Neural Basis of the Retrieval of People's Names: Evidence from Brain-Damaged Patients and fMRI

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Abstract

■ The aim of this study was to identify the neuroanatomical basis of the retrieval of people's names. Lesion data showed that patients with language-dominant temporal lobectomy had impairments in their ability to retrieve familiar and newly learned people's names, whereas patients with language-nondominant temporal lobectomy had difficulty retrieving newly learned people's names. Functional magnetic resonance imaging experiments revealed activations in the left temporal polar region during the retrieval of familiar and newly learned people's names, and in the right superior temporal and bilateral prefrontal cortices during the retrieval of newly learned information from face cues. These data provide new evidence that the left anterior temporal region is crucial for the retrieval of people's names irrespective of their familiarity and that the right superior temporal and bilateral prefrontal areas are crucial for the process of associating newly learned people's faces and names. ■

INTRODUCTION

Several researchers have reported that some brain-damaged patients show a specific impairment in their ability to retrieve people's names while relatively preserving their ability to retrieve common names (Fukatsu, Fujii, Tsukiura, Yamadori, & Otsuki, 1999; Reinkemeier, Markowitsch, Rauch, & Kessler, 1997; Verstichel, Cohen, & Crochet, 1996; Fery, Vincent, & Bredart, 1995; Harris & Kay, 1995; Moreaud, Pellat, Charnallet, Carbonnel, & Brennen, 1995; Cohen, Bolgert, Timsit, & Chermann, 1994; Hittmair-Delazer, Denes, Semenza, & Mantovan, 1994; Semenza & Zettin, 1994; Carney & Temple, 1993; Shallice & Kartsounis, 1993; Lucchelli & De Renzi, 1992; Semenza & Zettin, 1988, 1989; McKenna & Warrington, 1980). These findings suggest that there are specific neural systems responsible for the retrieval of people's names that have been learned before damage to the brain.

A selective deficit in the ability to retrieve people's names has been reported after damage to the left hemisphere (Semenza, Mondini, & Zettin, 1995). Although damage to various regions within the left hemisphere can cause a confined disturbance of people's name retrieval (the left thalamus; Moreaud et al.,

1995; Cohen et al., 1994; Lucchelli & De Renzi, 1992, left parieto-occipital lobe; Semenza & Zettin, 1989, left prefrontal and parieto-occipital lobe; Semenza & Zettin, 1994, and left internal capsule, Fery et al., 1995), damage to the left temporal lobe has been demonstrated in more than half of these cases (Fukatsu et al., 1999; Reinkemeier et al., 1997; Verstichel et al., 1996; Harris & Kay, 1995; Hittmair-Delazer et al., 1994; Shallice & Kartsounis, 1993; Semenza & Zettin, 1988; McKenna & Warrington, 1980). Damasio, Grabowski, Tranel, Hichwa, and Damasio (1996) conducted word-retrieval experiments with a large population of brain-damaged patients and a positron emission tomography (PET) study with normal subjects. They found that the retrieval of words signifying different categories of entities depended on different regions in the left temporal lobe: the rostral part of the temporal lobe for the names of famous people, the lateral inferior temporal area for the names of animals, and the lateral temporo-occipito-parietal area for the names of tools. These reports suggest that the temporal lobe in the language-dominant hemisphere is one of the most critical structures in the neural network for the retrieval of people's names.

Among previous reports of patients with disturbed retrieval of people's names, some cases were impaired in retrieving newly learned people's names from faces (Fukatsu et al., 1999; Hittmair-Delazer et al., 1994; Lucchelli & De Renzi, 1992). However, it remains unknown

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whether this deficit is caused by specific deficits in the retrieval of people's names, such as the deficit in retrieving famous people's names, or is due to deficits in associative learning of faces with names. There may be common, but partly different, cognitive processes for the retrieval of two types of people's names: those of famous people and those that have been newly learned.

There have also been some reports indicating the importance of the right temporal lobe for person-related semantics (Kitchener & Hodges, 1999; Evans, Heggs, Antoun, & Hodges, 1995; Ellis, Young, & Critchley, 1989; Hanley, Young, & Pearson, 1989). A traditional model of face processing claims that the process of retrieval of a person's name from his or her face is mediated by person-related semantics (Bruce & Young, 1986). If person-related semantics are necessary for the retrieval of people's names and are related to the right temporal lobe, not only the language-dominant but also the language-nondominant temporal lobe structures may have a specific role in the processes of association of faces, names, and knowledge about people.

The main purpose of the present study was to identify the brain regions related to the retrieval of people's names. In particular, we tried to elucidate the neuroanatomical bases of the retrieval of newly learned and familiar people's names. To achieve these aims, we employed two approaches. In Experiment 1, we assessed the behavioral performance during the retrieval of people's names in 10 patients who had undergone unilateral anterior temporal lobectomy (see Figure 1). These patients were classified into two groups depending on the side of resection: resection of the language-dominant temporal lobe (DTL) and resection of the language-nondominant temporal lobe (NDTL) (see Table 1). Ten age-matched, healthy volunteers (NC) also participated in this experiment as controls. The subjects performed six tasks related to the retrieval of various nouns: the names of famous people from their photographs (FNP), the names of famous people from a verbal description (FND), the names of famous buildings from their photographs (FBP), the names of prefectures from a blank map (PNM), common names from line drawings of objects (CNO), and newly learned names of people and other information from photographs of their faces (NNP). In the last task, participants memorized six sets comprising the faces, names, occupations, and hometowns of people unknown to them before the experiment (see Figure 2A).

In Experiment 2, the brain activation of normal adults during the retrieval of people's names was measured by functional magnetic resonance imaging (fMRI). Four behavioral tasks were prepared, in all of which photographs of faces were projected on a screen. In the first task (the retrieval of newly learned people's names, NN), the subjects recalled a name corresponding to a face. In the second task (the retrieval of newly learned people's occupations, NO), they recalled an occupation title from a face. The stimuli used in NN and NO were memorized just before the scanning phases (see Figure 2B). In the third task (the retrieval of the names of famous people, FN), they retrieved the names of famous people selected from well-known singers, actors, and so forth. The final task was the retrieval of the occupations of famous people (FO), in which the subjects were required to recall occupation titles from photographs of famous people.

RESULTS

Experiment 1

The mean scores in the four tasks of familiar proper-name retrieval, that is, FNP, FND, FBP, and PNM, are

Figure 1. The T1-weighted MR images of two patients with anterior temporal lobectomy. Four images of case T. B. (DTL) are shown on the left, and those of case N. K. (NDTL) are shown on the right.
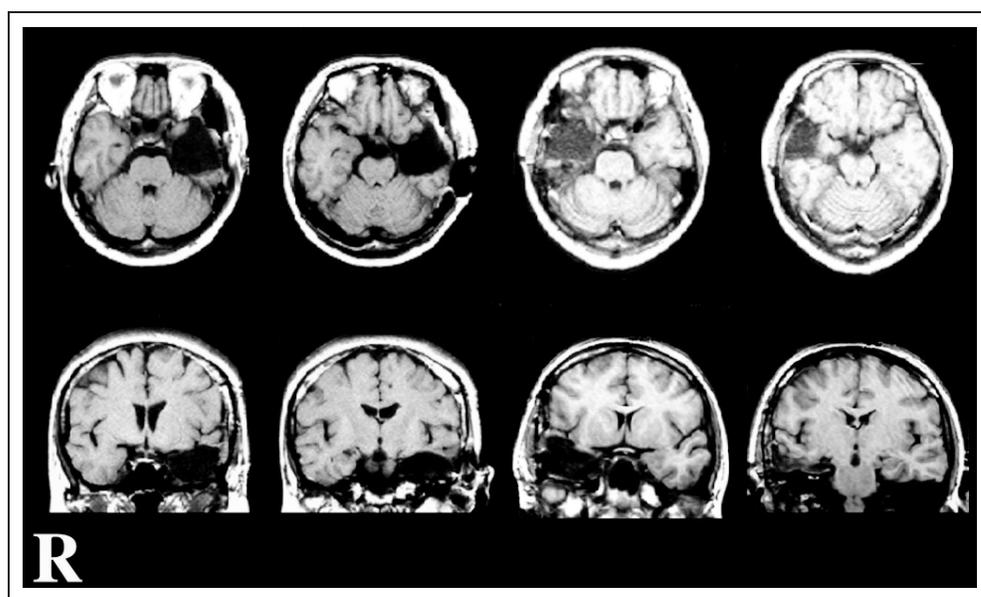
Table 1. Results of General Neuropsychological Testing in All Patients

