Affective value and associative processing share a cortical substrate

Supplementary Materials

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Supplementary Analysis

Control for fMRI task ratings

To guarantee that left mOFC activation for either valence or associativity (revealed by our initial results) was not a result of commonality ratings participants gave during the fMRI task (particularly because negatively valenced images differed from the other images in this regard), we controlled for these ratings on a within-subject basis. These analyses were performed using SPM8b (Wellcome Department of Imaging Neuroscience, Institute of Neurology, London, UK). Data pre-processing included motion correction, normalization of functional volumes to standardized (MNI) templates (including resampling to 2mm isotropic voxels), and spatial smoothing with a Gaussian kernel (FWHM = 6mm). All events were modeled with a single condition (including the full set of 276 images, excluding any missed trials because they lacked commonality ratings) parametrically modulated by commonality ratings, followed by a regressor for either valence (categorical regressors representing positive, neutral, and negative tertiles of valence) or for associativity. In order to show robustness of our associativity findings to the use of a continuous rather than categorical variable, associativity was modeled with a parametric regressor of our composite associativity index (but note that results reported below are very similar when using a categorical Strong vs Weak regressor instead). These regressors were serially orthogonalized, such that associativity or valence was only modeled on residuals after removing variance accounted for by within-subject ratings of commonality. (Note that valence and associativity analyses were performed separately, but the two stimulus dimensions were orthogonalized in our Freesurfer-based ROI analyses by sampling appropriately matched subsets of the stimulus set.) Parameter estimates from first-level (within-subject) analyses were combined at the second level into a group random effects analysis for each regressor of interest individually. One-sample t-tests were performed at the second-level to obtain significance values, which were False Discovery Rate (FDR) corrected at $p<0.05$ within our small volume of interest. To parallel our surface-based ROI analyses, we used a medial frontal cortex ROI from the Harvard-Oxford probabilistic atlas (provided by the Harvard Center for Morphometric Analysis, defined in MNI space), thresholded at 50% or greater probability of being labeled left mOFC based on the same parcellation tools used in our Freesurfer analyses.

After first accounting for variance attributable to these commonality ratings, we still found significant effects of associativity (peak MNI coordinates [x,y,z] and small-volume corrected p-value: -4, 40, -26; $p<0.001$) and valence (Positive vs Negative: -8, 40, -14; $p<0.01$; Positive vs Neutral: -8, 42, -14; $p<0.05$) in mOFC.

Supplementary Discussion

Use of independent ratings

As is the tradition in other studies of affect or associativity in mOFC (e.g., Aminoff, Schacter, & Bar, 2008; Bar & Aminoff, 2003; Moran, Macrae, Heatherton, Wyland, & Kelley, 2006; Nielen, et al., 2009; Ritchey, Bessette-Symons, Hayes, & Cabeza, 2011), as well as in dozens of behavioral studies, our valence and associativity categories were based on ratings from an independent sample of subjects (rather than idiographic ratings from the participants we scanned). We made this decision for several reasons. First, our goal was to get a “snapshot” of how valence and associativity are processed on first exposure to an image, while avoiding having participants rate these properties while viewing them in the scanner and therefore biasing them to one property or another. Second, we wanted to avoid relying on post-scan ratings from scanned participants when their perception of these objects could be altered by generic priming effects related to mere previous exposure (Zajonc, 1980) and having rated the stimuli along a different dimension earlier (e.g., Schyns & Oliva, 1999). For this same reason, we ensured that none of our independent raters assessed any object on more than one dimension. Moreover, our aim was to produce results that would generalize to (earlier and future) studies in both areas of research that rely on independently normed stimuli, as well as ones in which one or neither dimension is explored ideographically.

However, we do recognize that this represents a limitation to our study in that these were potentially noisy indicators of the level of valence and associativity the subjects in the scanner would ascribe to these objects. It would therefore be troublesome to interpret null results on the basis of these ratings. However, our findings are positive (i.e., significant effects were obtained) and the direction and location of effects highly convergent with previous literature in which both independent and idiographic ratings have been used (Aminoff, et al., 2008; Bar & Aminoff, 2003; Grabenhorst & Rolls, 2011; Lebreton, Jorge, Michel, Thirion, & Pessiglione, 2009; Nielen, et al., 2009; Ritchey, et al., 2011; Sass, et al., 2011). We therefore feel it is parsimonious to interpret our findings in the context of the two dimensions being varied, and believe the presence of such an effect independent of the ongoing task only strengthens their relevance to future research. It is important, though, for these findings to be replicated using idiographic measures in order to also determine whether a strong interaction additionally emerges between valence and associativity, something for which we did not find strong evidence, and which we avoid interpreting negatively.

Supplementary Table 1

Significant clusters of BOLD activation for each of the contrasts of interest between the four categories in the full object set. Activations are whole-brain corrected to achieve a clusterwise p<0.05, with a cluster-defining (voxelwise) threshold of p<0.01. No significant clusters were found for the reverse contrasts of any of these. See also Fig. 3.

