Three Dimensions in the State of Memory and Emotion Concerned with a Person: Factor Analysis Using Subject's Self Evaluation and PET

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Introduction

Although memory and emotion are closely related and intertwined in our daily life, they are usually separately studied on simple models based on the animal models in previous studies. Human brain imaging is expected to reveal the neurobiological correlates of human memory and emotion. However, so far, there seems to be no established model of human memory and emotion which can be compared with brain activity. Normal adults can verbally describe their states of memory and emotion with various terms. Many terms are used to discribe similar states of memory and emotion, but each term expresses specific nuance. We need to choose appropriate terms to construct a model of memory and emotion without a priori hypothsis. Here we propose new a approach to extract essential factors from these terms using factor analysis on phisyological data. In this study, rCBF image was obtained during the normal subject was retrieving memory concerening a specific person (target person), using positron emission tomography (PET). The subject evaluated his states of memory and emotion concerning the target person using the questionnaire with 23 items with five grade rating, after the PET scan. We made correlation map for each item, and principal component analysis (PCA) was performed for 23 items using correlateion coefficients of all voxels in the whole brain.

Methods

Subjects

Nine right handed normal male volunteers (age 18-21) participated in this study. Handedness was assessed by the Edinburgh Handedness Inventory[1]. None had any sign or history of psyconeurological disease. Written informed consent was obtained from each subject in accordance with the guidelines approved by Tohoku University and the Helsinki

Declaration of Human Rights, 1975. The protocol was approved by the local ethics committee of the Institute of Development, Aging and Cancer, Tohoku University.

Personal memory retrieval tasks

Each subject performed six tasks in each of which retrieval of memory about a specific person (target person) was required. The target person was specified before each task among the people with variety of relationships with the subjects (a comic character, a social figure, his recent friend, his old friend, one of his siblings, and his father). A single word or a sentence which describes a person, such as "honest", "tall", or "runs fast", was visually presented, in each trial. The subjects were required to determine whether the description of each presented word or sentence suites the target person. The subjects performed 40 trials during 120 sec in each task.

rCBF measurement

The PET scans were performed with a SET-2400W PET scanner (Shimadzu, Kyoto, Japan) in three-dimensional mode. The physical characteristics of this scanner have been described previously[2]. During each personal memory retrieval task, bolus injection of 200MBq $H_2{}^{15}O$ was followed by 60sec data aquisition.

Evaluation of memory/emotion states

Immediately after each task finished, the subject was asked to complete a questionnaire with five grade rating which consists of following 23 items which evaluate his state of memory and emotion concerned with the person.

1) I have memory for this person.
2) I have knowledge of this person.
3) I can visually imagine this person.
4) I like this person.
5) I hate this person.
6) I was influenced by this person.
7) I influenced this person.
8) I feel familiarity (intimacy) with this person.
9) I have loving memory for this person.
10) I have joyful memory for this person.
11) I have sad memory for this person.
12) I have fearful memory for this person.
13) I have experating memory for this person.
14) I feel love when I think of this person.
15) I feel joy when I think of this person.

16) I feel sad when I think of this person.
17) I feel fear when I think of this person.
18) I feel anger when I think of this person.
19) I feel love when I am with this person.
20) I feel joy when I am with this person.
21) I feel sad when I am with this person.
22) I feel fear when I am with this person.
23) I feel anger when I am with this person.

Data analysis

The PET images were anatomically normalized to the standard brain of the Human Brain Atlas[3] using the Automated Image Registration[4] and Elastic transformation[5]. All PET images were proportionally scaled into the global mean cerebral blood flow of 50ml/dl/min. Using all 54 normalized images, correlation coefficient was calculated for each voxel for each item, to make correlation map. Among some items, their correlation maps resemble each other, and these items may share some common memory/emotion factor(s). Correlation coeficients were Z transformed ($Z=\log((1+r)/(1-r))/2$), and resulting Zr maps (vectors with approximately 2×10^5 values (the number of voxels)) were used to calculate covariance matrix (23×23). Eigenvalues and eigenvectors were calculated using the covariance matrix. Calculation of correlation map and PCA were performed on MATLAB 4.2 (Mathworks Inc., Sherborn, Mass., USA). Cumulative proportion reached 80% by the third principal component, and first three principal components were considered as effective. Pricipal component score (PCS) map was calculated from Zr map and the eigenvector for each effective principal component (inverse Z transformation was performed to obtain correlation coefficient like characters).