| | Name | | | | | | Name | | | | | |
	M. T.	T. B.	A. I.	M. S.	H. T.	Mean	M. N.	Y. S.	S. W.	S. K.	N. K.	Mean
Sex	F	F	F	F	M		F	F	F	M	F	
Lobectomy	DTL	DTL	DTL	DTL	DTL		NDTL	NDTL	NDTL	NDTL	NDTL	
Handedness	+80	+70	+100	+90	+70	+82	+70	+100	+90	+80	+80	+84
Resection side	L	L	L	L	L		L	R	R	R	R	
Age (years)	24	38	23	48	17	30	24	28	20	38	23	27
WAIS-R (preoperative)												
FIQ	94	82	108	103	97	97	76	80	102	109	95	92
VIQ	93	78	94	99	84	90	74	73	94	106	98	89
PIQ	98	92	128	106	119	109	88	92	113	110	92	99
WMS-R (preoperative)												
General	72	79	97	81	91	84	70	88	113	93	105	94
Verbal	69	72	90	79	82	78	61	80	105	89	106	88
Visual	98	97	120	82	120	103	117	116	124	104	103	113
WAIS-R (postoperative)												
FIQ	113	97	110	105	107	106	90	85	101	114	100	98
VIQ	103	80	95	95	98	94	87	79	99	117	105	97
PIQ	123	119	131	115	119	121	98	97	104	107	93	100
WMS-R (postoperative)												
General	76	75	111	80	94	87	72	91	108	116	114	100
Verbal	75	61	92	72	86	77	62	81	99	82	107	86
Visual	98	114	138	103	120	115	117	122	129	120	123	122

The scores of handedness were assessed by the Edinburgh Handedness Inventory. WAIS-R refers to the Wechsler Adult Intelligence Scale-Revised and WMS-R refers to the Wechsler Memory Scale-Revised. These tests were administered before (preoperative) and after (postoperative) surgery. The significant main effect of resected side was found only in the performance IQ of WAIS-R.

shown in Figure 3A. The two-way analysis of variance (ANOVA) was performed to detect the effects of the two factors: subgroup and task type. This analysis revealed significant main effects of subgroup, $F(2,68) = 38.56$, and task type, $F(3,68) = 13.71$, $ps < .001$. A significant interaction of subgroup and task type was also detected, $F(6,68) = 6.96$, $p < .001$. The post hoc analyses showed significant differences between the DTL and the NDTL or NC groups in two tasks related to retrieving famous people's names (in FNP, DTL: $M = 54.26$, $SD = 15.98$, NDTL: $M = 86.08$, $SD = 10.88$, NC: $M = 94.15$, $SD = 5.54$; $p < .001$; and in FND, DTL: $M = 65.74$, $SD = 14.55$, NDTL: $M = 86.99$, $SD = 7.22$, NC: $M = 96.18$, $SD = 3.25$; $p < .001$). The DTL group ($M = 87.24$, $SD = 14.47$) was significantly impaired in the FBP task compared to the NC group ($M = 98.61$, $SD = 2.77$, $p < .05$) but not

compared to the NDTL group ($M = 94.16$, $SD = 4.99$, ns). No significant differences among subgroups were observed in the PNM task (DTL: $M = 97.33$, $SD = 5.33$; NDTL: $M = 94.67$, $SD = 4.99$; NC: $M = 99.33$, $SD = 2.00$). In the CNO task, all subjects performed without error.

In the NNP task, the data collected for recalling newly learned people's names or other types of information were analyzed in a two-way ANOVA (see Figure 3B). This analysis revealed significant main effects of subject group and of type of information, $F(2,51) = 56.89$ and 11.24, respectively, $p < .001$. The interaction between subgroup and type of information was also significant, $F(4,51) = 3.90$, $p < .01$. Post hoc comparisons of the main effect of subgroup showed significant differences between the DTL ($M = 6.2$, $SD = 3.77$) and NDTL ($M = 10.8$, $SD = 1.74$; $p < .001$) groups, between the DTL
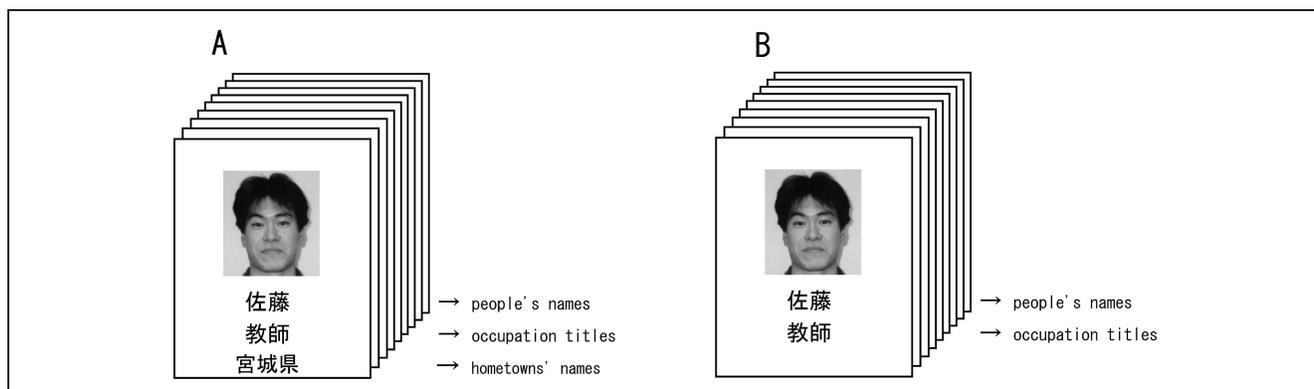
Figure 2. Examples of encoding stimuli in the two experiments. (A) In Experiment 1, before participating in the task of retrieval of newly learned people's names from photographs, subjects memorized newly learned faces of people with their names, occupations, and hometown names. (B) In Experiment 2, before the fMRI scanning session, subjects memorized newly learned faces of people with their names and occupations.

and NC ($M = 11.9$, $SD = 0.36$; $p < .001$) groups, and between the NDTL and NC ($p < .05$) groups. For the effect of type of information, the score for the retrieval of people's names ($M = 9.0$, $SD = 4.11$) was lower than that for both occupation titles ($M = 11.0$, $SD = 2.65$; $p < .001$) and the names of hometowns ($M = 10.6$, $SD = 2.16$; $p < .001$). Post hoc tests of the interaction between subgroup and type of information showed significant reduction in the ability to recall people's names, occupation titles, and hometown names for the DTL group ($p < .001$), and in recalling people's names in the NDTL group, ($p < .05$), compared to those in the NC group. In the DTL group, the recall of people's names was worse than the recall of occupation titles and hometown names ($p < .01$). In the NDTL group, the recall of people's names was worse than the recall

of occupation titles and hometown names ($p < .001$). The score for the retrieval of people's names in the DTL group was significantly lower than that in the NDTL group ($p < .001$). In the two tests involving the recognition of faces and people's names just after the recall tests, all subjects performed their tasks without making any errors.

