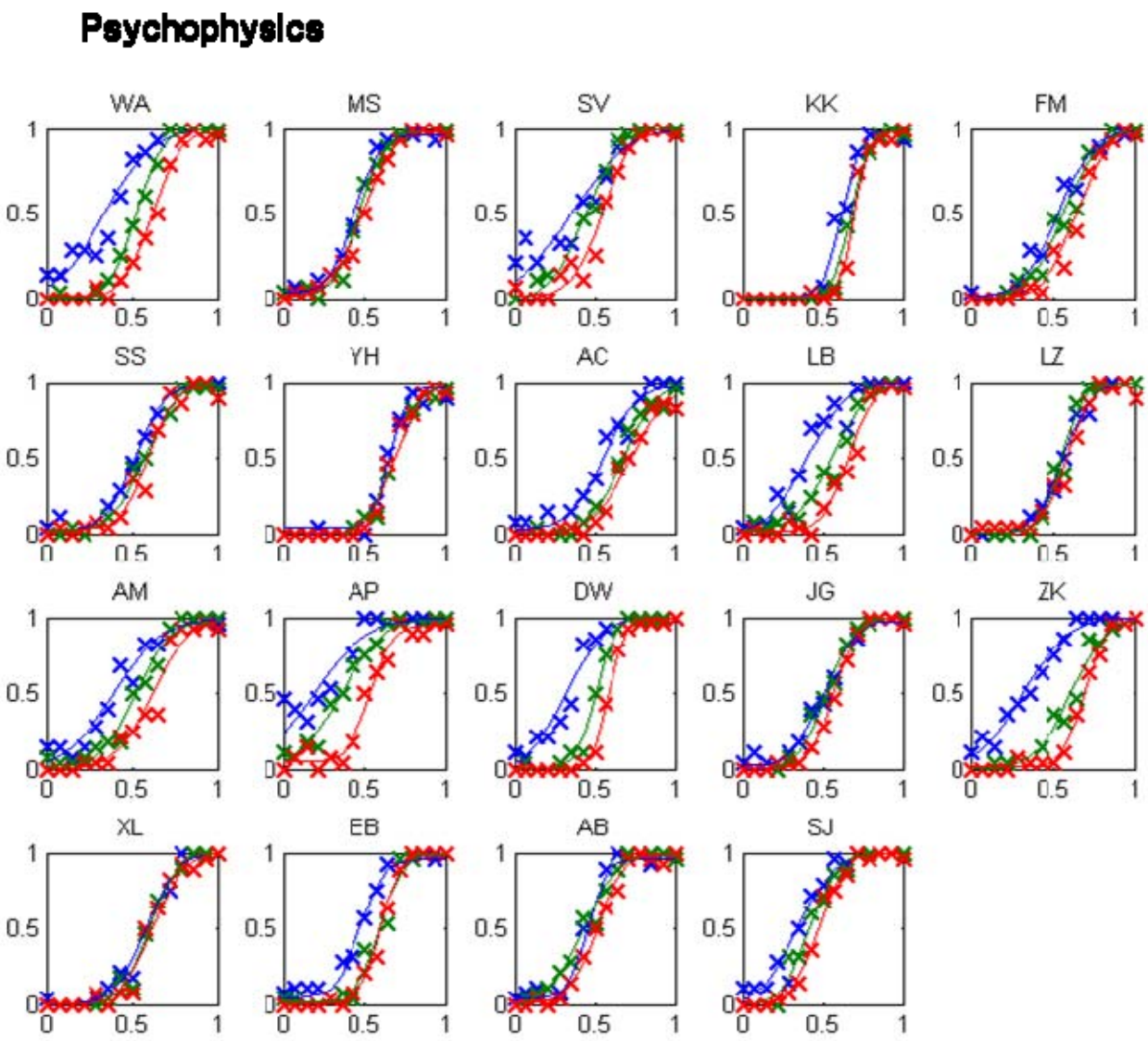
Supplementary Figure 1

Example Fourier phase transition from a single house image to a single face image. Numbers above each image indicate the proportion of "face" phase in the stimulus. In the experiment, stimuli were created from a face and house randomly drawn from the total image set on each trial, with a possible 15 levels spanning 0 – 100% face.

