

Anatomical Segregation of Representations of Personally Familiar and Famous People in the Temporal and Parietal Cortices

Motoaki Sugiura¹, Yuko Sassa^{1,2}, Jobu Watanabe³, Yuko Akitsuki⁴, Yasuhiro Maeda⁵, Yoshihiko Matsue⁵, and Ryuta Kawashima^{1,2}

Abstract

Person recognition has been assumed to entail many types of person-specific cognitive responses, including retrieval of knowledge, episodic recollection, and emotional responses. To demonstrate the cortical correlates of this modular structure of multimodal person representation, we investigated neural responses preferential to personally familiar people and responses dependent on familiarity with famous people in the temporal and parietal cortices. During functional magnetic resonance imaging (fMRI) measurements, normal subjects recognized personally familiar names (personal) or famous names with high or low degrees of familiarity (high or low, respectively). Effects of familiarity with famous people (i.e., high–low) were identified in the bilateral angular gyri, the left supra-marginal gyrus, the middle part of the bilateral posterior cingulate cortices, and the left precuneus. Activation preferentially

relevant to personally familiar people (i.e., personal–high) was identified in the bilateral temporo-parietal junctions, the right anterolateral temporal cortices, posterior middle temporal gyrus, posterior cingulate cortex (with a peak in the posterodorsal part), and the left precuneus; these activation foci exhibited varying degrees of activation for high and low names. An equivalent extent of activation was observed for all familiar names in the bilateral temporal poles, the left orbito-insular junction, the middle temporal gyrus, and the anterior part of the posterior cingulate cortex. The results demonstrated that distinct cortical areas supported different types of cognitive responses, induced to different degrees during recognition of famous and personally familiar people, providing neuroscientific evidence for the modularity of multimodal person representation. ■

INTRODUCTION

Person recognition has been modeled as a process of accessing a multimodal person representation via unimodal representations (e.g., a face, name, or voice) (Burton, Bruce, & Hancock, 1999; Bruce & Young, 1986). Multimodal person representation has been considered to have a modular structure, rather than to be a single module of information (Haxby, Hoffman, & Gobbini, 2000; Burton et al., 1999; Bruce & Young, 1986). The multiple classes of person-specific cognitive responses that person recognition entails have been assumed to comprise person representation: the retrieval of different types of person-specific knowledge (e.g., occupation, biography, personality traits), recollection of related autobiographical episodes, and person-specific emotional responses (Gobbini & Haxby, 2007; Haxby et al., 2000; Bruce & Young, 1986). Neuroscientific inquiry into the modular structure of multimodal person representation aims at

mapping these component cognitive responses onto distinct cortical areas or networks in the future.

The modules or component cognitive responses of multimodal representation may be shared by other daily real-world entities, particularly those categorized as personally familiar or autobiographical, including the place, object, and episode (Gobbini & Haxby, 2007; Sugiura, Shah, Zilles, & Fink, 2005; Gorno-Tempini & Price, 2001; Nakamura et al., 2000). Thus, the neuroscientific inquiry into the modular structure of multimodal person representation not only addresses person-recognition mechanisms but may also provide a holistic view of how the brain represents such daily real-world entities.

Although many functional imaging studies have addressed multimodal person representation, its modular structure remains to be investigated. To distinguish multimodal representation from unimodal representation, some studies reported neural response to familiar persons, relative to unfamiliar persons, common across multiple modalities (e.g., face, name, voice) (Nakamura et al., 2000, 2001; Shah et al., 2001; Gorno-Tempini et al., 1998). The activation reported in these studies, however, may have been affected by differences in the task-related mechanisms between familiar and unfamiliar stimuli, such

¹Tohoku University, Sendai, Japan, ²Japan Science and Technology Agency, Kawaguchi, Japan, ³Waseda University, Tokyo, Japan, ⁴Tohoku University Graduate School of Medicine, Sendai, Japan, ⁵Tohoku Fukushi University, Sendai, Japan

as differences in response selection (in explicit tasks) and strategy (in implicit tasks). These potentially confounding factors seem to have been controlled in studies that compared activation between different classes of familiar people: between famous and newly learned faces (Leveroni et al., 2000), between famous and personally familiar faces (Gobbini, Leibenluft, Santiago, & Haxby, 2004) and names (Sugiura et al., 2006), and between faces of personally familiar and the subjects' own babies (Leibenluft, Gobbini, Harrison, & Haxby, 2004). Most researchers in these studies discussed the results associating each activated area with a specific component of multimodal person representation. In particular, those who compared famous and personally familiar people underscored qualitative differences in the representation between the two classes of familiar people (Sugiura et al., 2006; Gobbini et al., 2004). However, the results of these studies do not actually argue the modular structure of the representation because only a single contrast between two different classes of familiar people was tested.

Some studies have indicated that the temporo-parietal and medial posterior cortices were preferentially involved in the representation of personally familiar people, but others have suggested that these regions were also relevant to famous people. The greater activation for personally familiar than for famous people both in face (Gobbini et al., 2004) and name (Sugiura et al., 2006) recognition tasks has been reported in the bilateral temporo-parietal regions and medial posterior cortices, including the posterior cingulate and the precuneus. The observed differential activation may have particular relevance to personally familiar people, given the implication of these activated areas in social interactions (Sassa et al., 2007; Rilling, Sanfey, Aronson, Nystrom, & Cohen, 2004), autobiographical episodes (Svoboda, McKinnon, & Levine, 2006), and emotional responses (Maddock, 1999). However, higher activation in similar areas was reported during recognition of famous people (Leveroni et al., 2000; Gorno-Tempini et al., 1998), suggesting that activation in these areas may reflect non-specific person familiarity, which would be applicable to both famous and personally familiar people. These differing interpretations may be reconciled by the involvement of different subdivisions of these areas in the representations of personally familiar and famous people, which is plausible, considering the known functional subdivisions in the temporo-parietal regions (Gobbini, Koralek, Bryan, Montgomery, & Haxby, 2007; Saxe, 2006) and medial posterior cortices (Cavanna & Trimble, 2006; Vogt, Vogt, & Laureys, 2006; Sugiura et al., 2005; Wagner, Shannon, Kahn, & Buckner, 2005).

In this functional magnetic resonance imaging (fMRI) study, to address the modular structure of multimodal person representation, we compared cortical areas preferentially relevant to recognition of personally familiar people and those sensitive to familiarity with famous people. We tested differential activation during name

recognition in two contrasts among the following three classes of familiar people: personally familiar (personal), famous with high familiarity (high), and famous with low familiarity (low). We contrasted personal against high, assuming differential activation would reflect cognitive responses relevant to personally familiar people. We contrasted high against low, assuming differential activation would primarily reflect cognitive responses relevant to familiarity with famous people. If the cortical distribution of activation differed between the two contrasts, the results would provide evidence of the modular structure of multimodal person representation, suggesting that cognitive responses relevant to personally familiar people would be supported by partially distinct cortical areas from responses to famous people. We scanned only the temporal and parietal cortices, where familiarity-dependent activation was observed previously (Sugiura et al., 2006). By limiting the scanning area, we took advantage of the reduced statistical demand for corrections of multiple comparisons by the reduced search volume, and the reduced susceptibility to artifacts resulting from adoption of a smaller voxel size for data acquisition. Thus, exhaustive identification of networks for person representations across the entire cerebral cortex was not the purpose of the study.

METHODS

Subjects

Twenty-eight healthy, right-handed volunteers (19 men and 9 women aged 18–32 years) participated in the study. All subjects had normal vision, and none had a history of neurological or psychiatric illness. Written informed consent was obtained from all subjects, in accordance with the guidelines of the ethics committee of Tohoku Fukushi University and the Declaration of Helsinki (1991). Handedness was evaluated using the Edinburgh Handedness Inventory (Oldfield, 1971). Because the quality of the data from three subjects was poor (see Image Preprocessing), we used only the data from the remaining 25 subjects (16 men and 9 women) for our analysis.