Experiment 2

We assessed the behavioral performances of the subjects during each retrieval task just after the scanning procedure. The mean retrieval rates were analyzed by two-way ANOVA, with the learning period (newly learned and famous) and the retrieval category (people's names and occupation titles) as factors. We detected no significant
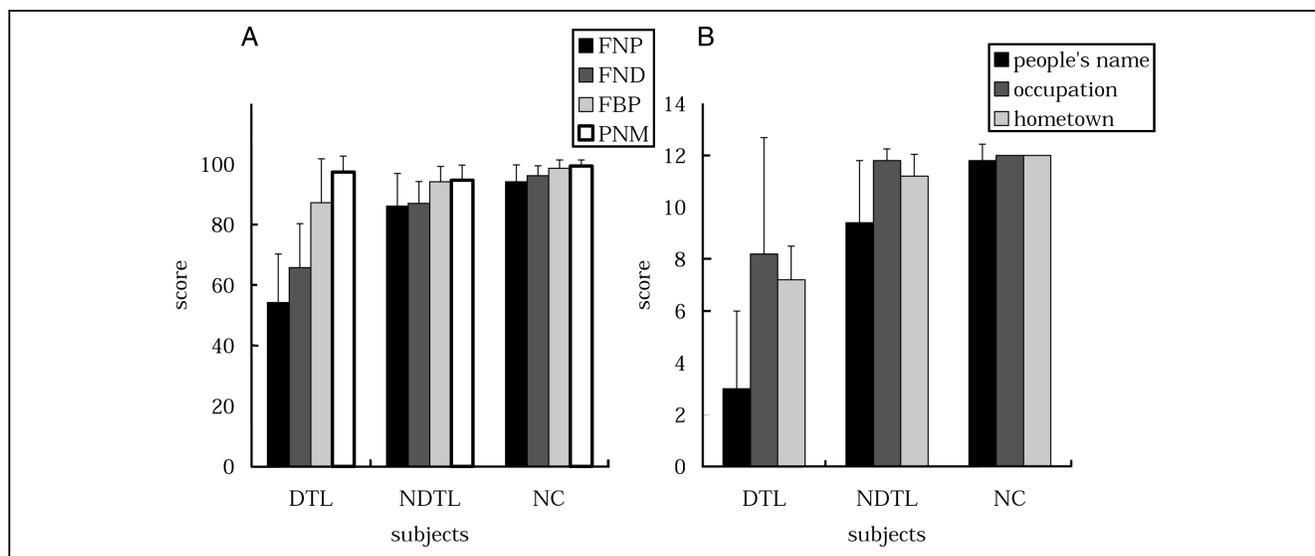

Figure 3. (A) Results of four tasks of familiar proper-name retrieval in Experiment 1. Each bar represents the percent correct responses and the error bar indicates *SD*. FNP = retrieval of famous people's names from photographs; FND = retrieval of famous people's names from verbal description; FBP = retrieval of famous buildings' names from photographs; PNM = retrieval of prefectures' names from a blank map. (B) Results of the retrieval task of newly learned people's names from photographs. Each bar represents the score of correct responses and the error bar indicates *SD*.

Table 2. Activation Foci in Experiment 2

	Regions	BA	*x*	*y*	*z*	Z Value
			*Talairach Coordinates*		
NN−NO						
Left	superior frontal gyrus	10	−24	63	12	3.67
	middle frontal gyrus	9	−49	32	30	3.41
	superior temporal gyrus	38	−60	14	−18	3.21
	superior parietal lobule	7	−38	−66	54	4.21
	precuneus	7	−4	−74	36	4.00
	posterior cingulate gyrus	23	−4	−38	24	4.25
Right	middle frontal gyrus	9	46	24	36	3.54
		10	35	56	18	3.35
	inferior temporal gyrus	37	60	−63	−6	3.68
FN−FO						
Left	superior temporal gyrus	38	− 49	21	−18	3.76
Inter	anterior cingulate gyrus	32	0	14	36	3.76
Conjunction analysis of NN−NO with FN−FO						
Left	superior frontal gyrus	10	−21	63	24	3.46
	anterior cingulate gyrus	32	−4	28	30	3.53
	posterior cingulate gyrus	31	−4	−38	30	5.71
	superior temporal gyrus	38	−52	24	−18	5.39
	striate cortex	17	−14	−105	6	4.23
	cuneus	18	−10	−98	18	4.04
		19	−7	−77	36	4.03
NN−FN						
Left	middle frontal gyrus	6	−42	18	54	4.10
	precentral gyrus	6	−63	10	6	3.24
	superior parietal lobule	7	−42	−66	54	5.54
	posterior cingulate gyrus	31	−4	−38	42	3.11
Right	middle frontal gyrus	11	46	18	54	4.41
	superior temporal gyrus	22	49	−4	−6	3.27
NO−FO						
Left	precuneus	7	−14	−74	48	4.27
	cuneus	18	−18	−66	18	3.87
Right	superior temporal gyrus	22	63	0	6	4.36
	precuneus	7	7	−70	42	3.43
	cuneus	18	14	−74	24	4.54

Table 2. (*continued*)

Regions		BA	Talairach Coordinates			Z Value
			x	*y*	*z*	
Conjunction analysis of NN–FN with NO–FO						
Left	middle frontal gyrus	6	−46	14	54	3.94
		11	−24	32	−18	3.28
		46	−52	42	18	3.48
Right	inferior frontal gyrus	46	42	42	6	3.18
	superior temporal gyrus	22	66	0	12	5.10
	precuneus	7	7	−74	42	7.11
Inter	posterior cingulate gyrus	31	0	−28	30	3.58

main effects for learning period or for category and no interaction of the two factors (NN: $M = 80.0\%$, $SD = 16.32$; NO: $M = 83.3\%$, $SD = 12.40$; FN: $M = 74.1\%$, $SD = 6.71$; FO: $M = 87.5\%$, $SD = 11.08$).

We identified significantly activated areas for the NN task compared to the NO task (see Table 2). Activations in the left hemisphere were observed in the superior and middle frontal gyrus (Brodmann's area: BA 10 and 9), posterior cingulate gyrus (BA 23), anterior superior temporal gyrus (BA 38; see Figure 4A), superior parietal lobule (BA 7), and precuneus (BA 7). In the right hemisphere, we identified significant activations in the middle frontal gyrus (BA 9 and 10) and inferior temporal gyrus (BA 37). Significant activities for the FN task compared to the FO task were observed in the left superior temporal gyrus (BA 38; see Figure 4B) and anterior cingulate gyrus across both hemispheres (BA 32; see Table 2). The reverse contrasts of NO–NN or FO–FN showed no significant activations at the same statistical level. To explore activations reflecting the effects of two contrasts (NN–NO and FN–FO), we analyzed the data obtained using the conjunction analysis method (Price & Friston, 1997). Brain activations were identified in the superior frontal gyrus (BA 10), anterior and posterior cingulate gyrus (BA 32 and 31), superior temporal gyrus (BA 38), striate cortex (BA 17), and cuneus (BA 18 and 19) in the left hemisphere (Table 2). No activations were observed in the right hemisphere. The activation of the left superior temporal gyrus (BA 38) is shown in Figure 4C.

The temporal lobe structures are sensitive to susceptibility artifacts in gradient echo echo-planar image (EPI) sequence. However, we could acquire EPI images with reliable intensity in the lateral anterior temporal lobe during fMRI scanning (Figure 4D), suggesting that the anterior temporal lobe activations observed are reliable.