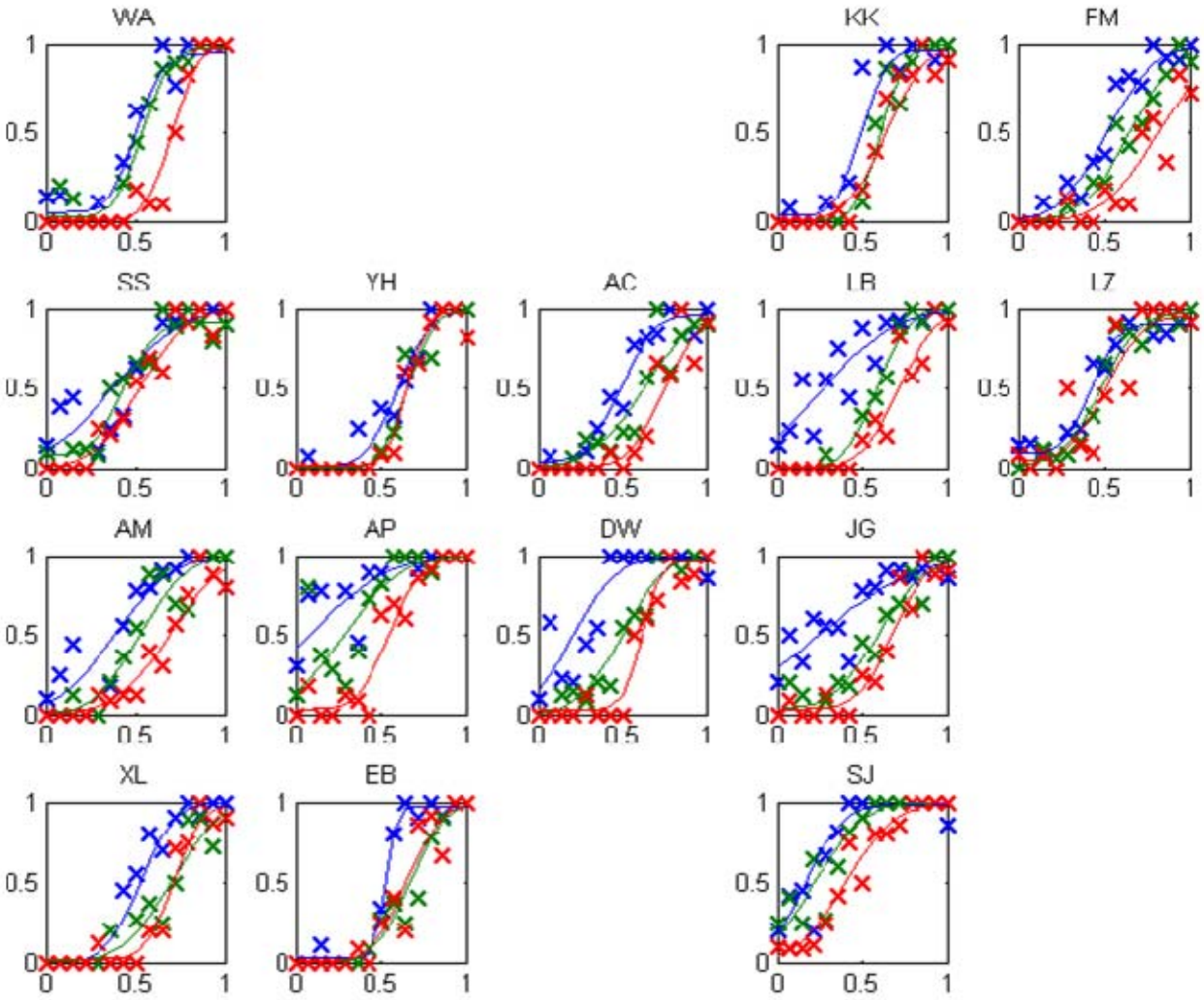


Supplementary Figure 2

Individual subject choice probability data from the psychophysics session (1260 trials) and fMRI experiment (420 trials). On each figure, the abscissa represents the proportion of face phase in the image, and the ordinate the proportion of "face" responses to that stimulus in the different cost conditions. Blue = face value; green = neutral value; red = house value.



