

:  
 (fMRI)  
 : 7 ( 22 ) (Blood  
 Oxygenation Level Dependence: BOLD) (BOLD - fMRI)  
 30  
 30 (+) 30  
 , 8 , (AC)  
 (PC) 10 , SPM99  
 :  
 (%) , Rhs - 35 PoCiG - 23 ICiG - 26 · 30  
 ,  
 ,  
 30% 10% ,  
 (% , ) ,  
 pixel  
 가  
 PrCeG - 4 Pr/PoCeG -  
 SCA - 25, SFG/MFG - 10,  
 43 , 가  
 IFG - 44 · 45, OrbG - 11 · 47, SFG - 6 · 8, MFG - 9 · 46 ,  
 (%) ,  
 )  
 2 가  
 :

memory system) (4) . ,  
 ,  
 (implicit memory) (explicit memory) ,  
 , 1980  
 가  
 ,  
 가 (4 - 6).

TR/TE=3000 msec/50 msec, (flip angle) 90 °  
 FOV 26×26 cm, matrix 128×128, 6 mm,  
 1 mm, NEX 1 , (an - terior commissure:  
 AC) (posterior commissure: PC) AC - PC  
 line 10 510  
 . EPI (equilibrium state)

4 (1 phase) (dummy scan) 가  
 , 154 .

3 2  
 (+) 가  
 가 , 가  
 가 3 8  
 가  
 (7, 8).  
 가 2  
 (fMRI)

fMRI 가 , , 가  
 7 (21 - 25 : 22 )  
 . T1 (T1 - weighted  
 image: T1WI) T2 (T2 - weighted image: T2WI)  
 1.5T Signa Horizon Echospeed MR  
 Scanner (GE Medical Systems, Milwaukee, U.S.A.)  
 . Bird cage T1WI  
 (repetition time: TR)/ (time to echo: TE) =500  
 msec/8 msec , T2WI TR/TE=3500 msec/102 msec

(1) : , , , , ,  
 , , , , , , , , , , ,  
 (2) : T ( ), T ( ),  
 H ( ), t ( ), t ( ), ± ( ), l  
 ( ), t ( ), t ( ), l ( ), T ( ), T  
 ( ), H ( ), ± ( ), ± ( ), T ( )  
 (3) : , , , , ,  
 , , , , , , , , , , ,

(field of view: FOV) 22 cm×22 cm,  
 matrix 256×192, NEX (number of excitation) 2,  
 5 mm, 2 mm  
 5  
 EPI - BOLD

MR BOLD  
 SPM99 (statistical parametric map -  
 ping99, The Wellcome Department of Cognitive Neurology,  
 University College London, UK)  
 (motion correction) (realign -

$$\begin{aligned}
 \text{Lateralization Index(\%)} &= \frac{\text{Activation Index(\%)} - \text{Lateralization Index(\%)}}{\text{Activation Index(\%)} + \text{Lateralization Index(\%)}} \times 100 \quad [1] \\
 \text{Activation Index(\%)} &= \frac{\text{Activation Index(\%)} - \text{Lateralization Index(\%)}}{\text{Activation Index(\%)} + \text{Lateralization Index(\%)}} \times 100 \quad [2]
 \end{aligned}$$

Brodmann's area (Table 1).

[1] [2] (lat -  
eralization index) (activation index)

(%)

, SFG (superior frontal gyrus) - 6 · 8,  
IFG (inferior frontal gyrus) - 44 · 45, Parietal (parietal lobe) -  
7, Occipital (occipital lobe) - 17 · 18 · 19 100%  
MFG (middle frontal gyrus) - 9 · 46, OrbG (orbital  
sulcus) - 11 · 47, STG/MTG (superior & middle temporal

**Table 1.** Quantitative Comparison of Activated Cerebral Regions (Brodmann's Areas) under Implicit and Explicit Memory Retrieval Tasks

