Role of the Thalamus in Episodic Encoding: An fMRI Study

Mei Tan, Weihui Yang and Xiaodong Lu
Jilin Province Economic Management Cadre College

Abstract. People can get the information through the transfer function of thalamus. As a transfer station of information; the thalamus plays an important role in acquisition and transmission of information. Numerous study how the thalamus processing the information which come from different channels, but there are no research about the different format of information, which come from the same channel. The present research investigates the function of thalamus in encoding of statistical graph and text. We addressed this issue in an event-related fMRI study by measuring the brain activity in 36 normal subjects. In our study, the experimental materials were designed three forms of information: T(text), SG(statistical graph) and SGT(statistical graph + text), and the result show that the thalamus was more activated during encoding SG and SGT, and the activation of statistical graph was greater than SGT, which suggests that the thalamus is more sensitive to the SG.

1. Introduction
The brain contains an organ called thalamus, which is located at the center of it, organizes the information’s fluxing from the sensory organs toward all the parts in the body, also works to give orders for all the structures inside and around the brain, such as neural network and neural activities (cortical and subcortical structures), Almost all of the scientists call it as control center of the motors signals to the cerebral cortex, and responsible for organizing the consciousness, sleeping, and alertness, underlying memories processes too, It has multiple functions, which responds to visual sensory signals then returns the signals to the cerebral cortex, also the same way for auditory, and somatosensory.

The thalamus responsible of the formation of new memories in the human life, research’s has proven the role of the thalamus related to the memory [3-5], also the uses of strategies in memories [6-7], we must be aware of the side effects of reactions and stimuli, Any defect may affect the thalamus by leading the domain of encoding or retrieval to be disabled[10]. Although there are many investigations on thalamus, the function of thalamus in encoding different formats of information’s has been no consensus yet.

Either A defect or deficit may occur in the verbal or non-verbal domain, As a result of memory deficit following thalamic damage, which is easy to distinguish between patients with unilateral or asymmetrical lesions, after examining the memory, also controversial because we all used to think that deficits caused by unilateral lesions are only found in the domains thought to be belonged to, but it spreads to be found in the bilateral hemisphere[7, 12-14].

Aggleton and Brown (1999) propose that the connections between the hippocampus and the thalamus provide explanation for the wide spread involved in spatial memory [15-16]. Most of the studies have shown that thalamus is involved in spatial processing such as the effects of thalamus on spatial learning and memory [17-18], which mainly depends on the radial arm maze task.

To date, the function of thalamus in processing of verbal or non-verbal tasks remains unclear. To address the issue, we designed three visually presented forms of tasks: text, statistical graph and statistical graph + text. Text is a verbal description of the information; statistical graph contains the
spatial/place information that describes the relationships to represent the same information as text; statistical graph + text is the combination of both statistical graph and text. The encoding of statistical graph requires spatial processing, which may need the involvement of thalamic. Previous studies reported that the thalamic was sensitive to spatial processing [19] and the region is similar to hippocampus system. Moreover, the lesion study suggested that damage to the hippocampus system causes spatial processing deficits. We through the types of stimulates to discuss the different role of left and right thalamus, which can further verify whether the left thalamic is related to verbal and the right is related to non-verbal or not. In the present study, we hypothesis: thalamus is involved in the encoding of both statistical graph and text, but compare to text, the region is more related to statistical graph processing which has spatial features.

2. Methods

2.1. Participants
Participants a thirty six native Chinese-speakers (18 males and 18 females), had volunteered in the study after been given the consent information with a mean age of 22.5 (standard deviation 1.7) and mean education level of 15.6 (standard deviation 0.9) years.

2.2. Materials
We used three presenting forms: T(text), SG(statistical graph) and SGT(SG + text). All these texts were presented during the encoding with different periods.

| Type            | Duration |
|-----------------|----------|
| text            | 14 seconds |
| statistical graph| 16 seconds |
| statistical graph + text | 18 seconds |

The experiment consisted of four sessions. The order of different type stimuli within the sessions was presented randomly in an event-related design. The images for the initial 10s were discarded because of unsteady magnetization, and the remaining images per session were analyzed. The participants were instructed to read text, statistical graph and statistical graph + text information attentively. Four sessions were collected per each participant.

2.3. Image Acquisition
We used the Siemens 3-T Trio scanner (Siemens Magnetom scanner, Erlangen, Germany) in order to collect the BOLD signal. For the functional data, TR = 2000 ms, TE = 31 ms, FA = 90°, in the same plane for the high resolution T1-weighted anatomical images with a different parameters (TR = 130 ms, TE = 2.89 ms, FA = 70°, the matrix size = 320 × 320 mm, Voxel = 0.8 × 0.8 × 4 mm, FOV = 240 × 240 mm). The matrix size = 64× 64 mm, Voxel = 4 × 4 × 4 mm, inter-slice gap is 0.8 mm.