Next, we compared activations during the NN task with those of the FN task. This analysis revealed activations in the middle frontal gyrus (BA 6), precen-

tral gyrus (BA 6), posterior cingulate gyrus (BA 31), and superior parietal lobule (BA 7) in the left hemisphere, and in the middle frontal gyrus (BA 11) and superior temporal gyrus (BA 22) in the right hemisphere. The coordination and maximum *Z* values are shown in Table 2. In the contrast of NO–FO, we identified activities in the left precuneus (BA 7) and cuneus (BA 18), and in the right superior temporal gyrus (BA 22), precuneus (BA 7), and cuneus (BA 18). Detailed data for this activation pattern are shown in Table 2. The reverse contrasts of FN–NN or FO–NO showed no significant activations at the same statistical level. Common activations between two contrasts of NN–FN and NO–FO, using the conjunction analysis method, were observed in the left middle frontal gyrus (BA 6, 11, and 46) and in the right inferior frontal gyrus (BA 46), superior temporal gyrus (BA 22), precuneus (BA 7), and posterior cingulate gyrus (BA 31; see Table 2). The activations superimposed onto 3-D templates are shown in Figure 5.

DISCUSSION

Experiment 1 revealed two major findings. First, the DTL group was significantly impaired in their ability to retrieve famous people's names both from their photographs and from their verbal descriptions and slightly impaired in their ability to retrieve the names of famous buildings, but not of prefectures from blank maps and of common names from line drawings of objects. The NDTL group was not impaired in these tasks. Second, the DTL group showed impairment in retrieving newly learned people's names and other types of information from corresponding faces. The mean score for retrieving newly learned people's names was much lower than that for occupation titles and hometown names. The NDTL group showed a significant deficit only in their ability to retrieve newly learned people's names, and the impairment of the NDTL group was less severe than that of the DTL group. Both the DTL and NDTL groups

Figure 4. (A) The activation of the left anterior temporal area identified in the comparison of NN with NO. (B) The activation of the left anterior temporal area identified in the comparison of FN with FO. (C) The activation of the left anterior temporal area identified in the conjunction analysis of NN minus NO with FN minus FO. (D) An example of the mean intensity image acquired in Experiment 2.
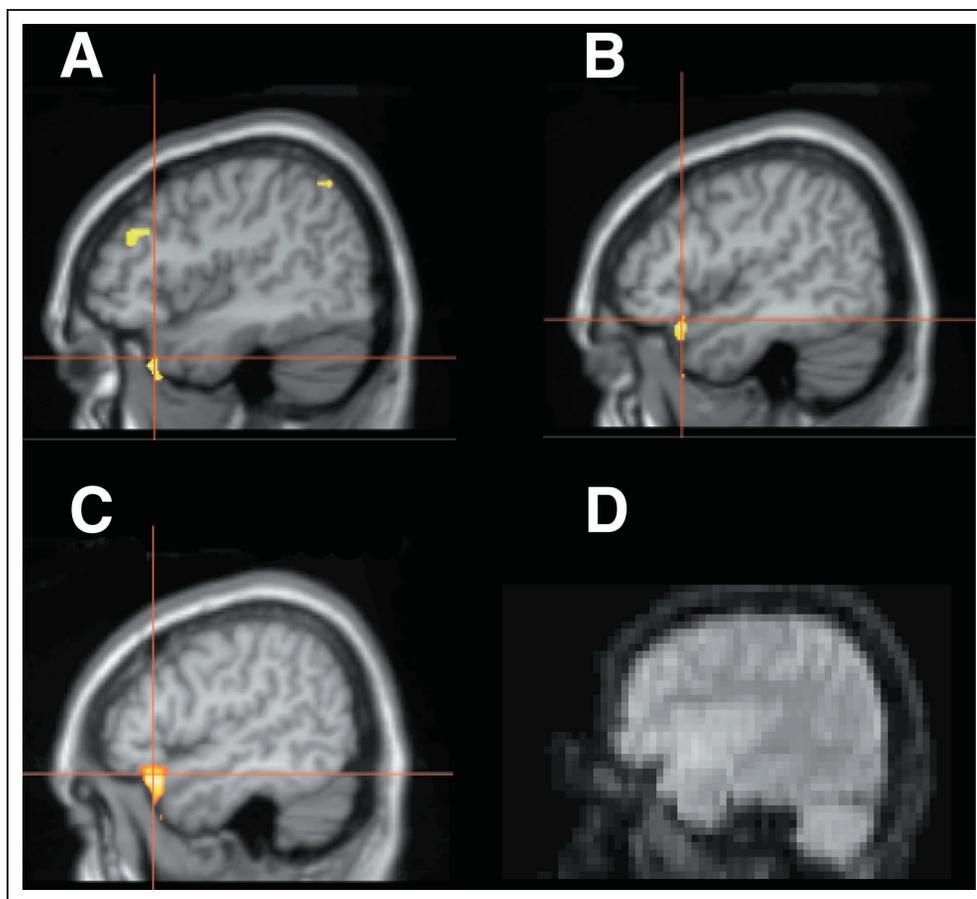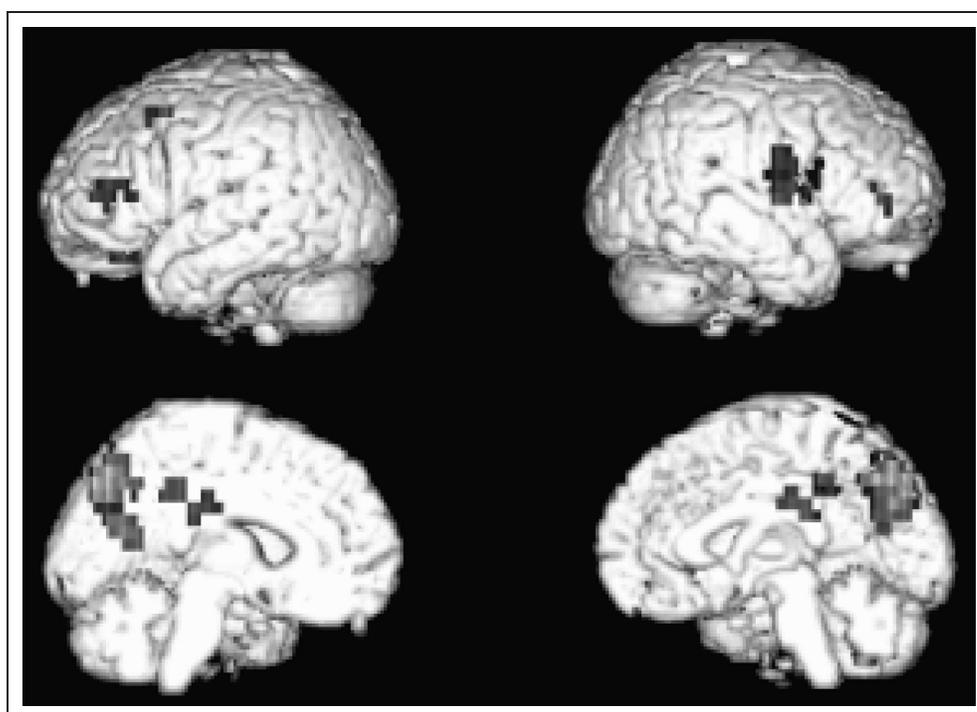

Figure 5. Activated areas identified in the conjunction analysis of NN–FN with NO–FO. Images are superimposed onto 3-D rendered images of an SPM template.

could recognize people's faces and names that had been memorized after the recall tests.