Stimuli and Tasks

A Japanese name consisting of a family name and first name written in Japanese kanji or kana characters was presented visually during each trial. A list of 40 personally familiar names (e.g., family members, relatives, friends) and a list of 40 famous names (e.g., politicians, athletes, actors, writers) were provided by each subject 1 to 3 weeks before the experiment. The names on the two lists were designated as personal and high, respectively, when correctly recognized during the experiment. Another list of 60 famous names, which was used for all subjects, was prepared by the experimenters, such that

approximately 40 of the 60 names, on average, were familiar to each subject, according to preparatory screening. The names on this list were regarded as low names when correctly recognized during the experiment. When some names in the list of low names overlapped with the list of high names given by the subject, they were substituted by other reserve famous names. A list of 60 unfamiliar names, taken from the lists of personally familiar names from other subjects, was made for each subject. In total, 200 names from the four lists were randomly reordered. Each name was presented only once to each subject.

During each trial, each stimulus was presented at the center of the visual field for 0.5 sec, followed by presentation of a fixation cross for 5.5 sec. The visual stimuli were back-projected on a semitranslucent screen attached to the head coil of the MRI scanner, and the subject viewed the stimuli via a mirror. In each trial, the subject was instructed to judge whether the presented name was familiar. A response, by pressing a button with the right index finger, was required when the name was familiar and no response was required for unfamiliar names. Any additional effort related to person recognition, such as visual imagery or episodic retrieval, was neither encouraged nor discouraged.

fMRI Measurement

Twenty-one oblique gradient-echo images (echo time = 60 msec, flip angle = 90°, slice thickness = 2 mm, slice gap = 1 mm, FOV = 192 mm, matrix = 64 × 64) covering the entire temporal lobe and a major part of the parietal lobe were acquired at a repetition time of 2.5 sec using an echo-planar image (EPI) sequence and a Siemens Vision (1.5 T) MR scanner (Siemens, Erlangen, Germany). The scan area was determined using horizontal, sagittal, and coronal T1-weighted localization scans and included the areas found by Sugiura et al. (2006) to exhibit differential activation for personally familiar names relative to unfamiliar names. Excluding six dummy scans for stabilization of the T1-saturation effect, 480 volumes were acquired. A volume composed of 64 slices, obtained using the same scanning protocol as for the fMRI measurement but covering the entire brain, was also acquired. This whole-brain EPI was used to co-register the functional images (temporo-parietal EPI) to a T1-weighted anatomical image, acquired using SP-RAGE on a separate occasion, for each subject.

Post-MRI Name Categorization and Evaluation

Immediately after each subject completed the fMRI measurements and exited the scanner, the subject was shown the list of presented names again and asked to categorize the names as personally familiar, famous, or unfamiliar. No time constraint was imposed. Subjects were instructed that any names that were first recognized in this

categorization task (i.e., not during the task in the MRI scanner) should be categorized as unfamiliar.

After the categorization task, each subject self-evaluated the amount of declarative information (“To what extent can you describe this person?”), vividness of visual imagery (“How vividly can you imagine this person?”), and the extent of emotional involvement (“To what extent are you emotionally involved with this person?”) for each familiar (personal/high/low) name, using a 6-point scale (0 = not at all to 5 = very much). This evaluation was used to ensure that the high names were more familiar than the low names in a casual sense. The three aspects of person familiarity and the questions used for the evaluation were arbitrary and were not meant to be associated with a specific cognitive response or module of the person representation.

Image Preprocessing

The following preprocessing procedures were performed using the Statistical Parametric Mapping (SPM2) software (Wellcome Department of Cognitive Neurology, London, UK) and MATLAB (Mathworks, Natick, MA): the adjustment of acquisition timing across slices, correction for head motion, coregistration to the whole-brain EPI, coregistration to the T1-weighted anatomical image (using the whole-brain EPI), spatial normalization (using a T1-MNI template), and smoothing using a Gaussian kernel with a 10-mm full width at half maximum. Data from two subjects with excessive head motion (more than 2 mm) and one with dubious task performance (less than 90% correct responses) were excluded from the analysis.

Image Analysis

Each trial was assigned as personal, famous (high/low), or unfamiliar on the basis of the post-fMRI name categorization, which allowed correct categorization of incidentally familiar names in the names prepared for other categories, and correction of response errors during the fMRI task. The famous-name trials were designated as high or low according to whether the name was provided by the subject or by the experimenter, respectively. This high/low distinction was also meant to control the episodic memory of preparing the name list prior to the experiment, as described below. Thus, the three post-fMRI self-evaluated familiarity measures for evaluation of familiarity of high and low names were not used for the high/low categorization.

A voxel-by-voxel multiple regression analysis of the expected signal change for the four trial categories was applied to the preprocessed images for each subject. This analysis employed a standard event-related convolution model using the hemodynamic response function provided by SPM2. Statistical inference on contrasts of parameter estimates was then performed with a second-level

between-subject (random effects) model using a one-sample *t* test.

Initially, activations for personal, high, and low names were contrasted with the activation for unfamiliar names. Then, three elaborative analyses were conducted to identify cortical areas that showed specific activation patterns of interest. The first analysis was dedicated to common activation, which was assumed to reflect processes related to unimodal person representation and behavioral responses (note that the subject was not required to respond to unfamiliar names). The second and third analyses—the key analyses in this study—were addressed to multimodal person representation, expecting different cortical distributions between activation sensitive to familiarity with famous people and activation relevant to personally familiar people. Several masks were applied to identify assumed activation patterns and to eliminate confounding factors.

For common activation, the main contrast was low–unfamiliar, and an inclusive mask (i.e., the analysis was confined to areas that showed significant activation in the mask contrast) of the high–unfamiliar and personal–unfamiliar contrasts was applied; the low, rather than the high or personal, name was selected for the main contrast because minimal involvement of person representation was expected. Exclusive masks (i.e., areas that showed significant activation in the mask contrast were excluded from the analysis) of high–low and personal–high were also applied, assuming equivalent degrees of activation across all familiar name categories. Additionally, an inclusive mask of the low-baseline contrast was applied to decrease the risk of reporting differential activation caused by deactivation for an unfamiliar name. Although sub-optimal sensitivity was expected for this mask contrast because of the fixed and relatively short interstimulus interval (6 sec), we chose to accept the risk of false-negatives rather than one of false-positives.

For cortical areas that showed activation sensitive to familiarity with famous people, the main contrast was high–low. Because activation for high names, but not for low names, could reflect retrieval of the episode of preparing the lists before the experiment, the inclusive mask of low–unfamiliar, which should reflect familiarity with famous people but no such episodic retrieval, was applied. In addition, to ensure that differential activation was caused by activation for the high names, rather than deactivation for the low names, an inclusive mask of the high–unfamiliar contrast was applied.

For cortical areas that showed activation relevant to personally familiar people, the main contrast was personal–high. To ensure that the differential activation was caused by activation for the personal names, rather than deactivation for the high names, the inclusive mask of the personal–unfamiliar contrast was applied.

For the main contrast in all these voxel-by-voxel analyses, the statistical threshold was set to $p < .001$ for height and corrected to $p < .05$ for multiple comparisons using cluster size. For the masks, $p < .05$ was used

without applying a correction for multiple comparisons. To inspect the characteristics of activation in the identified areas, parameter estimates (i.e., partial regression coefficients from the multiple regression model) at the peak voxel were compared post hoc across name categories using paired *t* tests with a threshold of $p < .05$.