|                 |                         | Implicit memory |                           |                    | Explicit memory   |                           |                    | Act. index<br>(%) |
|-----------------|-------------------------|-----------------|---------------------------|--------------------|-------------------|---------------------------|--------------------|-------------------|
|                 |                         | Location        | Act. pixels<br>(Ave ± SD) | Act. ration<br>(%) | Lat. index<br>(%) | Act. pixels<br>(Ave ± SD) | Act. ration<br>(%) |                   |
| Frontal lobe    | PrCeG-4                 | 7.0 ± 13.5      | 42.9                      | 79.6               | 28.6 ± 50.0       | 42.9                      | 9.0                | - 60.6            |
|                 | PrCeG/PoCeG-43          | 22.1 ± 39.7     | 42.9                      | 0.6                | 25.9 ± 39.2       | 42.9                      | 60.2               | - 7.7             |
|                 | SFG-6, 8                | 473.1 ± 361.2   | 100.0                     | 28.3               | 401.7 ± 440.4     | 100.0                     | 42.8               | 8.2               |
|                 | SFG/MFG-10              | 62.4 ± 137.5    | 57.1                      | - 23.1             | 23.7 ± 47.0       | 42.9                      | 72.3               | 44.9              |
|                 | MFG-9, 46               | 172.6 ± 166.8   | 85.7                      | - 7.6              | 169.0 ± 200.0     | 71.4                      | 15.1               | 1.0               |
|                 | IFG-44, 45              | 428.6 ± 158.4   | 100.0                     | 27.0               | 342.1 ± 190.3     | 100.0                     | 49.1               | 11.2              |
|                 | OrbG-11, 47             | 389.1 ± 549.6   | 85.7                      | - 1.1              | 317.4 ± 456.2     | 100.0                     | 39.9               | 10.1              |
|                 | SCA-25                  | 65.3 ± 166.6    | 28.6                      | - 30.4             | 11.1 ± 21.2       | 42.9                      | - 53.8             | 70.8              |
| Temporal Lobe   | STG-22                  | 157.7 ± 34.8    | 42.9                      | 54.5               | 59.6 ± 129.4      | 57.1                      | 32.9               | - 58.3            |
|                 | STG/MTG-38              | 48.6 ± 67.7     | 85.7                      | 30.0               | 48.4 ± 58.8       | 100.0                     | 31.6               | 0.1               |
|                 | MTG-21                  | 40.7 ± 70.5     | 42.9                      | 86.0               | 48.0 ± 114.1      | 42.9                      | 29.2               | - 8.2             |
|                 | ITG-20, 37              | 76.1 ± 104.5    | 71.4                      | - 12.6             | 142.7 ± 130.6     | 71.4                      | 19.9               | - 30.4            |
|                 | Temporal-28, 34, 36, 42 | 9.4 ± 23.6      | 42.9                      | 93.9               | 36.7 ± 48.6       | 71.4                      | 31.5               | - 59.1            |
|                 | RhS-35                  | 0.0 ± 0.0       | 0.0                       | -                  | 4.6 ± 10.1        | 28.6                      | - 100.0            | - 100.0           |
|                 | AnTG-41                 | 22.6 ± 28.7     | 42.9                      | 17.7               | 48.9 ± 70.4       | 42.9                      | 8.2                | - 36.8            |
| Parietal lobe   | PoCeG-1, 2, 3           | 53.0 ± 61.1     | 71.4                      | - 59.0             | 69.9 ± 111.3      | 42.9                      | 73.4               | - 13.7            |
|                 | Parietal-7              | 285.1 ± 181.9   | 100.0                     | 18.7               | 420.0 ± 263.8     | 100.0                     | 26.1               | - 19.1            |
|                 | AG-39                   | 133.1 ± 132.4   | 85.7                      | - 29.0             | 278.4 ± 144.2     | 100.0                     | 7.1                | - 35.3            |
|                 | SMG-40                  | 218.3 ± 207.7   | 85.7                      | 27.0               | 268.3 ± 206.0     | 100.0                     | 11.7               | - 10.3            |
| Occlipital lobe | Occipital-17, 18, 19    | 586.3 ± 319.3   | 100.0                     | 15.7               | 753.4 ± 312.1     | 100.0                     | 26.7               | - 12.5            |
| Cingulate gyrus | AnCiG-24, 32            | 243.4 ± 238.4   | 85.7                      | 22.3               | 242.1 ± 245.0     | 100.0                     | 23.2               | 0.3               |
|                 | PoCiG-23                | 0.0 ± 0.0       | 0.0                       | -                  | 21.0 ± 44.9       | 42.9                      | - 7.5              | - 100.0           |
|                 | ICiG-26, 30             | 0.0 ± 0.0       | 0.0                       | -                  | 17.7 ± 35.4       | 28.6                      | - 1.6              | - 100.0           |

