Dissociable neural correlates of stereotypes and other forms of semantic knowledge

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Semantic knowledge refers to the information that people have about categories of objects and living things. Social psychologists have long debated whether the information that perceivers have about categories of people—i.e. *stereotypes*—may be a unique form of semantics. Here, we examine this question against well-established findings regarding the neural basis of semantics, which suggest that two brain regions—left inferior frontal gyrus and inferotemporal cortex—are critical for general semantic knowledge. During functional magnetic resonance imaging, participants answered questions about their knowledge of both non-social and social categories. We reasoned that if stereotypes are a typical form of semantic knowledge, then these same regions should subserve the activation and retrieval of stereotypes. Inconsistent with this possibility, left inferior frontal gyrus and inferotemporal cortex were activated only during non-social category judgments. Instead, judgments of social categories were associated with regions frequently linked to social cognition, including medial prefrontal cortex, posterior cingulate, bilateral temporoparietal junction and anterior temporal cortex. Together, these results suggest that social stereotypes should be considered distinct from other forms of semantic knowledge, and may have more in common with representing mental states than retrieving semantic knowledge about objects and non-human living things.

Keywords: semantic knowledge; social cognitive neuroscience; social knowledge; stereotypes; fMRI

INTRODUCTION

Over the course of a day, we encounter a large number of objects. Even before we leave our homes in the morning, we have already interacted with dozens of objects, from alarm clocks to armoires, beds to belts and cups to chairs. These interactions require the capacity to distinguish these objects from each other by recognizing their unique physical features, understanding the discrete functions they serve, and recalling the correct procedure for their use (how to set the alarm clock to snooze, the order in which to put on one's socks and shoes, etc.).

Philosophers and psychologists have long posited that such knowledge is necessarily organized around categories that distinguish among different sets of entities (Kant, 1781/2003; Aristotle, 1975; Smith and Medin, 1981; Medin and Smith, 1984; Murphy, 2002). Categories obviate the need to repeatedly work out what to expect from each object, by allowing perceivers to instead make use of generalized knowledge about a whole class of entities. For example, by recognizing a particular object as an instance of the category 'microwave ovens', one gains immediate access to a wealth of additional information about it—such as that it can

be used to heat food, cannot accommodate metal pots and will probably have a button marked 'defrost'—without the need to discover each of these features anew.

Psychologists have held that categories not only organize our understanding of inanimate objects, but also guide interactions with the myriad individuals with whom we come into daily contact (Allport, 1954). We readily categorize other individuals into a wide range of social groups, such as those based on gender, race and ethnicity, age, occupation, place of origin, socioeconomic class and so on. Much as recognizing a particular object as a member of a general category provides useful information about that object 'for free', categorizing a particular individual as a member of a social category (e.g. 'men'; 'New Yorkers') gives us ready access to the likely characteristics of this person (e.g. 'he will probably be an aggressive driver'). Typically, the information that derives from social categorization is referred to as a *stereotype*—the inferences and assumptions made about a particular person as a consequence of categorizing him into one or another social group.

Given that stereotypes serve much the same function as other forms of category-based knowledge, many researchers have naturally assumed that stereotypes reflect merely ordinary semantic knowledge about a particular class of entities—other people. For example, stereotypes have been described as the 'perception of social objects (e.g. groups) that is in principle little different to categorization and perception of other "physical" objects' (Spears *et al.*, 1997, p. 3); 'not essentially different from other cognitive structures or processes' (Hamilton, 1981, p. 28); and 'rooted in the

ordinary mechanisms of perception and categorization' (Banaji and Bhaskar, 1999, p. 144). At the same time, a number of researchers have argued that stereotypes may instead be a unique form of semantic knowledge (e.g. Ostrom, 1984). Social groups are generally more complex than categories of non-social objects (Cantor and Mischel, 1979; Wattenmaker, 1995), individuals typically belong to several social categories simultaneously (Lingle *et al.*, 1984; Schneider, 2004), and stereotypes often evoke more emotion than other forms of semantic knowledge (Norris *et al.*, 2004). Given these distinct aspects of social knowledge, some researchers have suggested that social knowledge may require specialized forms of cognitive processes that distinguish it from other forms of semantics.