RESULTS

Behavioral Data

In the post-MRI name categorization, all subjects correctly categorized all 40 personally familiar and all 40 famous names provided by the subject himself/herself; these names were then categorized as personal and high names, respectively. Among the 60 names on the famous name list that the experimenters had prepared, the subjects categorized 42.8 ± 9.2 (mean \pm standard deviation) names as famous; these names were assigned to the low category. The percentages of correct responses for personal, high, and low names during the fMRI experiment were $96.6 \pm 4.6\%$, $95.2 \pm 5.8\%$, and $86.1 \pm 9.1\%$, respectively, and the mean reaction times were 1056 ± 216 , 1083 ± 200 , and 1190 ± 236 msec, respectively. The percentage correct response was significantly lower, and the mean reaction time was significantly longer, for low than for personal or high names ($p < .05$, paired *t* test). No significant difference was detected in the two behavioral measures between personal and high names.

Mean self-evaluated scores for person-related information for the personal, high, and low names, respectively, were 2.98 ± 0.55 , 2.03 ± 0.59 , and 1.57 ± 0.54 for the amount of declarative information; 3.49 ± 0.69 , 2.64 ± 0.77 , and 2.20 ± 0.66 for vividness of visual imagery; and 2.14 ± 1.14 , 1.36 ± 0.91 , and 0.85 ± 0.71 for the extent of emotional involvement. Scores were significantly higher for personal than for high and low names, and for high than for low names in all three measures ($p < .05$, paired *t* test). These results thus confirmed our assumption that the high names were more familiar to the subjects than the low names.

Imaging Data

Significant activations for personal, high, and low names, relative to unfamiliar names, are presented in Table 1 and Figure 1. The temporal pole, the supramarginal gyrus, a region in the angular gyrus or the lateral wall of the posterior part of the intraparietal sulcus (AG/IPS), and the orbito-insular junction were bilaterally activated for all familiar name categories. The left posterior middle temporal gyrus, temporo-parietal junction, rhinal sulcus, precuneus, right anterior middle temporal gyrus, and medial anterior part of the posterior cingulate cortex were also activated for the familiar name categories. The bilateral hippocampus, left anterior middle temporal gyrus, amygdala, globus pallidus, right rhinal sulcus, and posterodorsal part

Table 1. Activation for Each Name Category

Structure		Personal	High	Low
Temporal pole	L	-44, 8, -30 (6.65, a) -38, 20, -30 (6.07, a)	-44, 10, -32 (7.92, 30,072a) -38, 20, -30 (6.81, a)	-44, 10, -32 (6.32, 10,440a)
	R	40, 22, -36 (5.99, b)	42, 22, -34 (5.72, b)	42, 24, -34 (4.28, b)
Anterior middle temporal gyrus	L	-56, -4, -28 (6.71, 29,472a)	-52, -2, -32 (6.56, a)	
	R	56, 10, -30 (9.05, b)	56, 6, -28 (4.02, 312*)	50, 16, -30 (5.87, 1800b)
Anterior superior temporal sulcus	R	66, -6, -16 (9.12, b)		
Posterior middle temporal gyrus	L	-60, -24, -8 (6.36, a) -66, -30, -6 (6.34, a)	-62, -36, -4 (7.29, a)	-62, -42, -2 (5.76, 1496*)
	R	66, -40, -2 (6.87, b)		
Temporo-parietal junction	L	-46, -66, 36 (8.91, c)	-36, -68, 34 (8.51, c)	-36, -68, 30 (5.25, c)
	R	62, -58, 24 (6.71, b)		
Supramarginal gyrus	L	-46, -56, 46 (10.16, 26,600c)	-58, -54, 32 (7.55, c)	-46, -58, 50 (5.91, 11,768c)
	R	52, -58, 48 (8.07, b)	52, -56, 52 (6.27, d)	50, -62, 50 (4.19, 960d*)
AG/IPS	L	-40, -68, 50 (9.06, c)	-40, -66, 54 (9.74, 22544c)	-48, -70, 40 (5.49, c)
	R	44, -70, 38 (11.37, 57608b)	42, -70, 50 (6.93, 14,104d)	40, -72, 50 (3.80, d)
Orbito-insular junction	L	-32, 8, -16 (5.35, a)	-36, 0, -20 (6.90, a) -36, 18, -20 (6.43, a)	-32, 12, -22 (5.15, a)
	R	32, 6, -16 (6.13, b)	34, 10, -18 (7.51, 12464b)	32, 4, -16 (4.71, 720*)
Rhinal sulcus	L	-22, -8, -30 (5.49, a)	-22, -6, -32 (4.79, a)	-32, 0, -38 (4.74, a)
	R	24, -2, -34 (4.82, b)	24, -4, -34 (4.27, b)	
Hippocampus	L	-28, -24, -18 (5.78, a)	-30, -24, -16 (4.80, a)	
	R	30, -18, -20 (5.24, b)	24, -22, -14 (5.29, b) 34, -14, -22 (5.24, b)	
Amygdala	L	-22, -6, -18 (4.92, a)	-26, -6, -20 (5.18, a)	
Globus pallidus	L	-14, -8, -10 (5.30, a)	-18, -6, -10 (5.24, a)	
Posterior cingulate cortex (anterior part)	M	0, -8, 32 (5.32, d) 2, -30, 40 (8.94, 58,440d)	0, -10, 34 (8.70, 35,168e) 4, -26, 40 (7.48, e)	0, -12, 38 (3.85, e) 0, -30, 36 (6.63, 6448e)
	L		-6, -36, 40 (7.88, e)	
Posterior cingulate cortex (posterodorsal part)	L		-14, -52, 32 (6.88, e)	
	R	8, -52, 26 (13.84, d)	12, -56, 26 (4.62, e)	
Posterior cingulate cortex (caudal part)	L		-4, -54, 16 (5.44, e)	-2, -52, 16 (4.84, e)
Precuneus	L	-10, -62, 42 (13.32, d)	-4, -56, 44 (5.79, e)	-2, -56, 38 (3.85, e)

Coordinates (x, y, z) of peak activation are given for each area that showed activation for each familiar name category, relative to the unfamiliar name. The *t* value at the peak and cluster size (mm³) is shown in parentheses. The height threshold for significant activation was $p < .001$. Correction for multiple comparisons ($p < .05$ in cluster size) was made for personal names, but not for the same activation clusters for high or low names. L = left; R = right; AG/IPS = region in the angular gyrus or the lateral wall of the posterior part of the intraparietal sulcus. An asterisk (*) indicates that the cluster size did not survive the correction for multiple comparisons. A lowercase letter given with the cluster size indicates that the peak is in the same activated cluster as the other peaks with the same letter.

of the posterior cingulate cortex were activated for personal and high names. The right anterior superior temporal sulcus, posterior middle temporal gyrus, and temporo-parietal junction were activated for personal names only. In the left posterior cingulate cortex, activation peaks were observed in the middle and posterodorsal parts for high names and in the caudal part for high and low names; the activation cluster for personal names covered all these peaks, but activation peaks were not identified there.

In the first elaborative analysis, common activation to equivalent degrees for all familiar name categories was observed in the bilateral temporal poles, the left orbito-insular junction, the middle temporal gyrus, and the anterior part of the posterior cingulate cortex (Table 2, Figure 2).

The second elaborative analysis identified a significant effect of familiarity with famous people (i.e., high–low) in the bilateral AG/IPS, the left supramarginal gyrus, the middle part of the posterior cingulate cortex (with peaks in both hemispheres), and the left precuneus (Table 3, Figure 3). Inspection of the activation profiles showed that in all activated areas, activation was comparable between personal and high names, but greater for personal than for low names (Figure 3).