Experiment 2 also provided two major findings. First, conjunction analysis of the NN–NO with FN–FO, which reflects the main effect of retrieval category (people's names and occupation titles), showed left-lateralized activation in the anterior part of the superior temporal gyrus (BA 38), superior frontal gyrus (BA 10), cingulate gyrus (BA 32 and 31), striate cortex (BA 17), and cuneus (BA 18 and 19). Activation of the anterior part of the left superior temporal gyrus (BA 38) was identified across each contrast of NN–NO or FN–FO, although the activation sites differed slightly. This area was involved in the resected site of the DTL group in Experiment 1. Second, conjunction analysis of the NN–FN with NO–FO tasks showed bilateral prefrontal activations, such as in the left middle frontal (BA 6, 11, and 46) and right inferior frontal gyri (BA 46), and right-lateralized activations of the superior temporal gyrus (BA 22) and medial parietal lobe. Among these activation foci, the right superior temporal gyrus overlapped with the resected area in the NDTL group in Experiment 1.

The lesion data derived from our study indicate that the anterior part of the left temporal lobe plays a critical role in the retrieval of famous people's names and are consistent with those of some previous studies (Fukatsu et al., 1999; Damasio et al., 1996; Barr, Goldgerg, Wasserstein, & Novelly, 1990). In addition, our experiments demonstrated that the anterior part of the left temporal lobe is involved in retrieving people's names irrespective of the stimulus familiarity (famous or newly learned). We also found that the anterior part of the right temporal lobe does not have to be involved in retrieving famous people's names (consistent with the findings of Barr et al., 1990), but has a role only in associative learning of faces with names or retrieving newly learned people's names from face cues. However, these data from epileptic patients should be interpreted carefully, because it is probable that the organization of the operated lobe was disturbed by the presence of the epileptic lesion. In fact, some degree of verbal memory deficit was found on the Wechsler Memory Scale-Revised (WMS-R), although there were no significant differences between patient groups (DTL and NDTL) and between testing phase (preoperation and postoperation). To obtain more conclusive evidence, formal data should be collected of the ability of patients to retrieve people's names both before and after surgery.

With regard to the functional imaging data, the finding of activation of the anterior part of the left temporal lobe during the retrieval of famous people's names is compatible with that of previous studies (Grabowski et al., 2001; Gorno-Tempini et al., 1998; Damasio et al., 1996). In addition, we found activation of the left anterior temporal region during the retrieval of newly learned people's names and activation in the right superior temporal and bilateral prefrontal cortices during the retrieval of newly learned information in response to faces. So far, none of the imaging studies has focused on the difference between the retrieval of newly learned and famous people's names, although an fMRI study contrasting newly learned and famous faces has been reported (Leveroni et al., 2000).

In summary, the lesion data from our study showed that the ability to retrieve famous people's names involves the anterior part of the left temporal lobe only, whereas new associative learning of faces and names or the retrieval of newly learned people's names from face cues involves the anterior parts of both temporal lobes. The neuroimaging data showed that the retrieval of people's names, irrespective of their familiarity, was associated with activity of the anterior part of the left temporal lobe, whereas the retrieval of newly learned person-related information (either names or occupation titles) was associated with activations of the anterior part of the right temporal lobe and bilateral prefrontal cortices, compared to retrieving information related to famous people.

Before discussing the relationship between brain areas and cognitive function, we should briefly consider the effects of task difficulty in both experiments. The pattern of behavioral performance in Experiment 1 may be explained by the difference of task difficulty between learning and remembering people's names and their occupations or hometowns. However, it is not possible to determine whether this is a reasonable explanation because the NC group performed at ceiling level for all three features in Experiment 1. The opposite pattern of disturbances, that is, preserved retrieval of people's names (supposed to be difficult) and impaired retrieval of common names (supposed to be easy), has been reported by a previous study (Semenza & Sgaramella, 1993). A study reported by Damasio et al. (1996) also demonstrated that some brain-damaged patients were more impaired in their ability to retrieve common nouns than to retrieve the names of famous people. The existence of the reverse pattern of deficits, that is, double dissociation, suggests that impairments observed in the present study cannot be simply explained by the greater difficulty of retrieving people's names than of retrieving common names. The behavioral data for the normal subjects in Experiment 2 showed no significant differences between the retrieval of people's names and occupation titles. However, an effect of task difficulty on activation pattern cannot be ruled out, because the population for statistical analysis was relatively small. In addition, our study did not collect data concerning response latencies in the two experiments, which would have allowed us to detect any effect of task difficulty. Therefore, the impaired patterns observed in Experiment 1 and some of the activated areas in Experiment 2, particularly those in the frontal lobe, may partially reflect task difficulty or, in other words,

retrieval effort (Schacter, Alpert, Savage, Rauch, & Albert, 1996).

Left Anterior Temporal Lobe

In Experiment 1, the DTL group showed impairments in retrieving familiar and newly learned people's names. In Experiment 2, we identified activations in the anterior part of the left superior temporal gyrus for the retrieval of people's names irrespective of their familiarity compared to that of occupation title. The present findings are consistent with those of previous studies in which specific disturbances of the ability to retrieve people's names have been observed after left hemisphere damage (Semenza et al., 1995). However, various sites of lesions within the left hemisphere have been reported to result in impairment of the retrieval of people's names, such as the thalamus (Moreaud et al., 1995; Cohen et al., 1994; Lucchelli & De Renzi, 1992), parieto-occipital lobe (Semenza & Zettin, 1988), fronto-parieto-occipital lobe (Semenza & Zettin, 1994), internal capsule (Fery et al., 1995), and temporal lobe (Fukatsu et al., 1999; Reinkemeier et al., 1997; Verstichel et al., 1996; Harris & Kay, 1995; Hittmair-Delazer et al., 1994; Shallice & Kartsounis, 1993; Semenza & Zettin, 1989; McKenna & Warrington, 1980). In the present study, left-lateralized activation for the retrieval of people's names was identified in the frontal, temporal, and occipital lobes, suggesting the existence of a neural network contributing to this process.

Among the brain areas involved in the retrieval of people's names, the rostral part of the left temporal lobe should be emphasized. In Experiment 1, the DTL group showed a significant impairment in the retrieval of people's names irrespective of whether they were familiar or newly learned. We have previously reported a patient with a confined impairment of retrieval of people's names after a surgical resection of the rostral part of the left temporal lobe (Fukatsu et al., 1999). Barr et al. (1990) have also reported a deficit in naming famous people in patients with left temporal lobectomy. Furthermore, in Experiment 2, activation of this area was observed in all comparisons of the retrieval of people's names to occupation titles, as well as in the conjunction analysis between them. These findings suggest that the left temporal lobe plays a critical role in the neural networks involved in the retrieval of people's names irrespective of whether they are familiar or newly learned.

In Experiment 1, the DTL group was impaired in retrieving occupation titles and hometown names as well as people's names associated with newly learned faces. This finding suggests the possibility that the resected area in the DTL group plays an important role in retrieving any type of information related to people. However, the retrieval scores for information associated with newly learned people were significantly worse for people's names than for occupation titles or hometown names. One possible explanation for this statistical finding is that the DTL group's deficits in retrieving newly learned information may reflect combined deficits arising from anterior lateral temporal and medial temporal lesions, the specific deficits in the retrieval of people's names being derived from the former lesion, which is consistent with the deficits in the retrieval of familiar people's names, and deficits in visual–verbal associative learning derived from the latter lesion.