Are stereotypes a typical form of semantic knowledge or do they represent a unique form of knowledge about the (social) world? Historically, it has been difficult to adjudicate between these competing accounts of stereotyping. However, recent findings regarding the neural basis of semantics offer a novel strategy for addressing this question. Over the past decade, researchers have consistently demonstrated that a small number of left-lateralized brain regions subserve the retrieval, selection and integration of information from semantic memory: specifically, inferior frontal gyrus and inferotemporal cortex (for reviews, see Joseph, 2001; Martin, 2001; Bookheimer, 2002). For example, participants show greater hemodynamic activity in left inferior frontal gyrus when thinking about the meaning of a word than when they consider its perceptual characteristics (such as whether the word is written in uppercase letters; e.g. Poldrack, *et al.*, 1999), and regions of left inferotemporal cortex have routinely been observed when participants name or simply view categories of objects (Martin and Chao, 2001). Moreover, people with damage to these regions often demonstrate selective impairments in semantic memory, such as an inability to name common objects or define familiar words (Hodges *et al.*, 1992; Baldo and Shimamura, 1998; Caramazza and Shelton, 1998; cf. Patterson *et al.*, 2007).

To the extent that stereotypes are part of general semantics, these same regions should contribute to the retrieval of knowledge about the attributes of social groups. That is, if knowledge about social groups (i.e. stereotypes) does not differ significantly from knowledge about groups of objects, inferior frontal gyrus and inferotemporal cortex should be engaged when perceivers consider the typical features of social categories, such as those based on race, national origin or occupation. From the point of view of the neural processes involved, thinking about Dutch ovens, Swedish meatballs or Great Danes should be not be significantly different than thinking about the typical residents of Amsterdam, Stockholm or Copenhagen.

On the other hand, if stereotypes are a distinct form of general semantics, these brain regions should not participate in the retrieval of social knowledge. Functional

neuroimaging studies have routinely demonstrated that many social-cognitive tasks recruit a network of brain regions—including medial prefrontal cortex (MPFC), posterior cingulate, bilateral temporoparietal junction and anterior temporal cortex—that distinguish them from closely matched tasks that require participants to engage in non-social processing (Mitchell, 2009b). To the extent that stereotypes are indeed a unique form of knowledge, their retrieval may rely on this network as well. In the present study, we used functional magnetic resonance imaging (fMRI) to arbitrate between these predictions by scanning participants while they answered questions alternately on the basis of their knowledge of social and non-social categories.

METHODS
Participants

Nineteen right-handed college undergraduates and community members from the Boston suburbs (9 females, age range 19–28 years, mean age 22.2 years) with no history of neurological problems participated in exchange for monetary payment. All participants provided informed consent in a manner approved by the Committee on the Use of Human Subjects in Research at Harvard University.

Stimuli and behavioral procedure

During fMRI scanning, participants completed two semantic knowledge tasks. During the 'categorical knowledge' task, participants answered a series of questions that required semantic knowledge about categories of people or categories of non-social stimuli such as objects. Each trial began with the appearance of two category 'labels' (e.g. men and women; guitars and violins). After 750 ms, a category 'feature' appeared below the labels (e.g. watch romantic comedies; have six strings) for an additional 3000 ms. Participants indicated which of the two categories was more likely to have that particular feature by pressing one of two buttons under their left hand (see Supplementary Data for full list of stimuli). Category labels and features varied between conditions to avoid a reliance on the few trivial features (e.g. size) that can appropriately describe social groups and object categories. Trials were segregated into four functional runs of 40 trials each (20 social and 20 non-social). Importantly, social stimuli were rated to be 'less' emotionally evocative than non-social stimuli—mean (s.d.) = 4.51 (0.38) *vs* 4.65 (0.51)—by a separate group of 57 participants, precluding the possibility that any additional activation associated with social judgments might be due to greater affective processing of social stimuli (see Supplementary Data).