In the third elaborative analysis, activation relevant to personally familiar people (i.e., personal–high) was observed in the bilateral temporo-parietal junctions, the right anterior middle temporal gyrus, the anterior superior temporal sulcus, the posterior middle temporal gyrus, the posterior cingulate cortex (with a peak at the posterodorsal part), and the left precuneus (Table 4, Figure 4). Inspection of the activation profile revealed that the degree of activation for high and low names varied across these regions. Activation was greater for high and low names than for unfamiliar names in the bilateral temporo-parietal junction and the right posterior middle temporal gyrus (Figure 4A), and greater for high names than for low or unfamiliar names in the posterodorsal part of the right posterior cingulate cortex and the left precuneus (Figure 4B). There was no significant activation for high or low names relative to unfamiliar names in the right anterior middle temporal gyrus or superior temporal sulcus (Figure 4C).

Although the medial-temporal structures were activated for personal and high names, these regions were not included in the results of the three elaborative analyses for the specific processes modeled. Activation profiles at peak activations in the medial-temporal structures

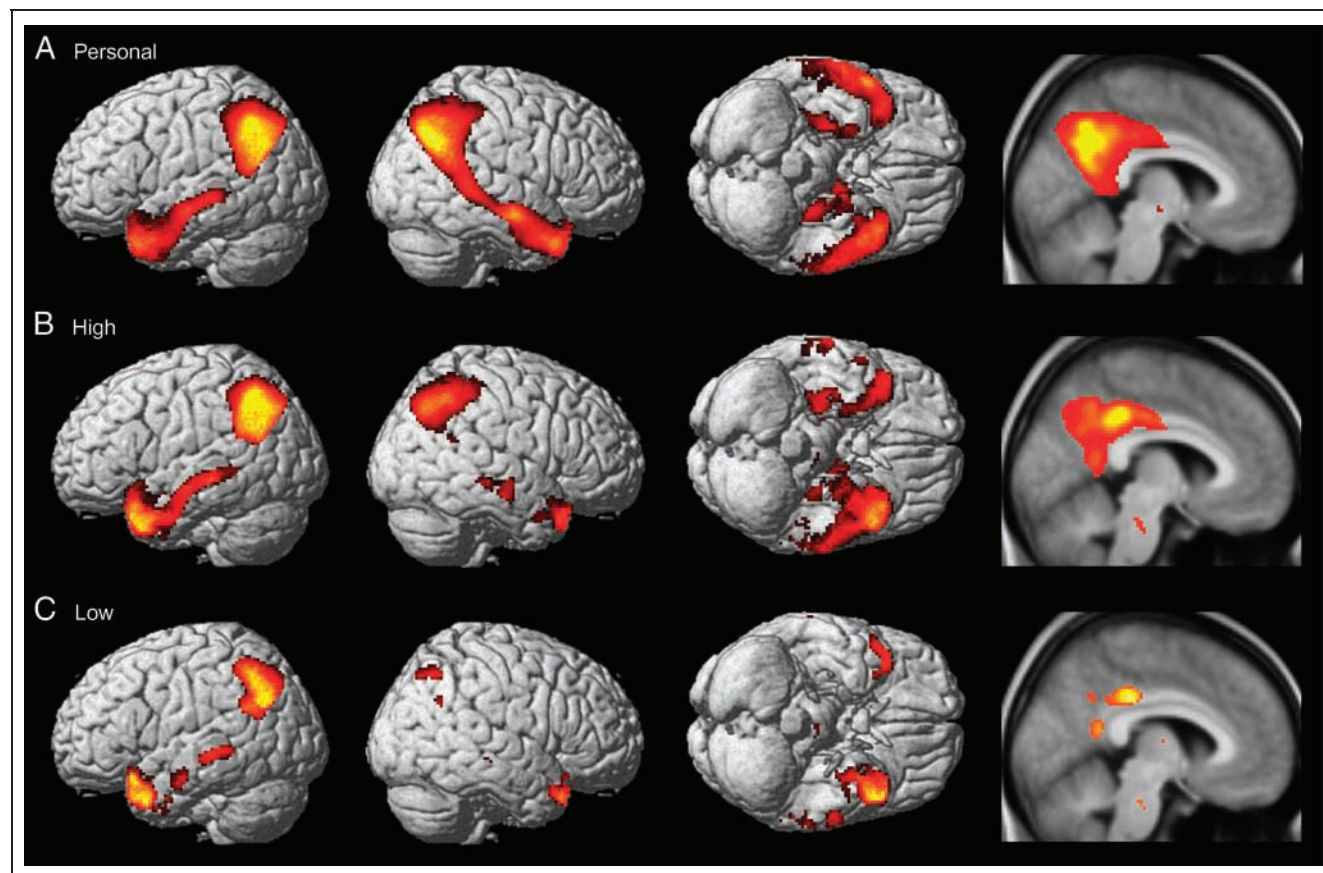


Figure 1. Activated areas for personal (A), high (B), and low (C) names, relative to unfamiliar names. The first three columns (left to right) show activation rendered on the standard single subject brain (provided by SPM2) from the left side, right side, and bottom of the brain, respectively. The fourth panel shows the activation superimposed on the parasagittal ($x = -6$ mm) section of the mean normalized anatomical image of all subjects.

Table 2. Activation Common across Familiar Names

Structure		Coordinate			<i>t</i>	Cluster Size (mm ³)
		<i>x</i>	<i>y</i>	<i>z</i>		
Temporal pole	L	-44	10	-32	6.32	8312a
	R	42	18	-30	4.79	736
Orbito-insular junction	L	-32	12	-22	5.15	a
Posterior middle temporal gyrus	L	-62	-42	-2	5.76	1304
Posterior cingulate cortex (anterior part)	M	0	-30	36	6.63	1432

The results of the low–unfamiliar contrast inclusively masked by high–unfamiliar, personal–unfamiliar, and low–baseline contrasts, and exclusively by high–low and personal–high contrasts. Coordinates, *t* values of peak activation, and cluster size are shown for each activated area. The height threshold for significant activation was $p < .001$ and was corrected to $p < .05$ for multiple comparisons using the cluster size. L = left; R = right. A lowercase letter given with the cluster size indicates that the peak is in the same activated cluster as the other peaks with the same letter.

identified in the personal–unfamiliar contrast are shown in Figure 5. The hippocampus and the rhinal sulcus bilaterally showed activation for all familiar name categories, and significantly greater activation was observed for personal and high names than for low names. The left amygdala also exhibited activation for all familiar name categories, but significantly greater activation was observed only for personal names compared to low names.

DISCUSSION

In this study, we sought to neuroscientifically demonstrate the modularity of multimodal person representation. Activation sensitive to familiarity of famous people (i.e., high–low; Figure 3) and that relevant to personally familiar people (i.e., personal–high; Figure 4) was found

in distinct cortical areas (summarized in Figure 6A). The results suggest that cognitive responses that are relevant to personally familiar people are supported by cortical areas that are partially distinct from those involving cognitive responses sensitive to familiarity with famous people. Additionally, within the cortical areas that exhibited activation relevant to personally familiar people, the activation profile revealed varying degrees of activation for high and low names (Figure 4). The results indicate that these areas support different types of cognitive responses, which are induced to different degrees during the recognition of famous people. Accordingly, this study provides the first direct evidence of the modular structure of multimodal person representation, which is composed of different types of cognitive responses that have varying degrees of relevance to the different types