Damasio et al. (1996) have proposed an interesting hypothesis concerning the function of this area. They postulated that the names of objects belonging to different semantic categories are organized in different areas in the left cerebral hemisphere. This category-specific organization is based on some hierarchical structures, in which there are various levels of representation. Naming is realized through several levels of the hierarchical neural representations. One of these representational levels may require the activation of the anterior part of the left temporal lobe. In retrieving an object's name, it is necessary to associate or bind many representations, such as a phonological word form, orthographical information, or its semantics. In the case of people's names, more complex representations may be required than for the retrieval of a common name because a selection mechanism for a unique name must necessarily be more complex due to the increased amount of similar information. For this more complex level of binding-related representations, the rostral part of the left temporal lobe may play a pivotal role. In Experiment 1 of the present study, the DTL group also showed a slight impairment in their ability to provide the names of famous buildings when compared to the NC group. The retrieval of buildings' names might require a more complex level of binding-related representations than that of common names, but may need a less complex level of binding-related representations than that of people's names. A recent PET study demonstrated findings supporting Damasio's hypothesis (Grabowski et al., 2001).

We should also consider the specificity of the DTL group's deficit in retrieving names belonging to several conceptual classes. In the common-name-retrieval task, the finding that all subjects, including brain-damaged patients and normal controls, performed without errors may be related to the ceiling effect of performance. This would appear, therefore, to be an inadequate assessment from which to suggest that the DTL group had only a deficit in the retrieval of people's names. Furthermore, the DTL group also showed a slight impairment in providing geographical proper nouns on one test when compared to the NC group. Although the DTL group's deficit in retrieving people's name was pronounced, there is a possibility that their deficits may include the retrieval of some proper

nouns or nouns belonging to domains other than people's names.

Right Anterior Temporal Lobe

In Experiment 1, the NDTL group did not show impairment in retrieving famous people's names but did show impairment in retrieving newly learned people's names. In Experiment 2, brain activities were identified in the right superior temporal gyrus (BA 22), bilateral prefrontal areas (BA 6, 11, and 46 in the left side and BA 46 in the right), and right medial parietal lobe (BA 7) during the retrieval of people's names or occupation titles from newly learned faces compared to that from famous people's faces. Initially, these findings seem to suggest that the anterior part of the right temporal lobe is involved in retrieving newly learned people's names. However, there was a discrepancy between the results of the two experiments. The lesion data indicated that this region was required for retrieving newly learned names but not occupation titles or hometown names, whereas the functional imaging data showed the activation of this area for retrieving both newly learned people's names and occupation titles. One possible explanation for this discrepancy may be provided by the fact that the lesion data tell us that destroyed areas are necessary for the specific cognitive function, whereas the functional neuroimaging data show that activated areas may participate in the required cognitive function.

With regard to the lesion data, there remains a possibility that the impairments of the NDTL group in Experiment 1 may be more related to encoding deficits than to retrieval deficits. In the recognition test of faces and names from Experiment 1, all subjects performed perfectly. Thus, if the NDTL group's impairments result from encoding deficits, this cannot simply be attributed to an encoding deficit of a single item such as each name or face, but must also involve a deficit in associating or binding newly learned people's faces with names. It is difficult at present to determine whether the NDTL group had a deficit in retrieving names from face cues or in associating newly learned faces with names.

Again, we should consider the possibility that the general declarative memory deficits arising from the medial temporal lobe (MTL) resections may explain the disturbance patterns of the NDTL group identified in Experiment 1. Even if the extent of the MTL was larger in the NDTL group than in the DTL group, the NDTL group's deficit in retrieving newly learned names could not be explained by the declarative memory problem in general arising from MTL resection, because the actual behavioral data of the NDTL group were less impaired than those of the DTL group. Furthermore, the finding of statistically significant impairments in the retrieval of newly learned people's names but preservation of the ability to retrieve occupation titles or hometown names suggests that verbal–visual associative learning deficits

in general arising from MTL resection cannot directly account for deficits in the retrieval of newly learned people's names. In addition, the neuropsychological findings on the WMS-R and the Wechsler Adult Intelligence Scale-Revised (WAIS-R) showed little declarative memory (episodic and semantic memory) problem arising from MTL resection in both groups. A review of previous studies of MTL amnesia also showed that unilateral MTL damage did not result in profound declarative memory deficits (Fujii, Moscovitch, & Nadal, 2000). Thus, we believe that the present lesion data should be interpreted in terms of effects derived from more lateral lesions, and not in terms of declarative memory deficits in general derived from MTL disruption.

Regarding the neuroimaging data, activation of the right superior temporal gyrus was found during the retrieval of people's names or occupation titles from newly learned faces compared to that from famous people's faces. Neither the contrast of the FN−NN tasks nor the contrast of the FO−NO tasks produced significant activations at the threshold applied in this study. Previous neuropsychological data have reported that damage of the right anterior temporal lobe caused the loss of person-related semantics but the preservation of general semantics (Kitchener & Hodges, 1999; Evans et al., 1995; Ellis et al., 1989; Hanley et al., 1989), although the NDTL group in the present study and in Barr et al.'s (1990) study showed no deficits in naming famous people. If person-related semantics are mediated by the right temporal lobe, differences of activity of person-related semantics might be reflected in the activity of this region. A previous fMRI study reported a more widespread network of bilateral brain activations involving the prefrontal, lateral temporal, and medial temporal regions during the recognition of familiar faces compared to that of recently learned faces or unfamiliar faces seen for the first time (Leveroni et al., 2000). Another PET study reported that the right temporal polar area was activated during recognizing not only familiar faces but also familiar scenes such as buildings (Nakamura et al., 2000). These imaging data are consistent with the notion that the right temporal lobe may be implicated in the semantic processing of unique entities such as people or buildings.

The discrepancy between our imaging findings and previous neuroimaging data may be explained by the degree of activation of person-related semantics. In the study by Leveroni et al. (2000), subjects studied faces without associating them with other kinds of information. Therefore, person-related semantics might be active only during the recognition of famous faces but not during that of recently learned faces. By contrast, in our study, subjects sufficiently learned to associate faces, occupation titles, and people's names during the encoding phase. During the retrieval phase with fMRI scanning, person-related semantics might be more activated during NN and NO than during FN and FO, probably because

more energy is needed to activate newly formed person-related semantics through which the retrieval of names from face cues might be accomplished.

Another possible explanation of right temporal activation is that it may be more related to relearning the associations of information concerning newly learned people rather than to the retrieval of newly learned names, although activation was identified during the retrieval of newly learned people's names. Buckner, Wheeler, and Sheridan (2001) noted that encoding processes are pervasive and occur in tasks nominally labeled as retrieval tasks. For associative learning tasks, Fletcher et al. (1995) performed a functional neuroimaging study of verbal associative learning and showed activations in the bilateral superior temporal gyrus (BA 22 and 21), left anterior and posterior cingulate gyrus, left prefrontal cortices, and other areas. Many neuroimaging studies have also demonstrated activation in the right or bilateral superior temporal areas during verbal associative learning (Fernandez et al., 1998; Dolan & Fletcher, 1997; Kapur et al., 1996). In contrast, activations of the right superior temporal lobe have rarely been observed in studies of verbal learning that do not require new associations (Jonides et al., 1998; Kopelman, Stevens, Foli, & Grasby, 1998; Wagner, Poldrack, et al., 1998; Wagner, Schacter, et al., 1998; Nyberg et al., 1996). These findings suggest that the anterior part of the right temporal lobe may contribute to making new associations among multiple stimuli. Our imaging data suggest that the right temporal lobe may contribute to associative learning of facial stimuli, people's names, and semantic components. In the present study, however, no other categories of visual–verbal associative learning were examined, limiting the notion of specific involvement of this region in the person-specific semantic domain. Further functional neuroimaging analyses would be required to provide clearer evidence concerning the role of the right temporal lobe in the person-specific semantic domain.