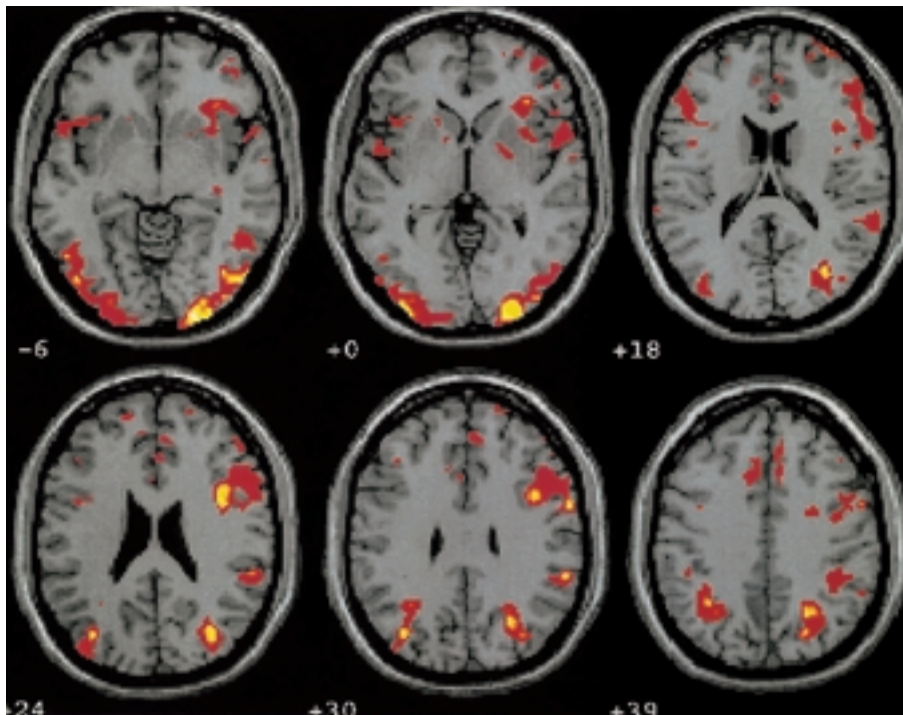
Act. pixel: number of activated pixel, Act. ratio: activation ratio, Lat. index: lateralization index, Act. index: Activation index, Ave: average, SD: standard deviation

\* PrCeG: precentral gyrus, PoCeG: postcentral gyrus, SFG: superior frontal gyrus, MFG: middle frontal gyrus, IFG: inferior frontal gyrus, OrbG: orbital gyrus, SCA: subcallosal area, STG: superior temporal gyrus, MTG: middle temporal gyrus, ITG: inferior temporal gyrus, Temporal: temporal lobe, RhS: rhinal sulcus, AnTG: anterior transverse temporal gyrus, Parietal: parietal lobe, AG: angular gyrus, SMG: supramarginal gyrus, Occipital: occipital lobe, AnCiG: anterior cingulate gyrus, PoCiG: posterior cingulate gyrus, ICiG: isthmus of cingulate gyrus

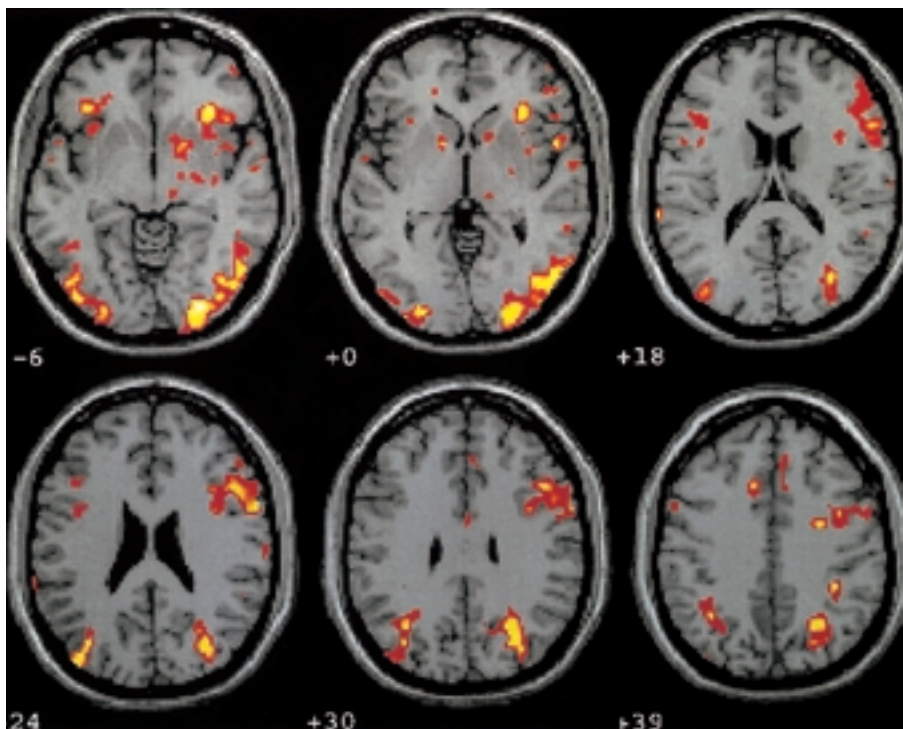
:

gyrus) - 38, AG (angular gyrus) - 39, SMG (supramarginal gyrus) - 40, AnCiG (anterior cingulate gyrus) - 24 · 32 85.7% ITG (inferior temporal gyrus) - 20 · 37, PoCeG (postcentral gyrus) - 1 · 2 · 3 71.4% SFG/MFG (superior & middle frontal gyrus) - 10 57.1% PrCeG (precentral gyrus) - 4, PrCeG/PoCeG (pre & postcentral gyrus) - 43, STG (superi-

or temporal gyrus) - 22, MTG (middle temporal gyrus) - 21, Temporal (temporal lobe) - 28 · 34 · 36 · 42, AnTG (anterior or transverse temporal gyrus) - 41 42.9% SCA (subcallosal area) - 25 28.6% SFG - 6 · 8 (100.0%), IFG - 44 · 45 (100.0%), OrbG - 11 · 47 (100.0 %), STG/MTG - 38 (100.0%), Parietal - 7 (100.0%), AG - 39 (100.0%),



A

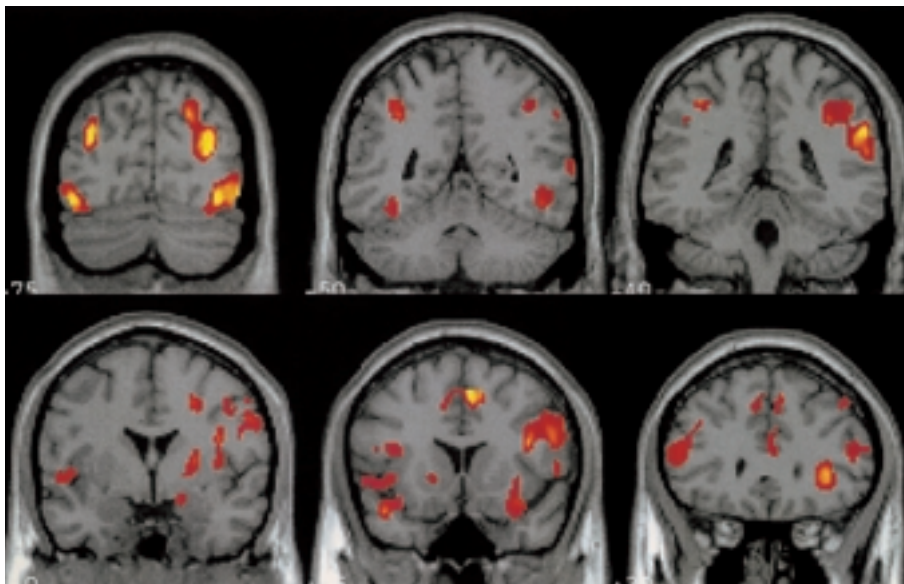


B

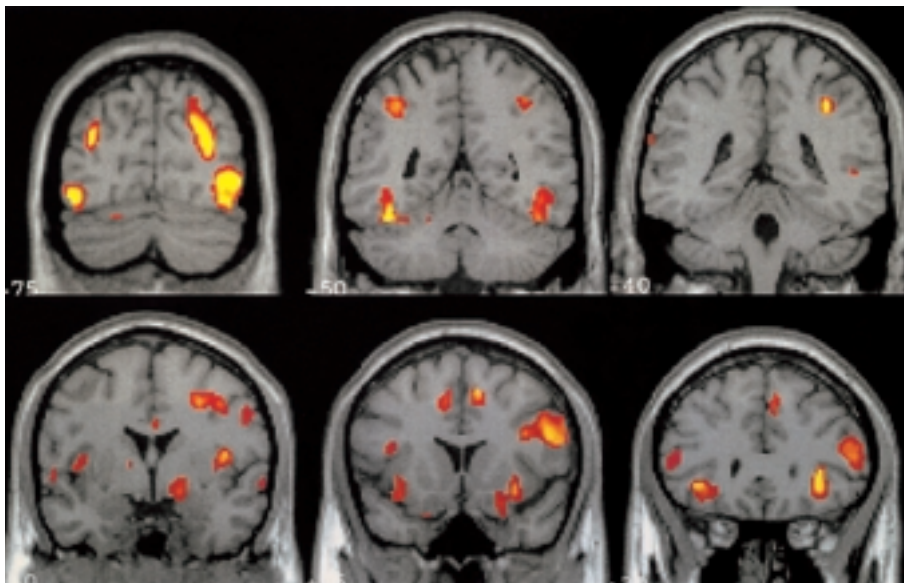
**Fig. 1.** BOLD-MR images from 6 contiguous axial slices: **(A)** implicit vs. **(B)** explicit retrieval of previously learned words under the level with conceptual processing. Color-coded pixels on the activation maps were scaled to the range between the cutoff-threshold and the highest t-score ( $p < 0.05$ ).