In-scanner



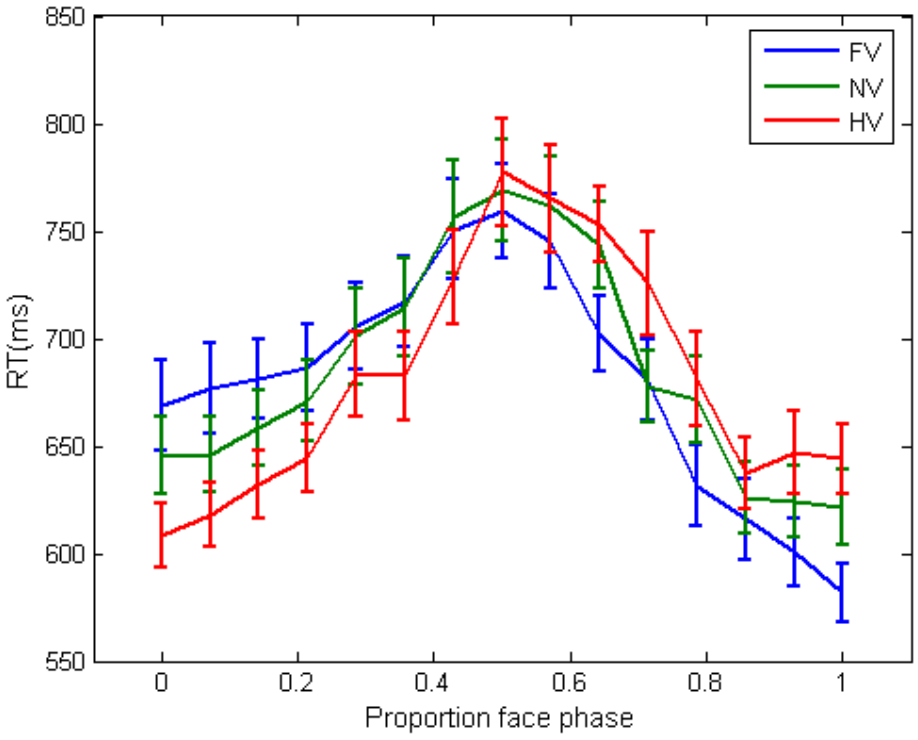
25

26

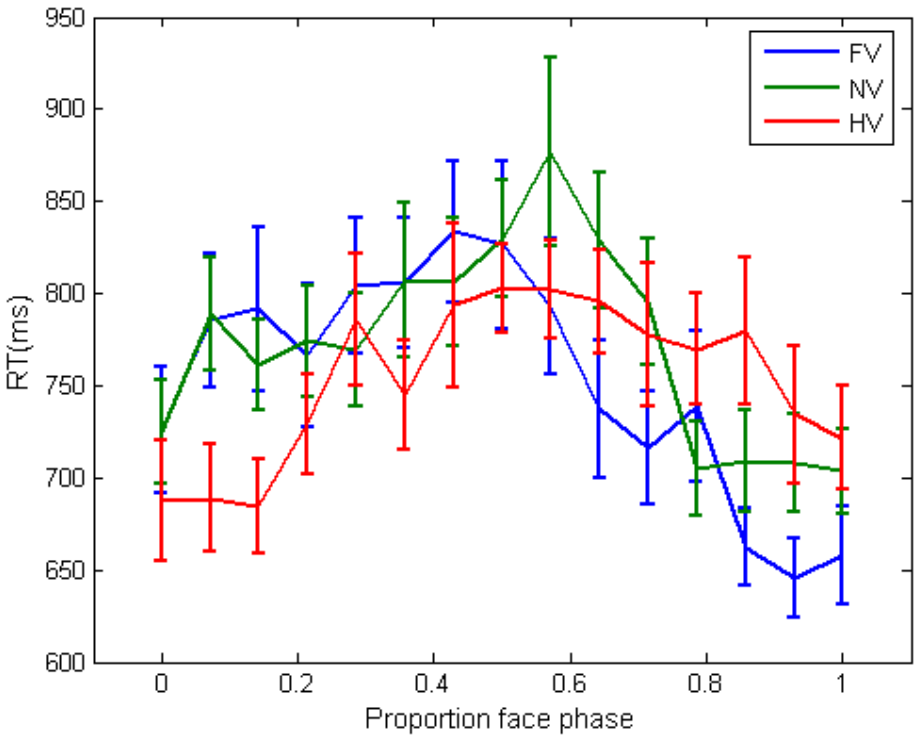
Supplementary Figure 3

Mean reaction times from **(a)** psychophysics and **(b)** the fMRI experiment, as a function of both cost