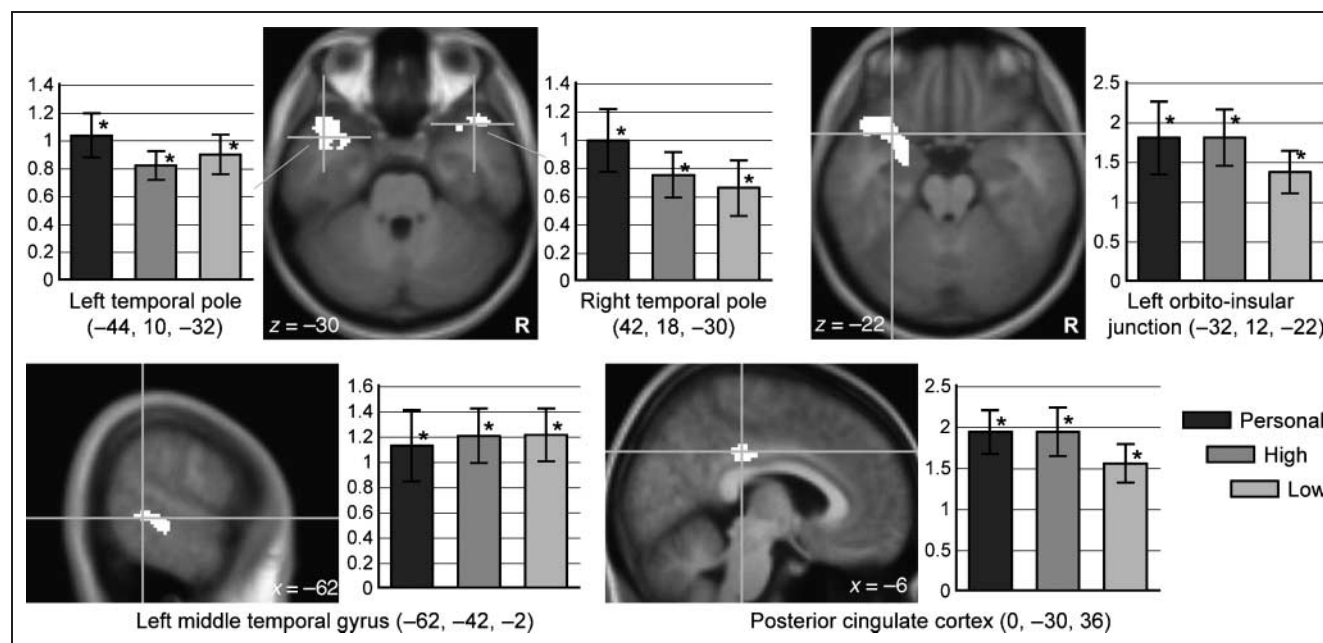


Figure 2. Areas showing equivalent extents of activation for all the familiar name categories. Activated areas (white) are superimposed on the appropriate sections of the mean normalized anatomical image of all the subjects. Each activation profile shows the mean differential parameter estimate (arbitrary units) relative to unfamiliar names at the peak voxel. * $p < .05$.

Table 3. Activation Sensitive to Familiarity with Famous People

Structure		Coordinate			<i>t</i>	Cluster Size (mm ³)
		<i>x</i>	<i>y</i>	<i>z</i>		
Supramarginal gyrus	L	-58	-52	40	4.60	1264
AG/IPS	L	-38	-62	50	4.91	2832
	R	36	-64	44	4.51	1112
Posterior cingulate cortex (middle part)	L	-8	-40	40	6.02	4000a
	R	10	-46	38	4.84	a
Precuneus	L	-10	-58	44	4.67	a

The results of the high–low contrast inclusively masked by high–unfamiliar and low–unfamiliar contrasts. AG/IPS = region in the angular gyrus or the lateral wall of the posterior part of the intraparietal sulcus. Other details are the same as in Table 2.

of familiar people (Figure 6B), supported by different cortical areas.

Lateral Temporo-parietal Region

Dorsal and ventral parts of the lateral temporo-parietal region exhibited different sensitivity to familiarity with famous people and to personally familiar people (Figure 6A and C). It appears reasonable to assume these two parts support different cognitive processes that characterize the two types of person familiarity. The dorsal regions (the left supramarginal gyrus and bilateral AG/IPS) were sensitive to familiarity with famous people (and also relevant to personally familiar people), and the ventral regions (the bilateral temporo-parietal junction and the right posterior middle temporal gyrus) were preferentially activated during recognition of personally familiar people.

This functional segregation appears to parallel the suggested differential involvement of the similar dorsal and ventral regions in personal semantic (i.e., repeated) events and personal episodic (i.e., unique) events, respectively, during autobiographical memory retrieval (Levine et al., 2004).

The possible involvement of the dorsal part in the retrieval of semantic knowledge, rather than of unique episodes, is also supported by the fact that the left angular gyrus has been implicated in lexical processing (Binder et al., 2003). Familiarity with famous people, as well as with personally familiar people, is likely to be related to the amount of semantic information available.

The ventral part is likely to support knowledge or episodic memory typically acquired in actual interactions with personally familiar people, while its nature is yet to be investigated. Greater activation for personally familiar

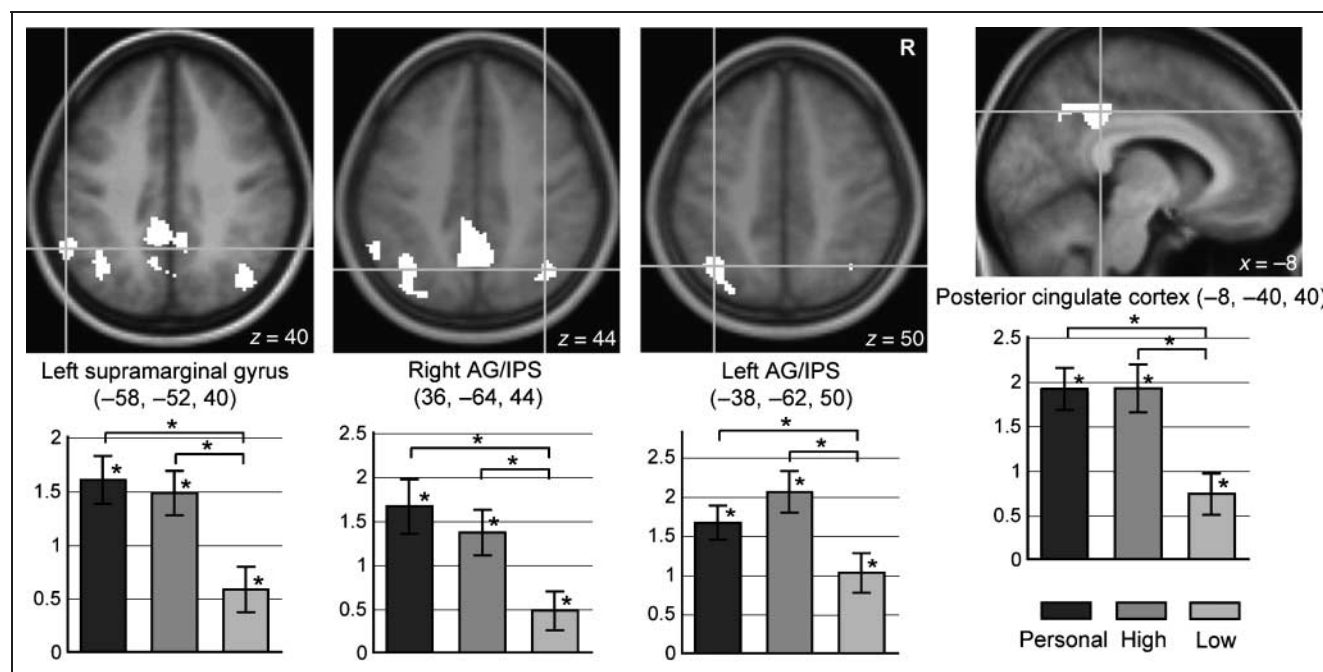


Figure 3. Areas sensitive to familiarity with famous names. Details of the presentation are the same as in Figure 2.