SMG - 40 (100.0%), Occipital - 17 · 18 · 19 (100.0%), AnCiG - 24 · 32 (100.0%) > MFG - 9 · 46 (71.4 %), ITG - 20 · 37 (71.4%), Temporal - 28 · 34 · 36 · 42 (71.4%) > STG - 22 (57.1%) > PrCeG - 4 (42.9%), PrCeG/ PoCeG - 43 (42.9%), SFG/MFG - 10 (42.9%), SCA - 25 (42.9%), MTG - 21 (42.9%), AnTG - 41 (42.9%), PoCeG - 1 · 2 · 3 (42.9%), PoCiG - 23 (42.9%) > RhS - 35 (28.6%), ICiG - 26 · 30 (28.6%) (Table 1, Fig. 1 - 3). RhS - 35 PoCiG - 23 ICiG - 26 · 30

(Table 1, Fig. 3).  
( ) ,  
가 , ,  
PrCeG - 4 (AI = - 60.6%) Pr/  
PoCeG - 43 (AI = - 7.7%) ,  
가 SCA - 25 (AI = 70.8%), SFG/  
MFG - 10 (AI = 44.9%), IFG - 44,45 (AI = 11.2%), OrbG -  
11,47 (AI = 10.1%), SFG - 6,8 (AI = 8.2%), MFG - 9,46  
(AI = 1.0%) (Table 1, Fig. 4).  
(%, )  
,  
SCA - 25 (LI = -  
30.4%), SFG/MFG - 10 (LI = - 23.1%), MFG - 9 · 46 (LI = -