Following the categorical knowledge task, participants also completed one run of a 'feature verification' task used to identify the neural regions typically associated with the retrieval of semantic knowledge (Mitchell *et al.*, 2002). On each of 40 'non-social' trials, participants read the name of a fruit (banana or mango) or item of clothing (glove or shirt) and were asked to verify whether an adjective

(ripe, threadbare or curious) could be appropriately used to describe the item. On each of 40 'social' trials, participants read the name of a person (John or Mary) and were asked to verify whether the adjective could be used appropriately to describe a person. Adjectives were appropriate and inappropriate descriptors on an equal number of trials, and each trial lasted 4000 ms. To optimize estimation of the event-related fMRI response during both tasks, trials were intermixed in a pseudorandom order and separated by a variable stimulus interval (0–10 s; Dale, 1999) during which participants passively viewed a fixation crosshair.

Functional imaging procedure

The experiment was conducted using a 3.0-Tesla Trio scanner with a standard head coil. Functional runs used a gradient-echo, echo-planar pulse sequence (TR = 2000 ms; TE = 35 ms; 3.75 × 3.75 in-plane resolution; 31 axial slices, 5 mm thick; 1 mm skip). Coverage extended to a ventralmost coordinate of $z = -22$. Stimuli were projected onto a screen that participants viewed by way of a mirror mounted on the head coil. A high-resolution T1-weighted structural scan (MEMPRAGE) was conducted following four runs of the categorical knowledge task (107 volume acquisitions each) and one run of the feature verification task (210 acquisitions).

fMRI data were preprocessed and analyzed using SPM2 (Wellcome Department of Cognitive Neurology, London, UK). First, functional data were time-corrected for differences in acquisition time among slices and realigned to correct for head movement. Functional data were then transformed into a standard anatomical space (3-mm isotropic voxels) based on the ICBM 152 brain template (Montreal Neurological Institute). Normalized data were then spatially smoothed using an 8-mm fullwidth-at-half-maximum Gaussian kernel. Preprocessed images were analyzed using the general linear model, in which trials were modeled using a canonical hemodynamic response function, its temporal derivative and additional covariates of no interest (a session mean and a linear trend). Comparisons of interest were implemented as linear contrasts using a random-effects model. A Monte Carlo simulation of our whole-brain volume was used to specify the minimum cluster extent necessary to obtain an experiment-wide statistical criterion of $P < 0.05$, corrected for multiple comparisons. Additional statistical comparisons between conditions were conducted using ANOVA procedures on the parameter estimates associated with each trial type.

RESULTS

Behavioral data

During the categorical knowledge task, participants responded significantly faster during social trials (mean = 1467 ms, s.d. = 165 ms) than non-social trials (mean = 1564 ms, s.d. = 181 ms), $t(18) = 4.27$, $P < 0.001$ and Cohen's $d = 1.01$, making it unlikely that any additional activation

associated with social judgments is a result of the greater complexity or difficulty of social stimuli. Item analyses demonstrated that participants converged on the same response equally often for social (mean = 92%) and non-social stimuli (mean = 89%), $t(158) = 1.22$, $P = 0.23$, and $d = 0.10$. During the feature verification task, participants responded faster during person (mean = 1063 ms, s.d. = 137) than object trials (mean = 1133 ms, s.d. = 129), $t(18) = 3.54$, $P < 0.002$ and $d = 0.83$.

fMRI data

For the categorical knowledge task, we first used a whole-brain, random-effects analysis to identify cortical regions that were more active during judgment of non-social than social categories. Inconsistent with the claim that social knowledge draws on similar processing as other forms of semantic memory, the contrast of 'non-social' > 'social' identified a set of brain regions regularly associated with semantic processing, including left-lateralized inferior frontal gyrus and inferotemporal cortex (Figure 1 and Table 1). Importantly, social categories elicited no additional response over baseline in both inferior frontal and inferotemporal regions (both P's > 0.14).