Results and discussion

For three principal components, items are listed from those with larger absolute factor loading until sum of square of the loadings exceeds 0.8 (Table 1), and PCS map is shown (Figure).

In the first principal component, large positive loadings were seen for the items evaluating a positive impression and memory for the target person. We refer this principal component as "Positive Emotion" factor. This factor was associated with high activity in the bilateral anterolateral prefrontal cortex and the right occipitotemporal region, and low activity in the bilateral anterolateral temporal cortex, superior part of amygdala, lateral orbitofrontal cortex, and sensorimotor cortex.

In the second principal component, large negative loadings were seen for the items evaluating a negative impression and memory for the target person. We refer this principal component as "Negative emotion" factor. This factor was associated with high activity in

the bilateral anteromedial temporal cortex, inferior part of amygdala and the left occipitotemporal region.

In the third principal component, large positive loadings were seen for the items evaluating a knowledge and visual imagenability of the target person, and large negative loadings were seen for the items evaluating memories bearing negative emotion. We refer this principal component as "Nonemotional Memory" factor. This factor was associated with high activity in the left inferior temporal cortex, which is in cotrast to the high activity in the right inferior temporal cortex associated with "Positive Emotion" and "Negative Emotion".

Application of the factor analysis to PET data and psychological measurements seems to be a powerful approach for the study of human memory and emotion.

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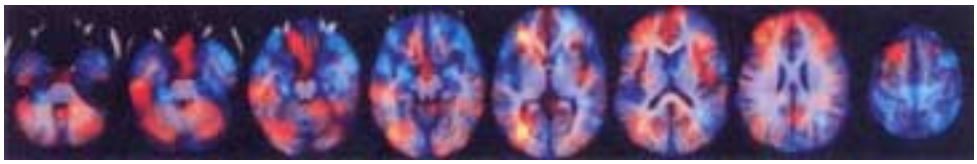
Table 1. Items with large absolute value of factor loadings for three principal component.

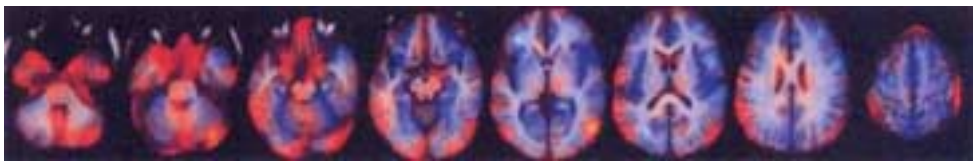
item	loading
first principal component	
I feel love when I am with this person	0.36
I have loving memory for this person	0.33
I feel love when I think of this person	0.31
I have knowledge of this person	0.29
I feel joy when I am with this person	0.25
I have memory for this person	0.25
I can visually imagine this person	0.24
I like this person	0.23
I have joyful memory for this person	0.22
I have sad memory for this person	0.21
I feel joy when I think of this person	0.20
I was influenced by this person	0.19
second principal component	
I feel fear when I am with this person	0.38
I feel sad when I am with this person	0.36
I feel anger when I think of this person	0.33
I feel anger when I am with this person	0.33
I feel sad when I think of this person	0.33
I have experating memory for this person	0.29
I hate this person	0.23
I like this person	-0.19
third principal component	
I have knowledge of this person	0.48
I have experating memory for this person	-0.44
I can visually imagine this person	0.38
I have sad memory for this person	-0.35
I have fearful memory for this person	-0.27
I feel familiarity with this person	-0.25

Figure PCS maps

first principal component



second principal component



third principal component

Figure 1. PCS maps are superimposed onto the mean normalized MRIs of all subjects. Positive correlation is shown in red and negative correlation is shown in blue. The left side of the brain is shown in the right side of the figure.