Table 4. Activation Preferentially Relevant to Personally Familiar Names

Structure	Coordinate				Cluster Size (mm ³)	High-Low	High-Unfamiliar	Low-Unfamiliar	
	x	y	z	t					
Anterior middle temporal gyrus	R	50	10	-38	5.32	6312a	<i>ns</i>	<i>ns</i>	<i>ns</i>
Anterior superior temporal sulcus	R	66	0	-18	7.60	a	<i>ns</i>	<i>ns</i>	<i>ns</i>
Posterior middle temporal gyrus	R	64	-38	2	4.11	10048b	<i>ns</i>	*	*
Temporo-parietal junction	L	-40	-54	20	5.06	5264	<i>ns</i>	*	*
	R	54	-64	30	8.10	b	<i>ns</i>	*	*
Posterior cingulate cortex (posterodorsal part)	R	8	-54	26	8.64	16120c	*	*	<i>ns</i>
Precuneus	L	-14	-56	44	4.34	c	*	*	<i>ns</i>

The results of the personal-high contrast, inclusively masked by the personal-unfamiliar contrast. Other details are the same as in Table 3. The results of the comparisons high-low, high-unfamiliar, and low-unfamiliar at each peak voxel (i.e., post hoc inspection of activation profile) are shown; *ns* = not significant. Other details are the same as in Table 2.

**p* < .05.

than for famous people in these regions has been discussed in previous studies, assuming social cognitive processes (Gobbini & Haxby, 2007) or egocentric spatial processing (Sugiura et al., 2006) being characteristically recruited when we meet personally familiar people. The temporo-parietal junction and the right posterior middle temporal gyrus have been implicated in social perception, including the processing of the actions and intentions of others (Saxe & Kanwisher, 2003; Allison, Puce, & McCarthy, 2000; Castelli, Happe, Frith, & Frith, 2000), as well as egocentric spatial judgment (Neggers, Van der Lubbe, Ramsey, & Postma, 2006; Vokeley et al., 2004). The two lines of apparently contradictory interpretations (i.e., social cognitive vs. spatial) may be reconciled by assuming that some of the social perceptive processes, such as the processing of actions by others and perspective taking, may involve the processing of an egocentric spatial representation (Jackson, Meltzoff, & Decety, 2006; Vokeley et al., 2004).

The peaks of differential activation for personally familiar and famous people in previous studies (Sugiura et al., 2006; Gobbini et al., 2004) were located between the dorsal and ventral foci in the current study. This suggests that the previously reported activation may reflect both the retrieval process of semantic information, which is relevant both to famous and personally familiar people, and cognitive processes preferentially relevant to personally familiar people.

Medial Posterior Cortex

Differential sensitivity to the familiarity of famous people and that of personally familiar names in the rostral and

caudal regions in the medial posterior cortex (Figure 6A and D) is also consistent with the functional segregation proposed in previous studies (Cavanna & Trimble, 2006; Vogt et al., 2006; Sugiura et al., 2005; Wagner et al., 2005). Larger responses to personally familiar than to famous names in the caudal region, but not in the rostral region, may parallel the suggested involvement of the caudal region in episodic retrieval (Cavanna & Trimble, 2006), episodic recollections (Wagner et al., 2005), and spatial representations (Sugiura et al., 2005). The caudal region is functionally connected with the temporo-parietal and medial prefrontal cortices (Vogt et al., 2006), areas that have been implicated in mental state attribution (Gallagher & Frith, 2003). All these cognitive processes implicated in the caudal region appear to be more relevant to personally familiar people than to famous people. The peak differential activation between personally familiar and famous people in previous studies (Sugiura et al., 2006; Gobbini et al., 2004) was located very close to our caudal activation foci.

Right Anterolateral Temporal Cortex

That activation of the right anterolateral temporal cortex was specific to personally familiar names (Figure 4C) may suggest a cognitive process that is predominantly recruited in interpersonal relationships. Greater activation for personally familiar than for famous faces in this region has been previously reported, although it was not discussed (Gobbini et al., 2004). Activation in this region was observed during retrieval of affect-laden autobiographical memory (Fink et al., 1996), viewing social scenes of moral violation (Moll et al., 2002), sad films of

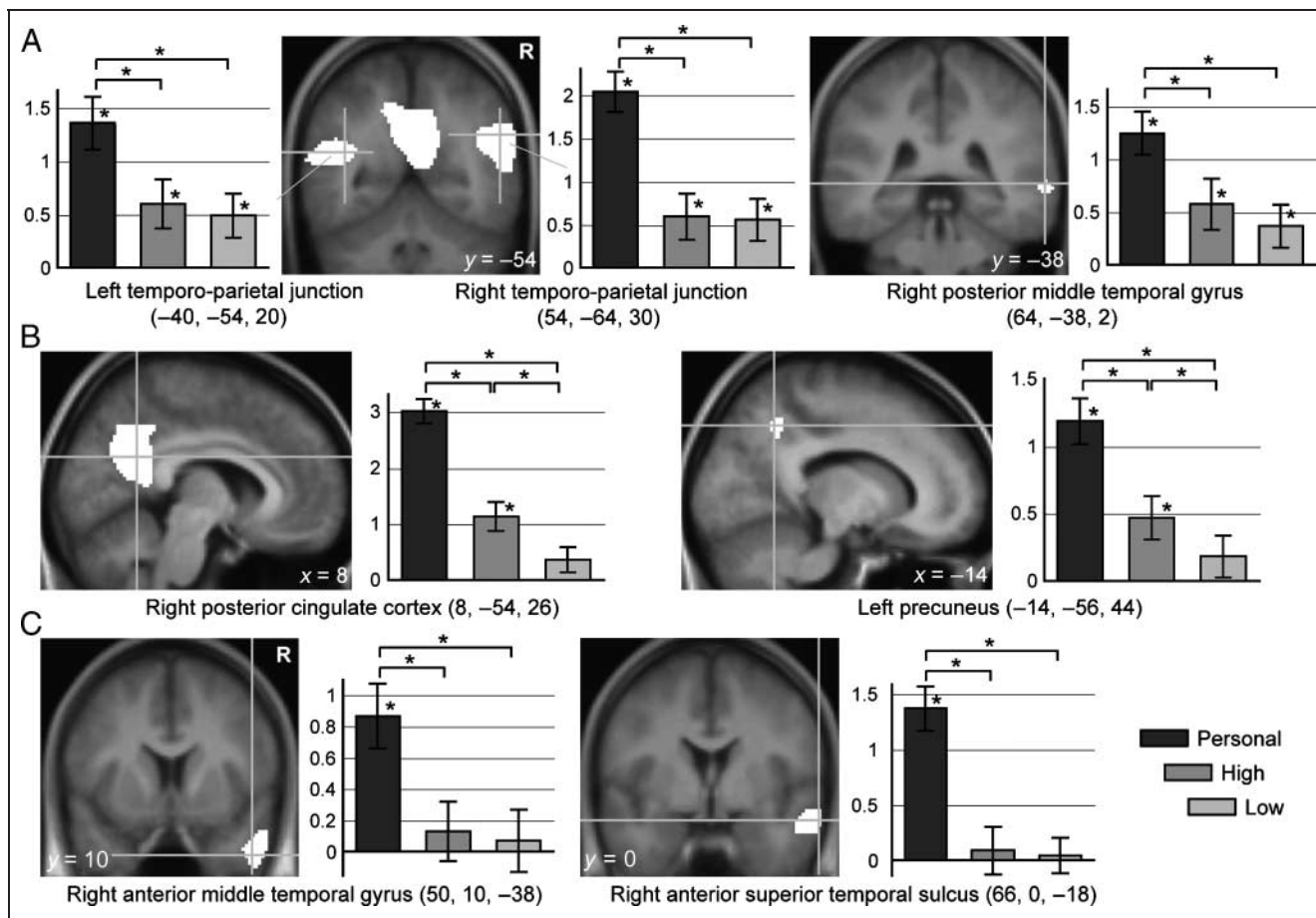


Figure 4. Areas preferentially relevant to personally familiar names. (A) Modest activation was observed for both high and low names. (B) Modest activation was also observed for high names. (C) Activation was specific to personal names. Other details are the same as in Figure 2.

a beloved person's death (Levesque et al., 2003), and judgment of an embarrassing situation (Takahashi et al., 2004); all these tasks include processing of social emotions. This region has also been implicated in communicative speech production (Sassa et al., 2007). Both social emotion and communicative speech are commonly experienced in interpersonal relationships.