These results were confirmed in region-of-interest analyses from the feature verification task. Replicating earlier work (Mitchell *et al.*, 2002), the comparison of 'object' > 'person' also identified left-lateralized regions in inferior frontal gyrus and inferotemporal cortex typically associated with semantic processing (Table 1). These regions were subsequently interrogated for differences between social and non-social trials during the categorical knowledge task. Consistent with the whole-brain analysis, inferior frontal
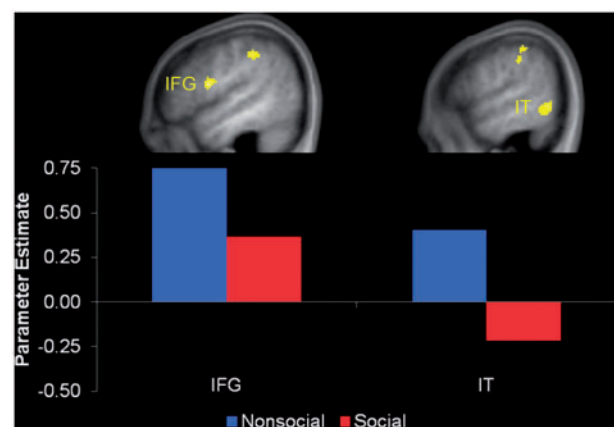

Fig. 1 Brain regions identified from the contrast of 'non-social' > 'social' for the categorical knowledge task. Whole-brain, random-effects analyses ($P < 0.05$, corrected) revealed left-lateralized regions of inferior frontal gyrus (IFG) and inferotemporal (IT) cortex that responded robustly during judgments of non-social categories, but did not respond differently from baseline during judgments of social categories. Regions are displayed on sagittal images of participants' mean normalized brain ($x = -50$ and -58, respectively). Bar graphs display the mean parameter estimates from these regions for non-social (red) and social (blue) trials.

Table 1 Peak voxel and number of voxels for brain regions obtained from the random-effects contrasts of non-social > social trials on the categorical knowledge task and object > person trials on the feature verification task, $P < 0.05$, corrected.

Region	x	y	z	Voxels	t
Categorical knowledge (non-social > social)					
Inferior parietal lobule	−46	−36	44	154	4.49
Inferotemporal cortex	−58	−60	−4	130	4.43
Corpus callosum	6	12	22	129	5.50
Inferior frontal gyrus	−48	6	18	95	4.79
Superior frontal gyrus	14	−18	68	95	4.08
Subcentral gyrus	42	−10	24	86	4.79
Middle frontal gyrus	−44	38	12	83	4.36
Superior frontal sulcus	−24	10	56	67	4.81
Feature verification (object > person)					
Inferotemporal cortex	−48	−52	−12	88	4.05
Inferior frontal gyrus	−40	32	14	80	4.66

Note. t-Tests reflect the statistical difference between the two conditions, as computed by SPM2. Coordinates refer to the stereotaxic space of the Montreal Neurological Institute (MNI).

Fig. 2 Brain regions identified from the contrast of 'social' > 'non-social' for the categorical knowledge task. Whole-brain, random-effects analyses ($P < 0.05$, corrected) revealed dorsal and ventral aspects of the MPFC, posterior cingulate cortex (PCC) and left and right temporoparietal junction (TPJ). Regions are displayed on both sagittal ($x = −4$) and axial ($z = 26$) images of participants' mean normalized brain. Bar graphs display the mean parameter estimates from these regions for non-social (red) and social (blue) trials.

gyrus displayed greater response to non-social than social categories, $t(18) = 3.07$, $P < 0.007$ and $d = 0.72$. A marginally significant difference was also observed in inferotemporal cortex, $t(18) = 1.91$, $P = 0.07$ and $d = 0.45$.

We next identified regions in which neural responses were greater for social than non-social categorical knowledge with the use of a whole-brain, random-effects analysis of trials on the categorical knowledge task. The contrast of 'social' > 'non-social' identified the network of brain regions previously associated with inferences about mental states: dorsal and ventral aspects of MPFC, posterior cingulate and bilateral temporoparietal junction (Figure 2 and Table 2). These results were confirmed by analyses of data from the feature verification task. Replicating earlier work (Mitchell *et al.*, 2002), the comparison of 'person' > 'object' also identified MPFC and a left-lateralized region of temporoparietal junction (Table 2). These regions were subsequently interrogated for differences between social and non-social trials during the categorical knowledge task. Consistent with the whole-brain analysis, greater response to social than non-social categories was observed in both MPFC [$t(18) = 6.91$, $P < 10^{-5}$ and $d = 1.63$] and temporoparietal junction [$t(18) = 7.66$, $P < 10^{-6}$ and $d = 1.81$].