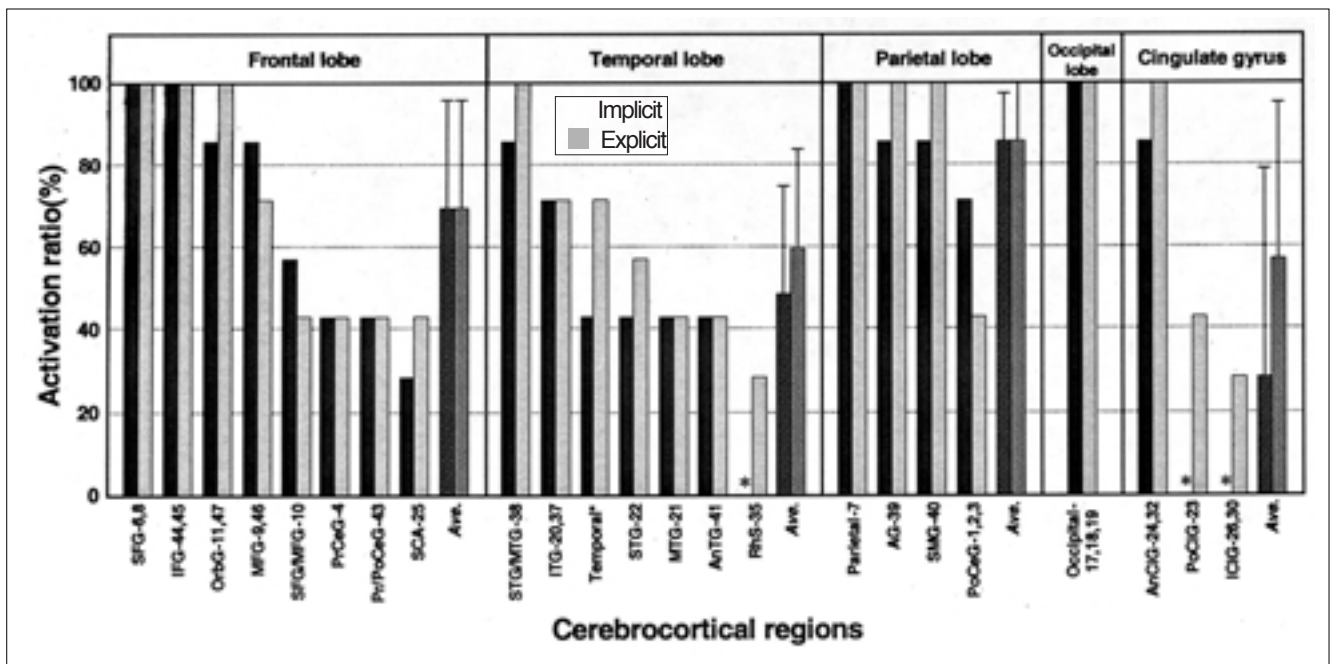
A



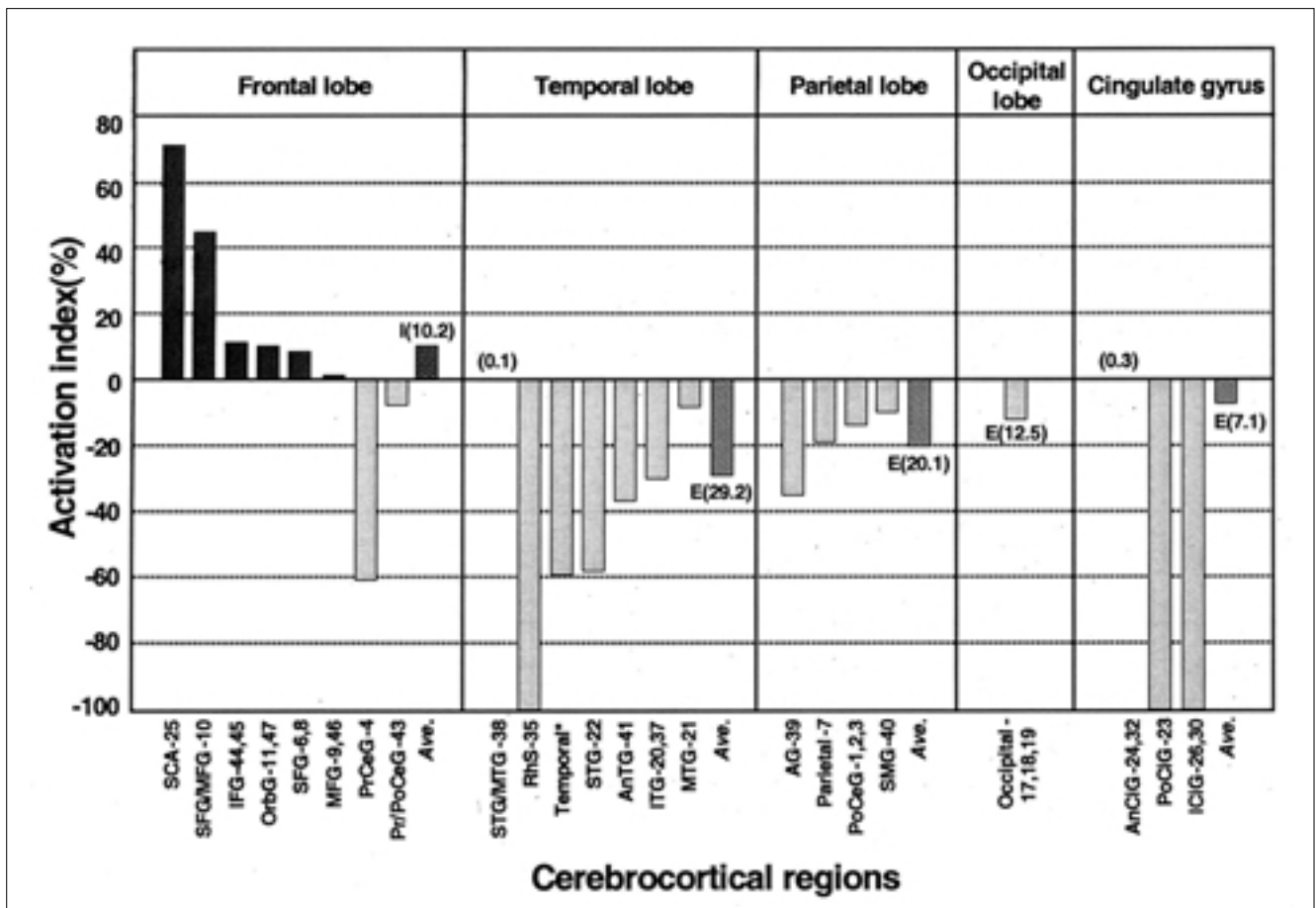
B

**Fig. 2.** BOLD-MR images from 6 contiguous coronal slices: (A) implicit vs. (B) explicit retrieval of previously learned words under the level with conceptual processing. Color-coded pixels on the activation maps were scaled to the range between the cutoff-threshold and the highest t-score ( $p < 0.05$ ).





**Fig. 3.** Comparison of the activation ratios (%) of the volunteers corresponding to the cerebral regions (Brodmann 's areas) activated during the performance of both implicit and explicit retrieval of previously encoded words under the level with conceptual processing. \* indicates the brain regions that were not activated.



**Fig. 4.** Bar graph showing the activation indices (%) corresponding to the cerebral regions during implicit and explicit memory retrieval tasks under the level with conceptual processing.