Medial-temporal Structures

Activation of the medial-temporal structures was observed for familiar names, consistent with previous findings on person recognition (Douville et al., 2005; Bernard et al., 2004; Haist, Bowden Gore, & Mao, 2001; Leveroni et al., 2000). Greater activation for personal and high than for low names appeared to be consistent with the established role of the hippocampus in the recollection of episodic memory (Wheeler & Buckner, 2004; Eldridge, Knowlton, Furmanski, Bookheimer, & Engel, 2000).

In the left amygdala, activation was greater for personal than for low names. The amygdala has been implicated in affective responses to familiar faces (Ishai, Schmidt, & Boesiger, 2005; Schweinberger & Burton, 2003; Ellis & Lewis, 2001; Breen, Caine, & Coltheart, 2000; Haxby et al.,

2000; see also Gobbini et al., 2004). The current results demonstrate that the amygdala responds not only to familiar faces, but also to familiar names, suggesting that the amygdala may be sensitive to amodal emotion-related representations of a person.

Personal Familiarity-relevant Activation for Famous People

Some of the temporo-parietal and medial posterior regions where activation was preferential for personally familiar faces overlapped with areas that exhibited activation for famous people in previous studies (Leveroni et al., 2000; Gorno-Tempini et al., 1998). This observation may be explained by activation in these regions not being exclusive to personally familiar people, but also relevant to famous people to some degree. Two lines of interpretation may be possible for the involvement of these personal familiarity-relevant regions during recognition of famous people. Some classes of person-specific knowledge, such as personality traits, are particularly relevant to personally familiar people, but are also relevant to famous people (see Gobbini & Haxby, 2007). Activation could also be related to the retrieval of autobiographical episodes related to the famous people, which has

been suggested to induce activation of several temporoparietal and medial posterior regions (Denkova, Botzung, & Manning, 2006).

Common Activation across Familiar Name Categories

Common cortical activation for all familiar name categories was identified in the bilateral temporal poles, the left orbito-insular junction, the middle temporal gyrus, and the anterior part of the posterior cingulate cortex; the results for the temporal pole were consistent with those obtained by Sugiura et al. (2006). Although the temporal pole plays a key role in person recognition, this role is likely to be independent of person representations per se, as suggested by neuropsychological studies (Markowitsch et al., 1993; Kapur, Ellison, Smith, McLellan, & Burrows, 1992; Ellis, Young, & Critchley, 1989). This functional characteristic of the temporal pole may be comparable to the person-identity node (PIN) in the Bruce and Young (1986) model, which is conceptualized as an entrance from a unimodal (e.g., face, name, voice) recognition process to a multimodal process (Bruce & Young, 1986), and as associating multiple person-related information units (Burton et al., 1999; Burton, Bruce, & Johnston, 1990) (Figure 6B). The lack of effect of the two person representations in the current results gives further support to these arguments.

The left middle temporal gyrus may play a role in the representation of a person's name (see Figure 6B); greater activation of this region during semantic processing of words than during processing of pictures has previously been reported (Chee et al., 2000; Vandenberghe,

Price, Wise, Josephs, & Frackowiak, 1996). An activation common to famous names and faces was previously observed in the left middle temporal gyrus (Gorno-Tempini et al., 1998), although the focus occupied a location slightly anterior to that found in our study.

Activation in the orbito-insular junction and the anterior part of the posterior cingulate cortex may be explained by processes involved in behavioral responses. A region in close proximity to our orbito-insular activation focus was activated during visual processing of an object at low spatial resolution and was assumed to play a role in the top-down facilitation of visual recognition (Bar et al., 2006). This top-down facilitation mechanism is likely to be more involved during the detection of familiar names than during the rejection of unfamiliar names in this study. The anterior part of the posterior cingulate cortex has been implicated in the execution of a skilled motor task (Tracy et al., 2003), and thus, may have been related to the motor response in this study. Although common activation was expected in the sensorimotor cortex, because the subject was not required to respond to unfamiliar names, this area was outside the scanning area.

Methodological Considerations

The discussion of our results is based on the assumption that multimodal person representations are accessed independently of the stimulus or task, as many models of person recognition assume (Burton et al., 1999; Bruce & Young, 1986). However, this assumption remains unproven. In fact, the results of the contrast between personally familiar and famous persons in Sugiura et al. (2006)

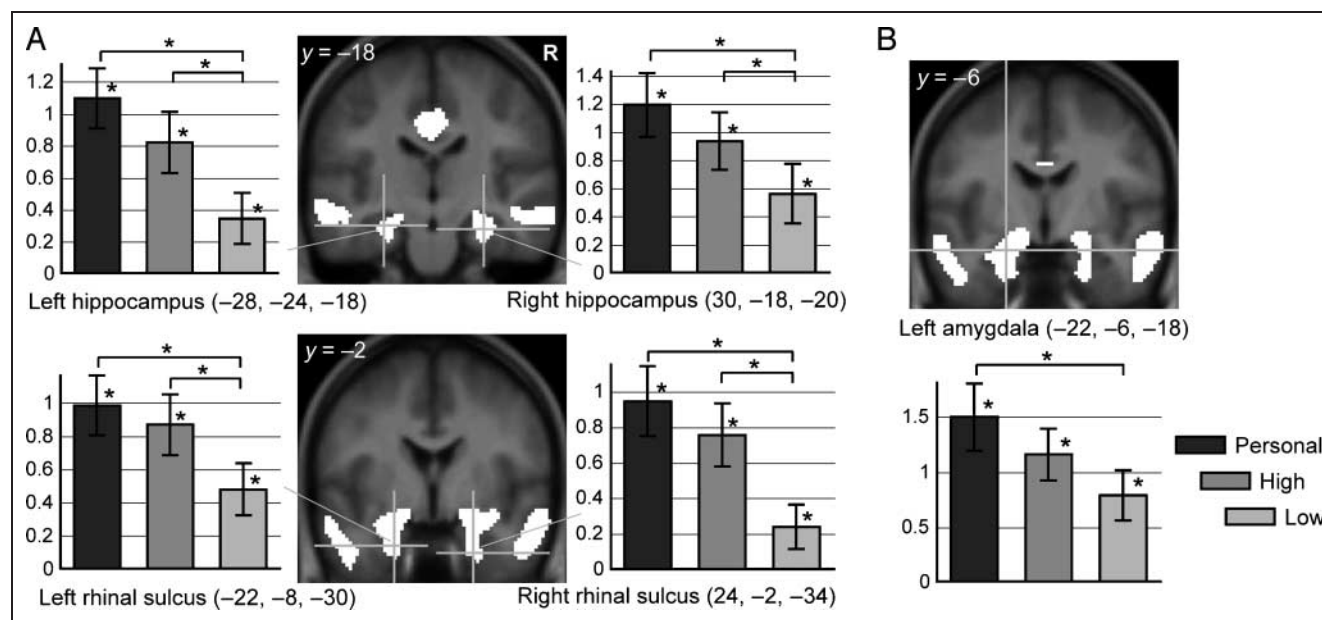


Figure 5. Activation of the medial temporal structures in the personal-unfamiliar contrast. (A) Activation was significantly greater for personal and high names than for low names. (B) Activation was significantly greater for personal names than for low names. Other details are the same as in Figure 2.