To confirm that task difficulty did not partially account for these results, we reconditionalized trials based on a median split of each participant's reaction times, resulting in four trial types: 'non-social-fast,' 'non-social-slow,' 'social-fast' and 'social-slow'. We then interrogated the regions observed in the primary analyses to ascertain whether any demonstrated differences between 'fast' and 'slow' trials. None of these regions significantly differed by reaction time: although the PCC demonstrated a non-significant trend toward greater activity during fast than slow trials
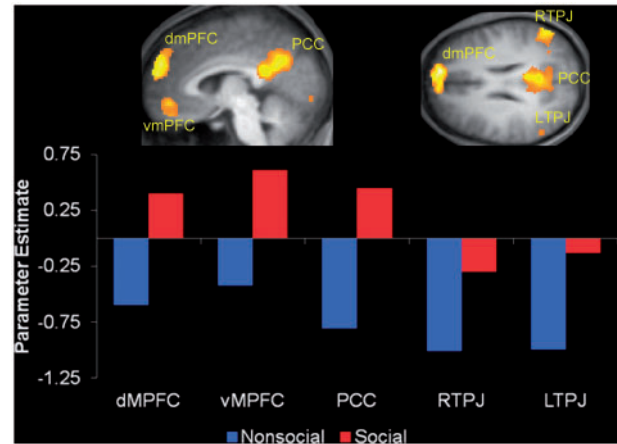
Table 2 Peak voxel and number of voxels for brain regions obtained from the random-effects contrasts of 'social' > 'non-social' trials on the categorical knowledge task and 'person' > 'object' trials on the feature verification task, $P < 0.05$, corrected.

Region	x	y	z	Voxels	t
Categorical knowledge (social > non-social)					
Posterior cingulate	−4	−58	28	1826	8.34
Medial prefrontal cortex	−8	56	34	1525	10.86
	−4	48	−8	356	6.47
Middle temporal gyrus	−50	−10	−22	1183	10.66
	60	−2	−22	104	5.39
Temporoparietal junction	−56	−60	24	572	7.57
	56	−56	18	78	5.92
Lingual gyrus	−12	−96	−4	548	8.36
Fusiform gyrus	−26	−74	−16	77	5.78
Superior frontal gyrus	−10	38	50	44	5.67
Feature verification (person > object)					
Medial prefrontal cortex	−2	58	22	1121	5.12
Middle temporal gyrus	−56	−4	−24	621	7.32
Lateral orbital gyrus	38	22	−22	272	4.25
Temporoparietal junction	−56	−64	26	197	4.00
Inferior temporal sulcus	54	−12	−32	170	4.23
Posterior orbital gyrus	−40	20	−16	151	4.38
Anterior thalamic nucleus	−4	0	6	135	4.02
Inferior frontal gyrus	44	30	−8	113	4.22
Precentral gyrus	62	18	16	79	3.80

Note. t-Tests reflect the statistical difference between the two conditions, as computed by SPM2. Coordinates refer to the stereotaxic space of the Montreal Neurological Institute (MNI).

($P = 0.07$), reaction time did not covary with the response in any other reported region (all P's > 0.30).

Finally, the stimulus set included two types of features (actions and physical attributes) used to assess knowledge

of each category. For example, in the case of non-social categories, 'destroy buildings in Kansas' was a possible action associated with tornados and 'be blue' was a physical attribute associated with jeans. Likewise, in the case of social categories, 'play video games' was an action associated with geeks and 'have wide hips' was a physical attribute that describes women more than men. Although ventral MPFC and PCC demonstrated non-significant trends toward greater response for actions than physical attributes for social trials (both P's < 0.07), no other region differentiated significantly between the two types of features (all P's > 0.15).

DISCUSSION

These findings suggest knowledge about the characteristics of social groups bears little resemblance to knowledge about other (non-social) categories. When participants made semantic judgments about a variety of non-social objects, brain regions traditionally associated with general semantics were engaged, including left inferior frontal gyrus and inferotemporal cortex. In contrast, making similar semantic judgments about groups of people—such as those based on gender, ethnicity or occupation—failed to engage these regions. Indeed, the response of left inferior frontal gyrus and inferotemporal cortex during social judgments did not differ from baseline: these regions were no more engaged when participants considered the characteristics of social groups than when participants stared at a fixation cross during periods of baseline.

