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Research report

Category-selective neural substrates for person- and place-related concepts

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ABSTRACT

The influence of object-category on the representation of semantic knowledge remains unresolved. We present a functional magnetic resonance imaging study that investigates whether there are distinct neural substrates for semantic knowledge of kinds of people (e.g., lawyer, nurse etc.) and places (e.g., bank, prison etc.). Access to semantic details about kinds of people produced selective responses in the precuneus, medial prefrontal cortex, left anterior temporal lobe, posterior middle temporal gyrus and the temporoparietal junction. Corresponding place-selective responses were present in the parahippocampal gyrus and retrosplenial complex. Category selectivity was found to be less pronounced when conceptual information was accessed about kinds of people compared to unique people (e.g., Obama). We attribute this to the greater importance of cross-categorical semantic knowledge in the conceptual representation of kinds. Together, these results show the importance of object-category in non-perceptual semantic representations and indicate the manner in which these systems may interact to create full conceptual representations.

1. Introduction

Semantic memory encompasses a broad range of knowledge about facts, beliefs and objects that are unrelated to specific experiences (Tulving, 1972). The extent to which object-category influences the cortical representation of semantic knowledge remains uncertain. Viewing different categories of objects has a well-documented influence on the cortical response. For example, viewing faces or places activates distinct sets of brain regions (Epstein and Kanwisher, 1998; Sergent et al., 1992). However, the majority of research has focused on perceptual rather than semantic properties and it is not clear whether the same or equivalent category-selective regions exist for non-perceptual semantic information. For instance, would accessing semantic knowledge related to kinds of people (e.g., different occupations) or kinds of places (different kinds of buildings) involve the same or partially distinct neural substrates?

Recently, using functional magnetic resonance imaging (fMRI) we (Fairhall et al., 2013) showed that category-selective neural substrates are involved in retrieving semantic information about unique people or places (e.g., Obama, the Eiffel Tower). Accessing semantic knowledge, such as the nationality of famous people selectively activates the precuneus and

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to a lesser extent the medial prefrontal cortex (mPFC). Conversely, accessing the nationality of famous places selectively activates the retrospenial complex (RSC), a section of the parahippocampal gyrus (PHG) and a section of the transverse occipital sulcus abutting the angular gyrus (TOS-AG). Furthermore, these responses are supramodal (they are evident during both word and picture cuing) and are anatomically distinct from the maximal person- and place-selective responses to images. These results demonstrate that individual person- and place-selective responses extend beyond perceptual processing. However, this study left uncertain whether these category-selective effects are specific to unique entities (UEs) or whether they reflect a general property of semantic organization.

It is uncertain whether the category-selective pattern observed for UEs will hold true for general person-related and place-related knowledge. It has been proposed that UEs represent a distinct class of conceptual representations (Grabowski et al., 2001; Semenza and Zettin, 1989) that systematically differ from other concepts. This view has been encouraged, in part, by neuropsychological evidence showing selective deficit or selective sparing of naming or recognition of UEs relative to common objects (e.g., Lyons et al., 2002; Miceli et al., 2000; Semenza and Zettin, 1989). Due to the systematic differences between general and entity-specific knowledge, the cause of such deficits is uncertain. UEs are associated with proper names, which may place-specific demands on the lexical system (Damasio et al., 2004; Gesierich et al., 2012). There is also a greater richness of information associated with these concepts (Rogers et al., 2006; Simmons and Martin, 2009) particularity evident in the degree of taxonomic specificity of the associated semantic knowledge (e.g., person > politician > senator; Brambati et al., 2010). Finally, there is the distinction of the uniqueness of the conceptual information associated with that specific entity (Gorno-Tempini and Price, 2001; Ross and Olson, 2012). As a result, there are several reasons why the category-selective activation pattern observed for UEs (Fairhall et al., 2013) may not apply to kinds of people and places. On the other hand, category-selectivity for UEs might reflect the co-localization of semantic representations shared amongst entities drawn from the same category (e.g., UE people all share semantic properties associated with people). If the representation of shared semantic properties drives the category-selective representation of UEs, then we would expect that knowledge about kinds of people and places would also be represented in these regions.

The present study investigates whether person-/place-selective neural responses are evident when participants access semantic knowledge about *Kinds* and not *UEs*. By 'Kind' here we mean general person- or place-related knowledge pertaining to types of people (e.g., lawyers) or places (e.g., prisons). Such semantic information is detailed but does not require the retrieval of knowledge associated with a specific entity. The persistence of category-selectivity for knowledge about kinds would indicate that category-selectivity is an underlying organizational principle of the representation of conceptual knowledge. The absence of such an effect would indicate that UEs represent a special class of knowledge, with properties dissociable from other forms of conceptual representation.

2. Methods

2.1. Subjects, stimuli and task

Sixteen right-handed native speaking Italians participated in this study (mean age 25.6 years, 9 female). All procedures were approved by both the University of Trento Human Research Ethics Committee and the Harvard University Committee on the Use of Human Subjects in Research.

2.2. Main experiment

The experiment was designed to elicit access to conceptual information that was broadly equivalent for people and places. The design was a 2×2 repeated measures factorial design with the factors category (person/place) and probe question. Participants were asked to perform a conceptual categorization task based on two types of questions. One question was related to government function; 'is this person usually a government employee?' (e.g., policeman, senator, teacher *vs* journalist, engineer, farmer) and 'is this building normally a government building?' (e.g., embassy, prison, university *vs* restaurant, gymnasium, bank). The other question was related to commerce function: 'does this type of person normally sell retail goods?' (fishmonger, greengrocer, jeweler *vs* surgeon, weatherman, driver) and 'is this type of building a place where retail goods are sold?' (hardware store, pharmacy, bakery *vs* cinema, hotel, garage). Half the items were designed to elicit a 'yes' response. Subjects indicated their response on a two-button response device (right hand). Eighty occupations and 80 types of buildings were presented as words. Written word frequency was matched for places and people (2.67 & 2.70 per 100 000 words, $t < 1$) as determined via the COLFIS database (http://www.ge.ilc.cnr.it/). An additional baseline condition was also included in the design. This control task was selected to control for visual/lexical processing and motor response. Subjects silently read words depicting animals and inanimate-objects and performed a 1-back matching task, responding with the index finger if the present word matched the previous word and the middle finger if it did not (~10% chance or repetition). Control stimuli consisted of 80 words representing basic objects (animals and artefacts). Word-length did not differ between conditions (buildings: mean = 8.4, standard deviation − SD = 1.97; occupations: mean = 8.9, SD = 1.75; control: mean = 8.2, SD = 1.3. All *p*-values >.28).

Stimuli were presented in two fMRI runs (11 min 22 sec each). Thirty 16-second blocks comprised each run (10 People, 10 Places, 10 Control). Each block was preceded by a 6-second fixation cross, the color of which (red/blue/green) indicated the task for the upcoming block. Question types (government *vs* commerce) were presented in blocks such that there were 5 blocks per run of each question type for professions and buildings. The block presentation sequence was pseudo-random. Consecutive sequences of 6 blocks contained the randomized presentation of each question for each stimulus category and two control blocks. Blocks were composed of 8 trials, which were 2 sec in duration. Each trial consisted of 400 msec stimulus presentation followed by the 1600 msec