7.6%), OrbG - 11,47 (LI = - 1.1%), ITG - 20 · 37  
(LI = - 12.6%), PoCeG - 1 · 2 · 3 (LI = - 59.0%),  
AG - 39 (LI = - 29.0%)

13

(Fig. 5).

(representa -

SCA - 25 (LI = - 53.8%),

tion)

RhS - 35 (LI = - 100%)

PoCiG - 23 (LI = -

7.5%), ICiG - 26 · 30 (LI = - 1.6%)

18

SCA - 25 (LI = - 53.8%)

1980

가

가

(4 - 6).

SFG/MFG - 10, MFG - 9 · 46, OrbG - 11, 47

ITG

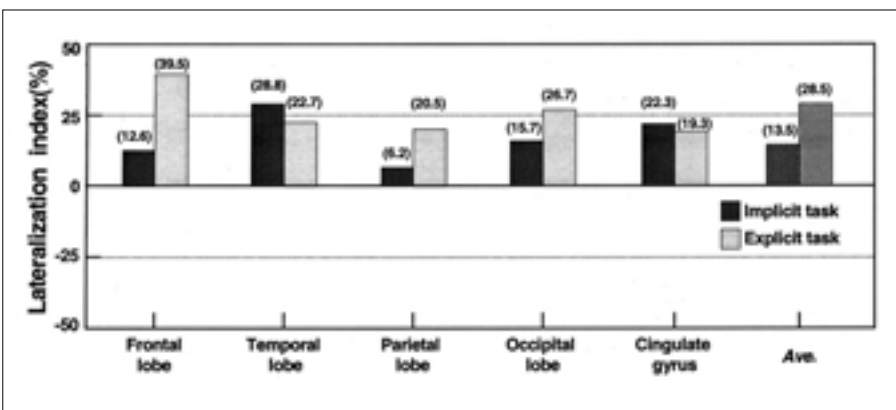
- 20 · 37, PoCeG - 1 · 2 · 3, AG - 39

PoCiG - 23 (Table 1, Fig. 6).

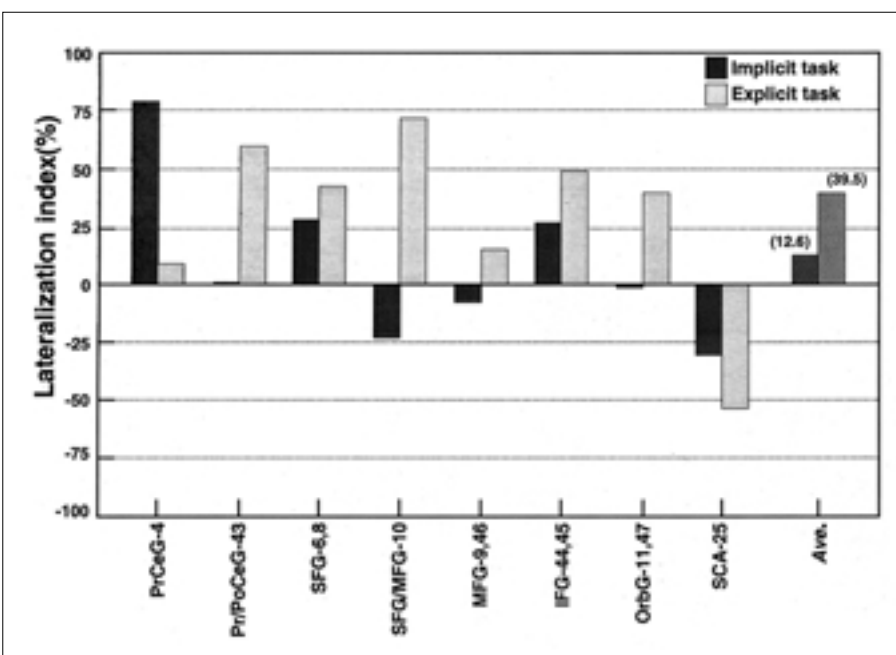
(sensory modality),

(level of processing),

(generation)



**Fig. 5.** Lateralization of the implicit and explicit memory retrieval tasks of the encoded words under the level with conceptual processing.



**Fig. 6.** Comparison of the lateralization indices (%) between implicit and explicit memory retrieval tasks in the frontal lobe.