condition and stimulus phase. Blue = face value; green = neutral value; red = house value.

(a)

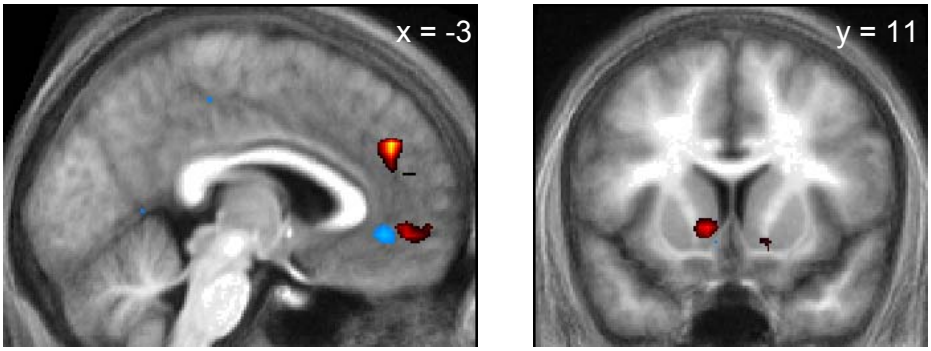


(b)


950
900
850
800
750
700
650
600
RT(ms)
0
0.2
0.4
0.6
0.8
1
Proportion face phase
FV
NV
HV