2.4. Data Analysis
Data analysis was performed with SPM2 from the Welcome Department of Cognitive Neurology, London, UK. MNI coordinates were transferred into Talairach coordinates (Talairach and Tournoux, 1988). The first two scans were discarded.

The images were spatially smoothed with a Gaussian kernel of 8 mm full-width at half-maximum (FWHM) after it had been reconstructed into 2-mm cubic voxels. SPM 2 provided the ability for the Statistical inferences to be drawn on the basis of the general linear modal after it had been achieved in it, also provides an evidence that stimulus onsets of the trials for each condition were convolved with the canonical form of the hemodynamic response function (hrf).

3. Results
Our study were mainly relied on the differences of T, SG and SGT during encoding stage, as shown in Table 1
Table 1. Brain activations within the thalamus related to three forms

| Period | regions       | Talairach Coordinates | V(mm³) |
|--------|---------------|-----------------------|--------|
|        |               | x  | y  | z  |        |
| SR     | Left thalamus | -8 | -26| 0  | 1144   |
|        | Right thalamus| 8  | -22| 4  | 1200   |
| STR    | Left thalamus | -8 | -26| 0  | 200    |
|        | Right thalamus| 6  | -22| 2  | 80     |
| TR     | ***           | ***| ***| ***| ***    |

TR, text encoding; SR, statistical graph encoding; STR, statistical graph + text encoding

We measured the brain activity during encoding three different information formats, the result show that the bilateral thalamus was more activated during statistical graph encoding (Fig. 1), also the bilateral thalamus activation was found during statistical graph + text encoding, but the activation is weaker than statistical graph encoding. We also found that the thalamus was not activated during text encoding. Statistical graph and statistical graph + text have common characteristics, during encoding stage, they all activated the thalamus (Fig. 2), the result suggest that the thalamus is sensitive to statistical graph characteristics. Because text has no statistical graph’s characteristics, the thalamus was not activated during encoding text. It is further evidence that the thalamus is more sensitive to statistical graph than text, the function of the thalamus is separated the semantic information from statistical graph information.

Figure 1. The left and right thalamus were activated when graph encoding (reading).

Figure 2. The left and right thalamus were activated when graph + text encoding (reading).

4. Discussion

The aim of this study was to investigate the function of the thalamus during encoding three different information presentation forms: T, SG and SGT. We scanned 36 subjects with fMRI using event-related design during encoding stage, the result show that the thalamus was highly activated during SG and SGT encoding, and no activation was found during text encoding. This result suggests that the thalamus have been implicated in statistical graph processing, it is more sensitive to statistical graph than text. Also the result show that the activation of statistical graph was greater than statistical graph + text, the result suggest that the function of thalamus was separated the semantic information from statistical graph information.
The thalamus was consistently activated during statistical graph + text and statistical graph encoding, however, the text didn’t evoke the activation of thalamus. This suggests that the thalamus is mainly involved in encoding and representing of forms, irrelevant to the information content.

In the three forms of information representation, SG and SGT contain statistical graph’s characteristic, which convert information by processing the statistical graph characteristic. However, text is the verbal description, has no spatial characteristics, which convert information by verbal description. A large number of studies suggest that the thalamus involved in spatial processing, especially lesions study. The thalamus defects may lead to the inability of many tasks together with a spatial component [17, 19, 20-22]. In order to ensure that thalamus functions are working efficiently It is preferable to do examinations such as spatial learning, while for the memory functions is preferable to do the radial arm maze task [17, 23, 24] which is responsible for the consistent test and examination of the hippocampal lesions on spatial learning and memory.

Remarkably, in some studies were suggested that the thalamus and the hippocampus have a strong correlation [2]. Although the hippocampal defect may lead to dysfunction in some tasks [25], because it wasn’t capable to keep the spatial memory in the water maze, also ATN lesions wasn’t capable to keep spare preoperatively trained spatial memory in this task [21], as a conclusion, if thalamus lesions deficits occur, will lead to deficits of spatial memory.

In our study, we designed the experimental materials as three type tasks—SG, T and the combination of SG and T, both of SG and SGT contain spatial information, whereas the written text have no spatial information. Many researches had shown that’s thalamus has an important role in spatial processing, and sensitive to spatial characteristic, then it was activated during encoding statistical graph and statistical graph + text, which have spatial characteristic. Thus, we considered that, the thalamus play a more important role in processing statistical graph-related information than text-related.

Previous study indicated that left thalamus implicated with verbal processing, and right thalamus implicated with non-verbal [26]. In our study, both statistical graph and statistical graph + text activated the bilateral thalamus during the encoding stage, it means bilateral thalamus involved in processing of non-verbal information. The activation of thalamus was not found during processing text, it means verbal information was not evoking the activation of thalamus. One possible explanation for this result is that left and right thalamus as a whole, they closed related. Also it is not feasible to investigate the left or right thalamus alone.

In summary, our findings indicated that the thalamus has been implicated in statistical graph processing, which is more sensitive to the statistical graph-related information than text-related, and separated the semantic information from statistical graph information.

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