

Subsequent recall related theta episodes observed in an object-place memory task: Evidence for theta phase coding theory

Naoyuki Sato, Yoko Yamaguchi

Lab. for Dynamics of Emergent Intelligence, RIKEN Brain Science Institute, Saitama, Japan

Objective: Object-place association memory is known to be critically managed by the hippocampus, while its neural mechanism is little known. Sato and Yamaguchi (2005) proposed a computational model for object-place memory, where theta rhythm in the cortico-hippocampal system enables instantaneous and integrative memory formation of complicated sets of objects and scenes during eye saccade sequences. This theory predicts that activation of theta rhythm in the brain during object-place memory encoding is followed by correct memory recall. In the present study, we experimentally investigated the relationship between scalp EEG in the object-place association memory task with voluntary saccadic movements.

Methods: 58-ch scalp EEGs, 5-ch EOGs and left and right eye movements were recorded from 12 subjects. Each subject performed 36 object-place association tasks. Subjects were instructed to remember the object and its locations of each frame. One frame includes a set of familiar 4 objects is presented with duration of 8 sec. After subsequent 10sec eye camera calibration, the subjects were asked to reconstruct the arrangement of objects in the computer display by using a mouse. After eye movement artifact removal by RAAA method (Croft & Barry, 2000), frequency analyses were done by using wavelet transformation.

Results & Discussion: Analyses of scalp EEGs indicated that the oscillation episodes in theta range are significantly correlated with correct memory recall. The correlation is the highest in the medial frontal and left fronto-central areas (maximum at Fc5), while correlation of EOGs is not significant in the theta range. Thus, we successfully caught brain activities in theta range distributing over multiple areas. These results suggest theta synchronization among task-relevant cortical regions in agreement with the computational model of theta phase coding.

Conclusions: The theta episode density of scalp EEG is correlated with the memory performance of object-place association tasks. It supports the computational theory of theta phase coding on the memory encoding of object-place associations.

References: Sato, N. and Yamaguchi, Y. (2005). On-line formation of a hierarchical cognitive map for object-place association by theta phase coding, *Hippocampus*, 15, 963-978.

Croft, R.J., Barry, R. J. (2000). Removal of ocular artifact from EEG: a review, *Neurophysical Clin* 30:5-19.

Figure: An example of EEG and eye position records and the result of group analysis. Left) Top: horizontal and vertical eye fixation positions; Upper middle: Raw EEG (Fz) and eye movement artifact corrected EEG (Fz); Lower middle: time-frequency energy at Fz with wavelet transformation; Bottom: oscillation episodes at Fz during 8sec encoding. Right) Significant theta episodes at 7.5Hz increase for subsequent memory recall obtained for all subjects.

