Assessing Human Conceptual Representation with fMRI

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INTRODUCTION:

Problematic interpretations of experience underlie many psychopathologies and health disorders. Understanding how conceptual knowledge produces interpretations has significant implications for diagnosing, understanding, and treating interpretive dysfunctions. In this study, participants learned three novel visual categories; each associated with a nonsense syllable name. High resolution fMRI experiments were then performed with a fast event-related design, in which participants indicated whether the pairs of name and visual instance match. Deconvolution analyses of fMRI data allowed us to establish the brain areas that represented familiar categories relative to unfamiliar categories, either when activated by a category name, or when activated by a visual instance. Because activations for input stimuli were removed, we were able to isolate conceptual representations of the familiar categories.

METHODS:

Data were acquired from fourteen subjects (Ten female and four male) with normal vision. All participants were trained with three novel visual categories. Each category's instances shared the same visual shape of a calligraphy-like character and were never repeated. Each category is also associated with a nonsense syllable name. After learning the categories and names outside the scanner on the previous day, participants were scanned as they performed two tasks. In the category verification task, participants received a category name, followed by a visual instance, and indicated whether the instance belonged to the category. In the naming task, participants received a visual instance, followed by a category name, and indicated whether the name labeled the instance correctly. Verification and naming trials were blocked but separated by random ISIs. Catch trials that contained various subsets of the events on verification and naming trials enabled the deconvolution of BOLD responses for the first stimulus, second stimulus, and response, each lasting 2.5 s. Throughout the scans, participants were required to focus on the center of screen, where stimuli and fixation cross appeared. fMRI data were acquired on a 3-T scanner (Siemens Trio) using 12-channel TIM head coil and parallel imaging technique. Thirty six axial slices (3mm-thick, 0.3mm gap) covering entire cortex, were acquired using gradient-echo EPI with parameters of TR = 2.5s, TE = 30ms and 128x128 matrix (in-plane resolution of 1.7mm). Each scan lasted 8.17min, and six scans were performed for each participant. AFNI (Analysis of Functional NeuroImages) was used for data processing, including motion correction, linear trend removal, and registration, spatial smoothing with FWHM=3mm, normalization, deconvolution and group analysis. Data with motion exceeding 1mm were discarded. ANOVA results revealed activations of familiar categories, relative to activations of unfamiliar (but comparable) categories, with linguistic and visual processing held constant.

RESULTS & DISUSSIONS:

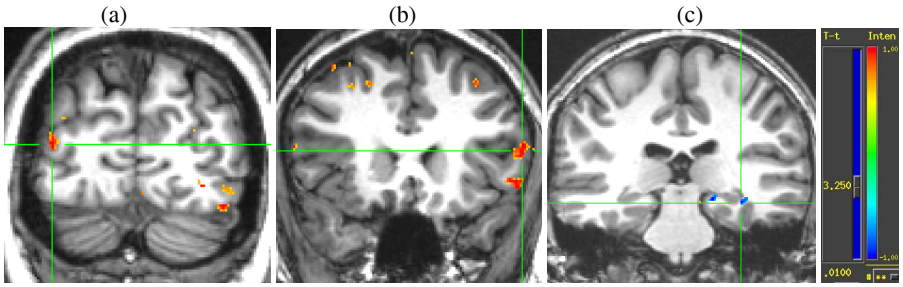

Fig. 1. Group analysis results of the contrast (familiar visual instances vs. unfamiliar visual instances), with threshold of t > 3.25 and cluster size of 6 voxels.
a) shows bilateral occipital cortex activations.
b) shows inferior frontal cortex activations.
c) shows activations in left fusiform gyrus and left parahippocampal gyrus area, where unfamiliar visual instances generate larger signal changes.

Table 1: Statistically significant clusters emerging from the group ANOVA testing the effect of familiar categories relative to the unfamiliar categories (including both names and visual instances) on BOLD response.

Brain Region (Brodmann area)	Cluster size	Talairach coordinates at center of mass			t value of max
familiar vs. unfamiliar visual instances	(mm^3)	x	y	z	
Left Inferior Frontal gyrus (44,45)	315	54	-18	15	5.6
Left Inferior Occipital Gyrus (18)	115	37	80	-18	6.2
Right Middle Occipital Gyrus (19)	72	-35	83	9	5.7
Left Parahippocampal Gyrus	*54*	*17*	*28*	*-8*	*-6.1*
Left Fusiform gyrus	*49*	*34*	*27*	*-9*	*-5.3*
familiar vs. unfamiliar names					
Left Superior Parietal Lobule	*105*	*22*	*70*	*38*	*-9.7*
Left Cuneus (31)	105	6	63	20	6.7
Left Inferior Frontal Gyrus (45)	79	50	-12	22	5.8
Right Fusiform Gyrus	*71*	*-32*	*76*	*-9*	*-7.4*
Right Precuneus (31)	68	-11	50	30	6.5
Left Parahippocampal gyrus	51	20	16	-13	5.0

As depicted in Fig. 1 and Table 1, activations resulting from familiar categories relative to unfamiliar categories reveal differences in the regions of occipital cortex, inferior frontal cortex as well as fusiform and parahippocampal gyrus. Because visual inputs were controlled in unfamiliar stimuli, occipital cortex being active for familiar categories indicated that conceptual representation might reside in modality-specific (in this case, visual) system. This finding is consistent with literature [1, 2]. Verbal working memory processes of familiar categories might activate left inferior frontal gyrus. Fusiform and parahippocampal gyrus were also involved. Note that other frontal and temporal activations are not shown here due to space. Data will be further investigated to understand the roles of different brain regions in the conceptual processing. More comparisons, for example, familiar visual instances appeared as the first stimulus vs. as the second stimulus, etc., will be made, to understand differences between bottom-up and top-down brain processing. In this study, we developed a new type of design enabling us to deconvolve multiple stimuli and brain responses, offering a useful tool for performing neuroimaging studies of complex behavioral tasks.

REFERENCE:

[1]. Barsalou *et al*, Trends Cogn Sci. 2003, 7(2):84-91. [2]. Martin *et al*, Curr Opin Neurobiol. 2001, 11(2):194-201.