Frontal Lobe

Another intriguing finding, which was observed in Experiment 2, is that the bilateral prefrontal areas (BA 6, 11, and 46 in the left side and BA 46 in the right) were activated during retrieving people's names or occupation titles from newly learned stimuli compared to familiar stimuli.

It is likely that the activation patterns reflect a difference between episodic and semantic remembering processes because, in the NN or NO task, subjects were required to recall people's names or occupation titles from newly learned faces, which were memorized just before the scanning procedure. In other words, to recall correct information in these tasks, subjects had to recall the correct names by retracing the temporal context when the subjects had ''memorized'' a new set of a face,

its name, and its occupation title (Tulving, 1972). In contrast, in the FN or FO task, subjects were required to retrieve ''known'' names from ''known'' faces, which hardly include temporal information when the stimuli had originally been encoded.

Recent studies using PET or fMRI increasingly indicate the importance of the right prefrontal contribution to many types of episodic retrieval task (Cabeza & Nyberg, 2000; Buckner & Koutstaal, 1998; Desgranges, Baron, & Eustache, 1998; Nyberg, 1998; Cabeza et al., 1997; Fletcher, Frith, & Rugg, 1997). Based on the meta-analyses of earlier PET studies, Tulving, Kapur, Craik, Moscovitch, and Houle (1994) proposed the hemispheric encoding/retrieval asymmetry (HERA) hypothesis, which emphasized the importance of the right prefrontal cortex for episodic memory retrieval and of the left prefrontal cortex for episodic memory encoding and semantic memory retrieval. However, several reports have shown retrieval-related activation in the left prefrontal cortex in addition to the right. To interpret these different activation patterns of the prefrontal cortices, a recent review proposed that left prefrontal activation is related to the ''reflective demands'' of retrieval tasks (Nolde, Johnson, & Raye, 1998). When these demands are low, as in two-alternative forced choice recognition, only the right prefrontal cortex is engaged. When reflective demands are high, as is the case in tasks requiring the evaluation of episodic detail or cross-modal recalling, the left prefrontal cortex is engaged. Nolde et al. (1998) called this the cortical asymmetry of reflective activity (CARA) model. In line with this hypothesis, several recent functional neuroimaging studies have presented strong evidence that the left prefrontal cortex is more important for the episodic retrieval of the detailed information of an event (Henson, Shallice, & Dolan, 1999; Rugg, Fletcher, Chua, & Dolan, 1999; Nolde, Johnson, & D'Esposito, 1998). Our finding of bilateral prefrontal activities supports the CARA hypothesis. Subjects were required to recall spontaneously the name of a person or an occupation title from a photograph of a face, in which cross-modal processes from visual to phonological modalities were necessary.

Neural Networks of the Retrieval of People's Names

Both the lesion data and the imaging data suggest that the rostral part of the left temporal lobe plays a critical role in the retrieval of people's names irrespective of whether they are famous or newly learned. The results also showed a contribution of the right anterior temporal lobe to knowledge of newly learned people, yet it is difficult to determine whether the right temporal lobe is involved in retrieving newly learned people's names from face cues or in new associative learning of faces with names. In addition, the imaging data showed that the bilateral prefrontal areas were

activated in the retrieval of newly learned information but not of familiar information.

These findings suggest that the prefrontal activities as well as the activity of the right temporal lobe may decrease as the nature of a memorized detail changes from novel to familiar. At the same time, the correlation between the prefrontal and temporal areas may also change with the progress of learning. A previous study using mice reported that the dynamic change of cortical activities occurred as learning progressed, and the degrees of cortical change were different in different brain regions (Bontempi, Laurent-Demir, Destrade, & Jaffard, 1999). Our results in Experiment 2 indicate the possibility that coordinated contributions of these activated areas are necessary for retrieving people's names, and these areas may show different patterns of cortical changes depending on how novel the memorized associations are among faces, knowledge such as occupation titles, and people's names.

At the early stage of learning, we retrieve people's names and many types of background information with some difficulty. In the course of time, we become able to retrieve specific people's names (such as those of our own friends or of famous people) without difficulty. Our subjective experience is probably based on cortical reorganization in the bilateral prefrontal and anterior temporal lobes. Unfortunately, the present study was not able to produce direct evidence for this dynamic reorganization of the human brain. However, the activation patterns identified suggest the possibility of time-dependent cortical reorganization in the retrieval of people's names.

METHODS

Experiment 1

Subjects

Ten patients with symptomatic epilepsy and 10 normal subjects participated in this study. The 10 patients underwent unilateral temporal lobectomy for the treatment of intractable seizures. All patients were tested at least at 1 month after surgery. The operations of five patients (one man and four women; mean age 30.0 years, range 17–48 years) were on the language-dominant hemisphere (dominant temporal lobectomy, DTL group) and of the remaining five patients (one man and four women; mean age 26.6 years, range 20–38 years) on the language-nondominant hemisphere (nondominant temporal lobectomy, NDTL group). Language dominance was based on the results of the intracarotid Amytal (Wada) procedure before surgery. No patients had generalized seizures after surgery. Table 1 summarizes the presurgical and postsurgical neuropsychological characteristics of these patients. A two-way ANOVA for the scores of each test showed no significant main effects of operational phases (before or after surgery)

and no significant interaction of resected sides (dominant or nondominant) by operational phases. Significant main effects ($p < .05$) of resected sides were detected only from scores of performance IQ of WAIS-R.

Of the 10 normal control subjects (NC) who participated in this study, two were men and eight were women (mean age 26.7 years, age range 20–35 years). The age differences among the three subgroups (DTL, NDTL, and NC) were not statistically significant by one-way ANOVA.

Brain Surgery for Epilepsy

The nondominant temporal resections were slightly more extensive than the dominant resections. The average extent of the nondominant resections was 3.7 cm (range 3.0–5.0 cm) from the temporal pole, and that of dominant resections was 3.0 cm in all DTL subjects. In all patients in the DTL and NDTL groups, the whole amygdala and varying portions of the hippocampal formation were removed. Typical examples of the postoperative T1-weighted MR images—of cases T. B. (DTL) and N. K. (NDTL)—are shown in Figure 1.

Experimental Stimuli and Presentation

All photographs were black and white, printed on a card measuring 14 × 11 cm. The order of presentation in all tasks was counterbalanced across all subjects. The name-retrieval tasks of familiar proper names consisted of (a) the retrieval of famous people's names from their photographs, (b) the retrieval of famous people's names from verbal descriptions, (c) the retrieval of famous buildings' names from photographs, and (d) the retrieval of prefectures' names from a blank map. In (a), the subjects were presented with 30 photographs of faces of famous people, one at a time, and were required to name each of them. Correct or incorrect scores for naming were only entered when the subject's responses proved that they could identify the person correctly. For example, if a subject only stated that a particular face was familiar, but could not provide further information such as occupation, the face was judged as unknown to the subject. If a subject stated that the person had been dead for about 5 years and named his or her most famous song, for example, the item was included in the naming score, either as correct when the name was provided or as incorrect when the name was not provided. Thus, whenever a response of name retrieval was counted as incorrect, we were certain that the subject correctly identified the item. In (c) and (d), the responses of subjects were scored using the same method in a total of 15 trials. In (d), subjects were presented with a blank map of Japanese prefectures and required to recall the names of the prefectures. In (b), subjects were required to give the name of a person, described by the examiner, and to provide further information. We

prepared 30 verbal definitions of famous people. The responses of name retrieval in this test were scored as correct or incorrect only if we were certain that the subjects were able to identify the correct semantics of people. In fact, all subgroups were able to provide information related to the stimuli at a rate of over 80%, there being no difference among the three groups (in FNP, DTL: $M = 26.8$, $SD = 1.92$, NDTL: $M = 26.0$, $SD = 1.58$, NC: $M = 27.1$, $SD = 1.2$; in FND, DTL: $M = 27.4$, $SD = 1.14$, NDTL: $M = 26.8$, $SD = 0.84$, NC: $M = 27.6$, $SD = 0.84$; in FBP, DTL: $M = 14.4$, $SD = 0.89$, NDTL: $M = 14.2$, $SD = 0.84$, NC: $M = 14.9$, $SD = 0.32$; and in PNM, $M = 14.2$, $SD = 0.84$, NDTL: $M = 14.4$, $SD = 0.89$, NC: $M = 14.9$, $SD = 0.32$).