:  
 (Brodmann area 44) 가  
 가 ,  
 가  
 ,  
 (8). Jacoby (9) (17 - 20).  
 ,  
 (Brodmann area 9, 10), bilateral circumstriate  
 가 (Brodmann area 18, 19)가 , left  
 ventral extrastriate (Brodmann area 18)가  
 가 . (right prefrontal lobe  
 cortex)  
 , 가  
 (18, 21).  
 가  
 (10). Korsakoff  
 (4,  
 12) 가 (medial temporal lobe: hippocampus, entorhinal cortex,  
 perirhinal cortex, parahippocampal gyrus )  
 (diencephalon) , 가  
 (8,  
 13 - 15). 가 (23).  
 (15). CA1  
 가 (24). PET (11).  
 (modularity) , Squire (25)  
 (4, 15). fMRI  
 가 .  
 (episodic memory) (conceptual  
 memory) “  
 ”  
 , “  
 ”  
 .  
 (16).  
 (parahippocampal gyrus) (fusiform gyrus),  
 (Brodmann area 6),  
 (Brodmann area 44),  
 44 · 45, SFG - 6 · 8, STG - 22, IFG -  
 7, Occipital - 17 · 18 · 19 Parietal -  
 (100%)  
 IFG - 44 · 45 Broca (IFG -  
 44 · 45) MFG -  
 9 · 46 OrbG - 11 · 47  
 MFG - 46 (working mem -  
 ory cortex)  
 MFG - 46  
 87.5%, 71.4%  
 SFG - 6 · 8 SFG/MFG - 10  
 Broca  
 가



SFG - 6 · 8 100% 가 27%, 14%, 9% .  
 , SFG/MFG - 10 , Pr/PoCeG - 43, IFG - 44 · 45, SFG - 6 · 8  
 57.1%, 42.9% 가 59.6%, 22.1%,  
 SFG - 6 · 8 14.5% PrCeG - 4  
 70.6% SFG/MFG - 10, MFG - 9 · 46, OrbG -  
 11 · 47 SCA - 25  
 Wernicke  
 (STG - 22) 42.9%, 57.1% .

Broca  
 Wernicke 가  
 PET , fMRI  
 , , ,  
 가  
 ( : ) 가 가  
 block  
 design event - related paradigm  
 가  
 (26).

20 - 70%  
 PET  
 가  
 (20, 27)  
 Fig. 3 4  
 rhinal sulcus (RhS - 35) (PoCiG -  
 23, ICiG - 26 · 30) rhi -  
 nal sulcus  
 , 가  
 가

fMRI . Desmond (22)  
 Wada  
 (%, )  
 가 13.5% 가  
 가 28.5%  
 가 2  
 가 6%, 3%

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## Neural Mechanism of Implicit and Explicit Memory Retrieval: Functional MR Imaging<sup>1</sup>

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**Purpose:** To identify, using functional MR imaging, distinct cerebral centers and to evaluate the neural mechanism associated with implicit and explicit retrieval of words during conceptual processing.

**Materials and Methods:** Seven healthy volunteers aged 21 - 25 (mean, 22) years underwent BOLD-based fMR imaging using a 1.5T Signa Horizon Echospeed MR system. To activate the cerebral cortices, a series of tasks was performed as follows: the encoding of two-syllable words, and implicit and explicit retrieval of previously learned words during conceptual processing. The activation paradigm consisted of a cycle of alternating periods of 30 seconds of stimulation and 30 seconds of rest. Stimulation was accomplished by encoding eight two-syllable words and the retrieval of previously presented words, while the control condition was a white screen with a small fixed cross. During the tasks we acquired ten slices (6 mm slice thickness, 1 mm gap) parallel to the AC-PC line, and the resulting functional activation maps were reconstructed using a statistical parametric mapping program (SPM 99).

**Results:** A comparison of activation ratios (percentages), based on the number of volunteers, showed that activation of Rhs-35, PoCiG-23 and ICiG-26 · 30 was associated with explicit retrieval only; other brain areas were activated during the performance of both implicit and explicit retrieval tasks. Activation ratios were higher for explicit tasks than for implicit; in the cingulate gyrus and temporal lobe they were 30% and 10% greater, respectively. During explicit retrieval, a distinct brain activation index (percentage) was seen in the temporal, parietal, and occipital lobe and cingulate gyrus, and PrCeG-4, Pr/PoCeG-43 in the frontal lobe. During implicit retrieval, on the other hand, activity was greater in the frontal lobe, including the areas of SCA-25, SFG/MFG-10, IFG-44 · 45, OrbG-11 · 47, SFG-6 · 8, and MFG-9 · 46. Overall, activation was lateralized mainly in the left hemisphere during both implicit and explicit retrieval tasks. For explicit retrieval, the lateralization index was more than twice as high as for implicit retrieval.

**Conclusion:** Our findings indicate that there is neuro-anatomical dissociation between implicit and explicit retrieval of words during conceptual processing, suggesting, on the basis of cognitive neuroscience, that the performance of implicit and explicit memory-related tasks involves different mechanisms.

**Index words :** Encoding and retrieval  
Explicit and implicit retrieval  
Functional magnetic resonance imaging, fMRI

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