Strong > Weak (Neutral)

Side	Region	Peak MNI coordinates			Peak statistic (*t*)	Cluster *p*-value	Extent (voxels)
B	Retrosplenial cortex/precuneus, L parahippocampal cortex	8	-51	1	8.02	<0.0001	6597
B	Medial OFC	-10	51	-15	6.56	<0.0001	5890
R	Middle temporal gyrus	58	-11	-19	6.36	0.038	321
L	Middle temporal gyrus	-64	-19	-17	5.83	<0.0001	1862
L	Superior temporal gyrus, inferior parietal lobule	-58	-67	15	5.40	<0.0001	3041
R	Inferior parietal lobule	38	-83	23	5.13	<0.0001	1604
R	Parahippocampal cortex	20	-35	-21	5.01	0.002	518
L	Middle frontal gyrus	-30	23	55	4.63	0.0004	635
R	Middle/superior frontal gyrus	22	33	43	4.22	0.012	390
L	Ventrolateral prefrontal cortex	-44	25	-3	3.87	0.03	336
R	Cerebellum	16	-51	-43	3.34	0.034	327

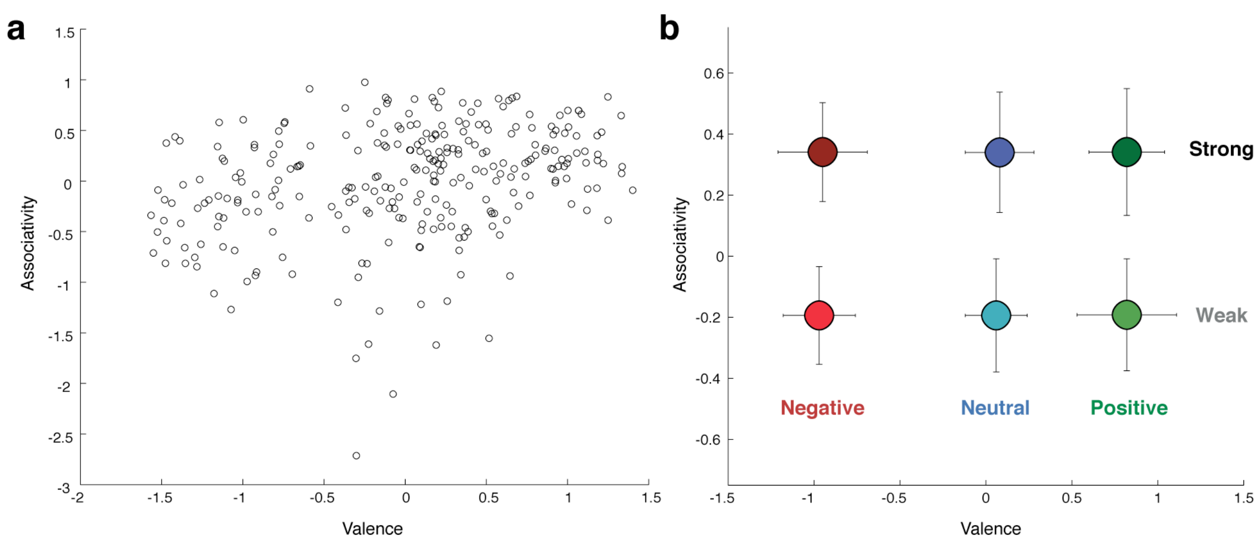
Positive > Neutral

Side	Region	Peak MNI coordinates			Peak statistic (*t*)	Cluster *p*-value	Extent (voxels)
B	Medial OFC/dorsal MPFC	-14	45	35	5.33	<0.0001	4517
R	Thalamus	18	-11	13	4.80	0.00001	1065
R	Middle temporal gyrus	42	-39	7	4.65	0.00001	1064
L	Inferior parietal lobule	-46	-65	33	3.99	0.018	434
L	Amygdala, posterior lateral OFC	-18	-3	-19	3.86	0.011	470
R	Cerebellum, fusiform gyrus	28	-83	-33	3.84	0.0004	742
R	Early visual cortex	0	-77	11	3.80	0.005	533
L	Cerebellum, fusiform gyrus	-26	-75	-7	3.61	0.00004	973
R	Inferior parietal lobule	50	-67	29	3.47	0.028	401