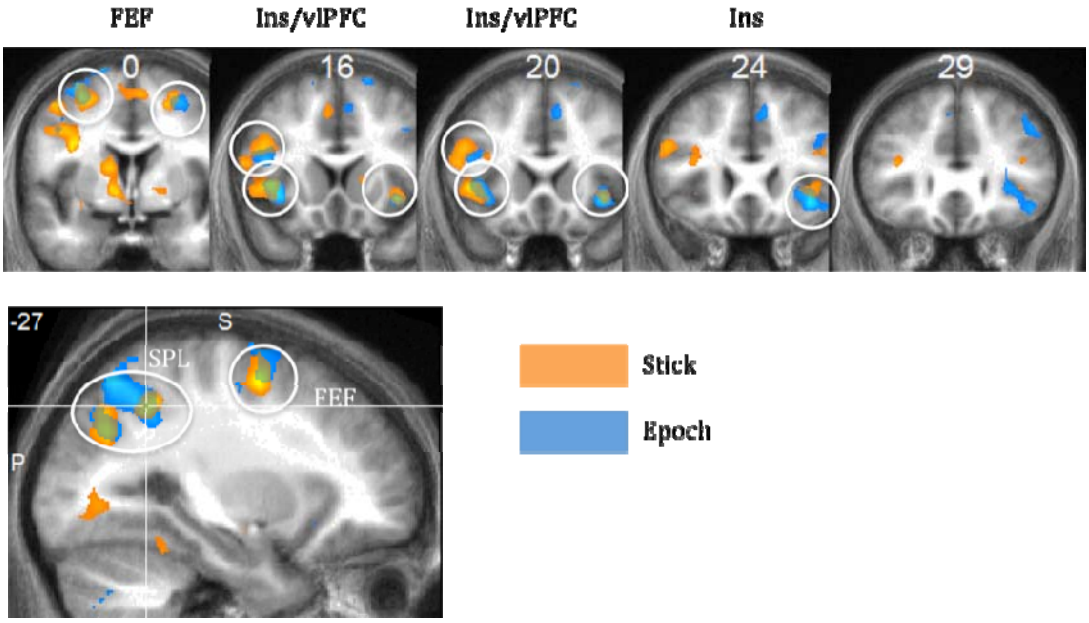
Supplementary Figure 4

Brain activations correlating with wins (negative losses) at each feedback screen (red), and increases in categorical certainty (blue). Saggital (x = -3) and coronal (y = 11) sections show clusters in ventromedial prefrontal cortex (vmPFC), [MNI coordinates (x, y, z)], -3, 42, 30 (peak Z-score = 4.65); and left ventral striatum (VS): -9, 9, -3 (Z-score = 3.93) correlated with increasing wins. An adjacent region of vmPFC responded strongly to increases in categorical certainty. Also significantly activated for increasing wins was a cluster in left cerebellum, 30, -81, -30 (Z-score = 4.10), not visible on the displayed sections.



Supplementary Figure 5

Due to the subtle variations in decision time across both stimulus and cost factors (Supplementary Fig. 3) we were concerned to establish the independence of our activations from the type of onset function (stick vs. epoch) we used in our fMRI model (cf. Grinband et al., 2008). To test this we constructed a second design matrix ("epoch") that modulated the duration of the stimulus-locked cost regressors (FV, NV, HV) as a function of trial-by-trial RT. This model produced very similar activations for the COST > NEUTRAL contrast when compared to the "stick" model reported in the main text; specifically, in left ventrolateral prefrontal cortex (vlPFC), insula, left superior parietal lobule (SPL) and bilateral frontal eye fields (FEF). Activation maps from both models (thresholded at $T > 3$) are shown here overlaid on saggital and coronal sections for comparison.



Supplementary Table 1

Regressors entered into the general linear model (GLM). Abbreviations: FV – face value; NV – neutral value; HV – house value; "f" – face decision; "h" house decsision; R – right button press; L – left button press orth. – orthogonalised; wrt – with respect to.

Onset	Condition	Parametric modulator
Cost cue	-	-
Stimulus (face/house image)	FV	*CP*
		U (orth. wrt CP)
	NV	*CP*
		U (orth. wrt CP)
	HV	*CP*
		U (orth. wrt *CP*)
Response	FV, "f", L	-
	FV, "f", R	-
	FV, "h", L	-
	FV, "h", R	-
	NV, "f", L	-
	NV, "f", R	-
	NV, "h", L	-
	NV, "h", R	-
	HV, "f", L	-
	HV, "f", R	-
	HV, "h", L	-
	HV, "h", R	-
Feedback screen	-	Monetary loss on previous mini-block

Supplementary Table 2

Summary of activations following exclusive masking for either cost or uncertainty-related activity. These clusters were obtained by masking out areas that are active in the alternative contrast at a liberal threshold of $P < 0.05$, uncorrected. Remaining significant activations reflect BOLD signal changes in regions that do not differ in the alternative contrast. Abbreviations: FEF – frontal eye fields; pMTG – posterior middle temporal gyrus; dMFC – dorsal medial frontal cortex; STN – subthalamic nucleus.

Contrast	Voxels	Z-score	*P* value (cluster FWE corrected)	Peak voxel MNI coordinates	Laterality	Label
[(FV + HV) > NV] ex. masked by *U*	35	4.56	0.013	-27, -3, 54	L	FEF
	93	4.28	< 0.001	15, -18, 0	L	Caudate/ Thalamus/ STN
	42	4.10	< 0.001	27, -9, 54	R	FEF
	43	4.04	< 0.001	-36, -72, 21	L	pMTG
	29	3.90	0.035	36, 15, -6	R	Insula
U ex. masked by [(FV + HV) > NV]	35	3.54	0.027	9, 12, 48	R/L	dMFC