Instead, stereotypes activated a network of brain regions that have been linked regularly to tasks that involve social cognition, including extensive areas of MPFC, posterior cingulate, bilateral temporoparietal junction and anterior temporal cortex. For example, these regions have been observed when perceivers infer the beliefs, feelings or opinions of others (for reviews, see Frith and Frith, 2006; Saxe, 2006; Mitchell, 2009a, 2009b); view objects moving in a way that implies agency (Castelli et al., 2000; Wheatley et al., 2007); form impressions of people (Mitchell, Macrae and Banaji, 2004, 2005; Mitchell et al., 2006; Schiller et al., 2009); and even when they think about the global characteristics of people as a class (Mitchell et al., 2002).

Taken together, the current findings suggest a novel way to think about stereotypes, one in which an understanding of social groups may derive less from general semantic knowledge than from our ability to represent the mental states of the members of a group. Many stereotypes about social groups involve inferences about the predilections and dispositions of their members, such as whether men or women prefer watching basketball, Asian-Americans or African-Americans are more likely to play basketball, or middle class or working class individuals are more likely to attend professional basketball games. The regions identified here in the comparison of 'social' > 'non-social' have also been observed when participants make comparable types of inferences about individuals, such as how much a specific person might enjoy watching or playing sports (Mitchell et al., 2006; Jenkins et al., 2008). Perhaps we deploy a similar set of processes when attributing mental states to social groups as we do to individuals; that is, perhaps we view such groups as mental agents with distinct likes, desires and proclivities (Brewer and Harasty, 1996; Hamilton and Sherman, 1996).

In this way, the current findings suggest that stereotyping shares more in common with representing mental states than with semantic knowledge of non-social categories. In turn, they demonstrate an important facet of the category-specific nature of semantic memory (Caramazza and Shelton, 1998): namely, knowledge about social categories is not like other forms of semantic knowledge. As such, the present results challenge longstanding claims that stereotypes may be one of many instances of general semantic knowledge.

The present experiment also builds on previous work that observed preferential engagement of MPFC when participants consider gender stereotypes (Quadflieg et al., 2009). Since participants in this earlier study were explicitly asked to think about what most other people believe about gender roles, it has previously been unclear whether this MPFC activation might be driven by participants' attempts to think about other minds—that is, to mentalize about how another person would answer these questions—rather than stereotyping per se. Here, participants were simply asked to judge social and non-social attributes on the basis of their own personal semantic knowledge, thus minimizing any explicit demand to consider how other people might answer the same questions.

Previous research has also identified anterior temporal cortex as a region important for representing social knowledge (for reviews, see Olson et al., 2007; Simmons and Martin, 2009). For example, activity in anterior temporal cortex has been observed when participants judge words that describe the personality of individual people (Zahn, et al., 2007, 2009; Ross and Olson, 2010) or encode biographical details about fictional persons (Simmons et al., 2010). Here, we extend this work by demonstrating that anterior temporal cortex is likewise engaged when drawing on knowledge about social groups: stereotyping trials were associated with sizeable activations in bilateral portions of middle temporal gyrus that extended rostrally into anterior temporal cortex.

Throughout its history, social psychologists have given a considerable amount of empirical attention to social group dynamics—how we think about groups, how being in a group influences the behavior of individuals, how groups interact with each other, how intergroup conflict and hegemony arise, etc. (for reviews, see Dovidio and Gaertner, 2010; Hackman and Katz, 2010; Yzerbyt and Demoulin, 2010). Although researchers have increasingly brought the methods of cognitive neuroscience to bear on questions of social

psychological interest, few such social neuroscience studies have examined how we think about and are influenced by groups. Here, we demonstrate that such emerging methodologies can furnish new insights into the nature of human intergroup cognition, including the current demonstration that knowledge about social categories shares little in common with other forms of semantic knowledge.

SUPPLEMENTARY DATA

Supplementary data are available at *SCAN* online.

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