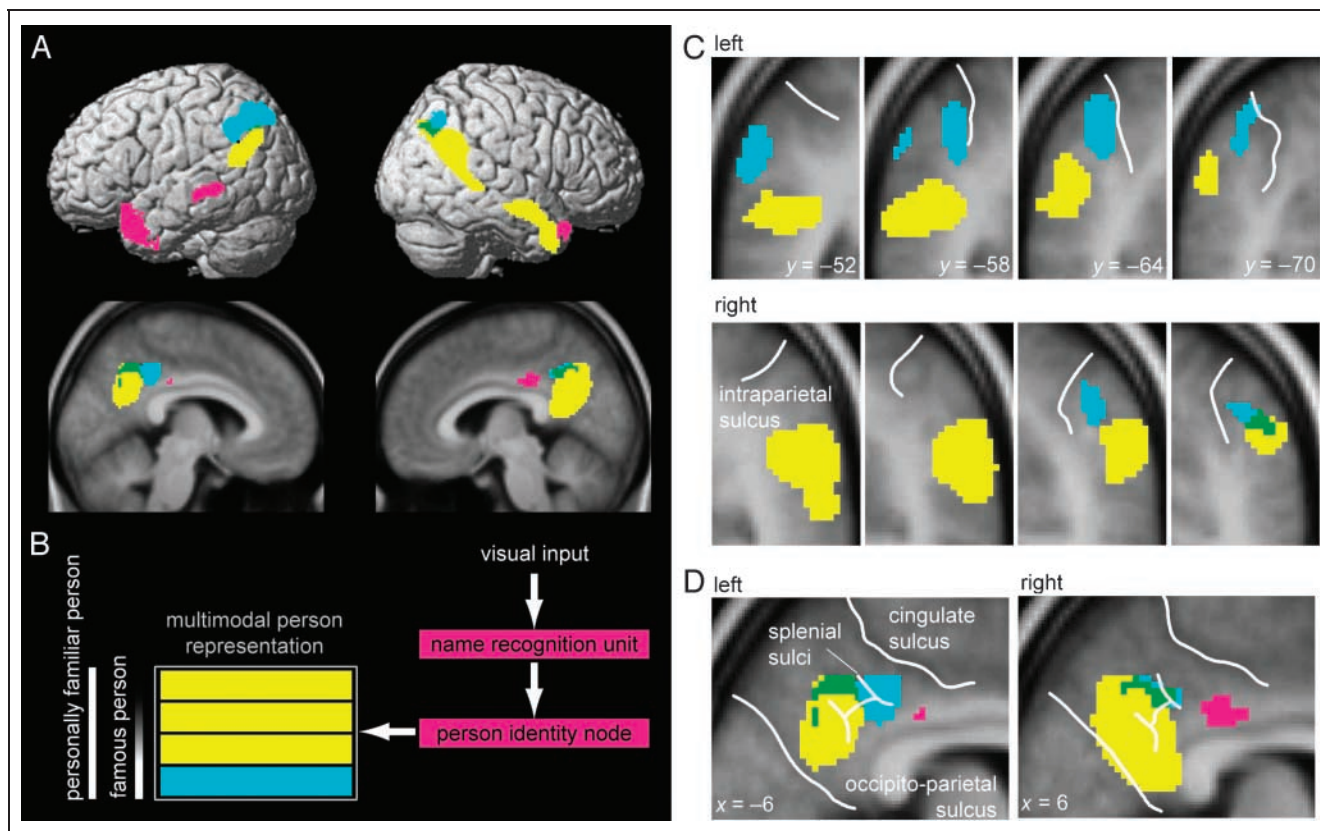


Figure 6. Schematic summary of the suggested modular structure of person representation. Component cognitive responses relevant to famous people (i.e., nonspecific to the familiarity type) and those preferentially relevant to personally familiar people are presented in blue and yellow, respectively; their overlap is shown in green. Commonly involved processes, which are assumed to be involved in unimodal processes and task execution, are shown in red. (A) Cortical activation was rendered on the left and right surfaces of the standard single-subject brain provided by SPM2 (top left and top right, respectively) and superimposed on the left ($x = -6$ mm) and right ($x = 6$ mm) parasagittal sections of the mean normalized anatomical image of all subjects (bottom left and bottom right, respectively). (B) Schema of the model of the name recognition process including the modular structures of multimodal person representations. (C) Serial coronal sections of the temporo-parietal activation in the left and right hemispheres (top and bottom, respectively) superimposed on the mean normalized anatomical image of all subjects. The white line indicates the intraparietal sulcus. (D) Parasagittal sections for the detailed presentation of posterior cingulate activation in the left and right hemispheres (left and right panels, respectively) superimposed on the mean normalized anatomical image of all subjects. The white lines indicate the cingulate, splenial, and occipito-parietal sulci.

and Gobbini et al. (2004) differ (e.g., medial prefrontal cortex), which may be explained by the stimulus (face vs. name, and presented six times vs. only once) or task (working memory vs. familiarity judgment). The effects of stimulus and task on activation for “multimodal representation” are important issues for future research to increase our understanding of the brain mechanism(s) of person recognition and representation.

In this study, each subject self-evaluated the amount of three types of person-related information for each familiar name, and we used the three measures to ensure that high names were more familiar than low names. One may be interested in the relationship between the three measures and the degree of cortical activation, and question why we did not use these measures to identify their neural correlates to show the modularity of the person representation. We did not plan this approach because strong correlations among three measures were inevitable (and, in fact, existed in the results); it is reasonable that the more familiar people are, the richer

they are in declarative information, in visual images, and in emotional involvement. This correlation among the measures prevented the adoption of a standard analytic approach to dissociate any correlates of these measures. All three measures were higher for personal than for high, and higher for high than for low names; that is, the three measures did not dissociate the familiarity of famous people and that of personally familiar people. This may suggest dissociation between the self-evaluative measure by introspection and degree of cortical activity in the implicated region/network, while both are assumed to be related to a conceptually similar cognitive process.

Conclusions

We demonstrated that multimodal person representation is composed of multiple types of cognitive responses, which have varying degrees of relevance to the different types of familiar people, and are supported by different cortical areas. Activation sensitive to the familiarity of

famous people and activation relevant to personally familiar people were observed in distinct cortical areas. The degree of activation for famous names varied across the regions that were primarily relevant to personally familiar people.

The observed modular structure of multimodal person representation appears to be shared by other real-world entities, such as place, object, and episode. Our results demonstrated that familiarity with famous people and that with personally familiar people are respectively related to activity in the dorsal and ventral parts of the temporo-parietal region, and the rostral and caudal parts of the medial posterior cortex. The functional segregation in the temporo-parietal region appears to parallel a similar dissociation for semantic and episodic components of autobiographical memory retrieval. The segregation in the medial posterior cortex is also in good agreement with the proposed roles of the caudal part in the episodic memory retrieval, place recognition, and mental state attribution.

Familiarity-dependent amygdala activation previously reported for face recognition was replicated for name recognition, and the familiarity independence of temporal pole activation, suggested by Sugiura et al. (2006), was further supported.

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Reprint requests should be sent to Motoaki Sugiura, Department of Functional Imaging, Institute of Development, Aging and Cancer, Tohoku University, Seiryomachi 4-1, Aoba-ku, Sendai 980-8575, Japan, or via e-mail: motoaki@idac.tohoku.ac.jp.

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