For the retrieval of common names from line drawings of objects, the stimuli consisted of 32 pictures selected from standardized pictures (Snodgrass & Vanderwart, 1980). These pictures were classified into four categories: body parts, vegetables, fruits, and daily objects, with each category including eight pictures. Responses in this test were scored using the same method as for the naming of famous people.

For the retrieval of newly learned people's names from photographs, six photographs of unfamiliar faces were first presented to the subjects, one at a time (Figure 2A). Each photograph was presented together with three specific pieces of information, presented in written form at the same time: the person's name, occupation title, and hometown (town's name). The subjects were asked to memorize these six photographs of unfamiliar faces and the background information for each one, which was repeated five times. They were then asked to recall the person's name, occupation title, and hometown's name for each face 5 min later. Two points were allocated for spontaneous recall and one point for a cued recall, in which the experimenter presented the subjects with the first syllable of the target word. Thus, a perfect score for each type of information is 12 points. However, the cueing, using the first syllable of a word, provided little aid to retrieval performance in all categories; almost all of the stimuli retrieved were recalled spontaneously without cues (in DTL, spontaneous recall: $M = 2.8$, $SD = 1.79$, cued recall: $M = 0.6$, $SD = 0.89$; in NDTL, spontaneous recall: $M = 5.2$, $SD = 0.83$, cued recall: $M = 0.4$, $SD = 0.89$; and in NC, spontaneous recall: $M = 5.9$, $SD = 0.32$, cued recall: $M = 0.1$, $SD = 0.32$). Immediately after the recall session, all subjects were tested for recognition of the learned people's names and faces. The stimuli presented in the face-recognition test consisted of 12 photographs, including six targets and six distracters. The stimuli were presented one at a time. Then, the subjects were asked to judge whether a photograph was learned or not. For the test of recognition of people's names, the subjects were required to select six target people's names from the 12 written names (six target names and six distracters) printed on a white piece of paper.

Data Analysis

Retrieval performance in the tests of the retrieval of familiar proper names and common names is shown as the percentage of the number of correct names out of the total items that were correctly identified; this value is unaffected by the number of items that were not identified, and thus distinguishes retrieval deficits for names from recognition deficits for objects such as faces. The mean percentages of naming were calculated for each subgroup. In the four tasks of familiar proper-name retrieval, the data were analyzed by a two-way ANOVA with subgroup as a between-subject factor (DTL, NDTL, and NC) and task type as a within-subject factor. The data in the common-name-retrieval test were analyzed by a one-way ANOVA. The mean scores in the test of associative learning were calculated for each subgroup. A two-way 3 (subgroups: DTL, NDTL, and NC) × 3 (types of information: people's names, occupation titles, and hometowns) ANOVA was carried out on these mean scores. In the tests of recognition of faces and people's names, recognition rates were calculated from the raw scores of hits and false alarms. The LSD procedure was used for post hoc tests.

Experiment 2

Subjects

Ten healthy men participated in the study (mean age 21.60 years, range 20–25 years). All subjects were right-handers, whose scores on the Edinburgh Handedness Inventory (Oldfield, 1971) were all above +80. Head movements were detected just before all procedures for data analyses, and the data sets from subjects with head motion exceeding 20% of the voxel size in any of three axes (x, y, and z) were discarded. The data sets acquired from seven subjects were used for analyses. Informed consents were obtained from all participants based on the Declaration of Helsinki (1975).

Task Procedures

Before MRI scanning, the subjects participated in the encoding session. Twenty stimuli, each containing a photograph of an unfamiliar face, a name, and an occupation title on a sheet of paper, were prepared (Figure 2B). Subjects were instructed to look at the stimuli one by one and to remember the face with its name and occupation title. The procedure was repeated five times with its order randomized. Immediately after this, we checked the subjects' recalling ability. Only subjects whose performance exceeded 90% were selected for the MRI scanning study. The stimuli were divided into two sets of 10 (Sets 1 and 2).

After the encoding session, we carried out a retrieval session with MRI scanning. A sequential boxcar design was employed, in which two experimental tasks were

alternated. The presentation of stimuli was controlled by Apple Macintosh stimulus-presentation software. The stimuli were presented through a projector and back-projected to a screen placed just beyond the subject's feet on the scanner table. Subjects were able to see the screen through a mirror fixed in the head cage. Prior to scanning, the subjects were instructed to recall targets in a whisper.

In the retrieval session with scanning, subjects participated in four tasks. Each stimulus was presented one by one at a rate of 4 sec. One task block included 10 stimuli.

In the first task, that is retrieval of newly learned people's names (NN), the subjects recalled a name corresponding to a face projected on a screen. Set 1 stimuli were used for this task. In the second task, that is retrieval of newly learned people's occupations (NO), subjects recalled an occupation title from a face in the Set 2 stimuli. In the third task, that is retrieval of famous people's names (FN), subjects named the faces of famous people selected from well-known singers, actors, and so forth. Two sets of 10 photographs of famous people were prepared (Sets 3 and 4). The final task was retrieval of famous people's occupations (FO), in which subjects were required to retrieve an occupation title from a person's photograph. In this task, we presented 20 photographs of faces in two sets (Sets 5 and 6).

The NN and NO tasks were performed in the first session, the FN (Set 3) and FO (Set 5) in the second, the NN and FN (Set 4) in the third, and the NO and FO (Set 6) in the fourth. The order of tasks and sessions was counterbalanced across subjects. Each task block was repeated three times per session. Thus, the total time for scanning was 240 sec for one session.

Scanning Methods and Data Analyses

All MRI studies were carried out by a 1.5-T Siemens Magnetom Vision MRI scanner. The subjects were positioned in the scanner and their heads were immobilized with support cushions. A gradient echo EPI sequence was used for functional imaging with the following parameters: TR = 4000 msec, TE = 66 msec, FOV = 224 × 224 mm^2, matrix size = 64 × 64, flip angle = 90°, slice thickness/gap = 5/1 mm. Twenty-four axial slices were obtained and 60 sequential images of each slice were collected in each session.

Analyses of the fMRI data were performed using the software Statistical Parametric Mapping 96 (SPM96, Wellcome Department of Cognitive Neurology, London, UK), implemented in Matlab 4 (Mathworks, Sherborn, MA, USA). First, 60 sequential images acquired from each subject were realigned to the first image with the sync-interpolated method. Second, the realigned images from each subject were transformed and normalized into standard space (Talairach & Tournoux, 1988) using EPI template and smoothed with Gaussian kernel of FWHM of 10 mm. Third, the effects of tasks on signal intensity at each voxel were estimated using the random effect model available for SPM96. The effects of each comparison were estimated using the general linear model, which yielded t statistics (expressed as a Z score) for a given comparison at each voxel. Activation was considered significant if it had a cluster of voxel thresholded above $p < .001$ (uncorrected, $k > 7$ voxels) with maximum Z value.

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