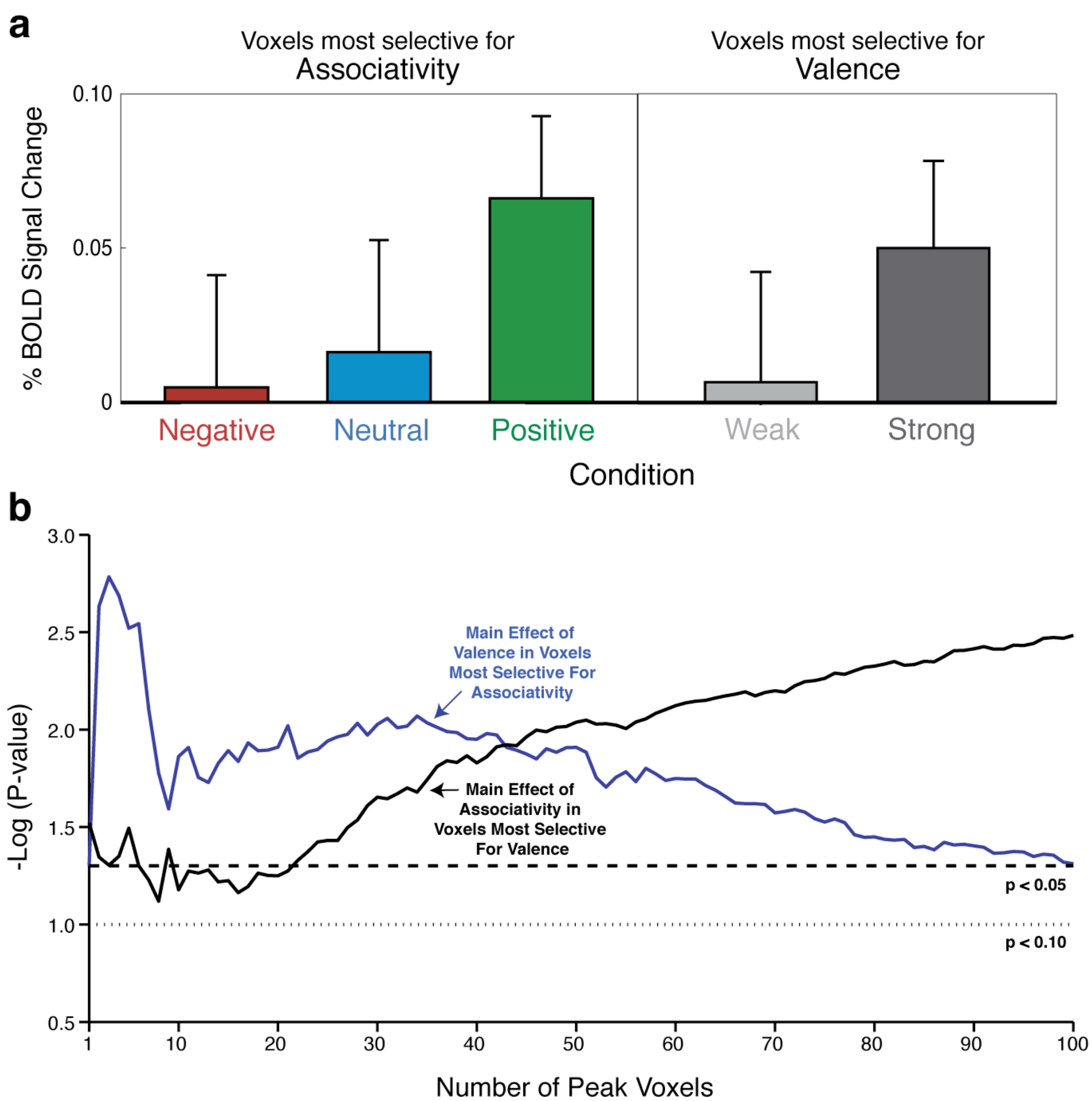
Positive > Negative

Side	Region	Peak MNI coordinates			Peak statistic (*t*)	Cluster *p*-value	Extent (voxels)
B	Medial OFC, frontal pole	-14	59	3	6.07	<0.0001	2713
B	Supplementary motor area	-6	-13	59	5.30	0.0001	943
R	Retrosplenial cortex, cerebellum, L parahippocampal cortex, hippocampus	-14	-67	5	5.11	<0.0001	7636
R	Superior temporal gyrus	66	-13	5	4.83	0.0017	693
L	Middle/superior frontal gyrus	-34	17	55	4.75	<0.0001	1489
L	Cerebellum	-20	-69	-57	3.87	0.005	594

Supplementary Figure 1. Distribution of (normalized) valence and associativity ratings across objects. a) All stimuli are plotted according to their average valence and associativity rating. b) Average valence and associativity ratings for the second analysis stage, which resorted a subset of stimuli to orthogonalize valence and associativity. Each point represents an average over 21 objects, and error bars reflect the standard deviation of ratings along the two dimensions. See also Table 1 and Figure 4.



Supplementary Figure 2. Analysis of BOLD sensitivity to affect and associativity in left mOFC for voxels most sensitive to one dimension are still significantly sensitive to the other, arguing against the possibility that affect and associativity originate from segregated voxel populations in mOFC. a) Average BOLD signal change within 20 most sensitive voxels. Error bars reflect between-subject standard errors of the mean. b) Random-effects ANOVA p-values (two-tailed) for valence (blue) and associativity (black) based on varying numbers of voxels most sensitive to the opposite dimension.



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