Original Article ICNSJ

# Semantic Encoding in Mild Cognitive Impairment: A Preliminary ERP Study

**Michael Kuo**

*School of Medical and Health Sciences, Tung Wah College, Hong Kong*

## ABSTRACT

**Background:** This study examines semantic encoding in mild cognitive impairment (MCI) using the event-related potential (ERP) technique. Subsequent memory effect (SME) is used as an index of successful memory encoding. Typically, SMEs are positive at P550 and late positive component (LPC) time windows.

**Methods:** Ten MCI participants were recruited to complete the ERP experiment. A study and recognition paradigm was employed. Participants determined whether the item referred to by the Chinese character was able to produce sound at study phase and whether the Chinese character was studied at recognition phase while having their electroencephalograms recorded.

**Results:** Behaviourally, correct percentage at study was 81% and reaction time was 998.5±325.5. Correct percentage at recognition was 61% (d prime=0.87±0.7). Significant SMEs were not identified in P550 and LPC windows.

**Conclusion:** The behavioural and ERP results showed extensive cerebral deficits in MCI when performing semantic encoding. These deficits may be associated with assessing semantic memory and binding new information with long-term memory store.

**Keywords:** Event-related potentials; subsequent memory effect; mild cognitive impairment

ICNSJ 2017; 4 (2) :51-56 www.journals.sbmu.ac.ir/neuroscience

**Correspondence to:** Michael Kuo, School of Medical and Health Sciences, Tung Wah College, Hong Kong; Tel: +852-34686656; E-Mail: michaelkuo@twc.edu.hk

**Received:** March 30, 2017 **Accepted:** April 23, 2017

## INTRODUCTION

Mild cognitive impairment (MCI) has been thought as an intermediate stage between normal aging and mild dementia. People with MCI can be of amnestic, memory deficient, type or have deficits in domains other than memory [1]. However, the amnestic type has received the most attention. Memory processes typically include encoding, storage and retrieval stages. People with MCI demonstrate deficits in both encoding and retrieval processes, while encoding deficits appeared to contribute to more of the memory problems they experience [2]. They have difficulties with semantic type of encoding particularly [3].

Subsequent memory effect (SME) has been used as an index of successful memory encoding in event-related potential (ERP) investigations e.g., [4]. Normally, in young adults the effect is positive and largest in the frontal cerebral regions at P550 and late positive complex (LPC) time windows [5]. Specific to semantic encoding, P550 indexes access to semantic memory and memory updates and LPC indexes the binding process of new information and information stored in the long-term memory [4, 6].

This is the first study examining semantic encoding processes in MCI using the ERP technique with a subsequent memory design. The aim of this study is to investigate whether people with MCI may produce robust SMEs at P550 and LPC windows and may engage typical encoding processes while remembering information semantically. If people with MCI were to engage in similar processes, SME would be positive in

P550 and/or LPC windows and show similar distribution. If robust SMEs cannot be identified, this would indicate deficits in cognitive processes in these time windows.

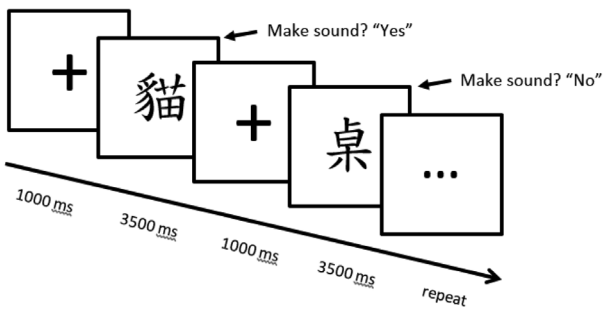
## MATERIALS AND METHODS

### Participants

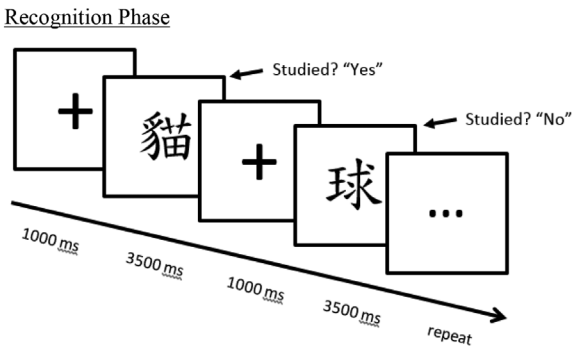
Ten people with MCI participated in this study. They had a mean age of 72.9 ± 3.8 years and an average education of 8.8 ± 5.0 years. All of them were age greater than 60, right-handed, native Chinese speakers, and with normal or corrected-to-normal vision. They had ae diagnosis of MCI—based on the research diagnostic criteria of Gauthier, Reisberg, Zaudig, Petersen, Ritchie, Broich (7)—by a medical doctor. The study was approved by the ethics committee of the school and hospital authorities. Informed consent was obtained from all participants.

### Task design and procedure

The materials and paradigm used were adapted from Kuo (4). There were two randomized study blocks (40 trials each) and two randomized recognition blocks (67 trials each). The timing of each study and recognition trial is shown in Figure 1. In the study phase, participants were asked to accurately judge whether the item referred to by the Chinese character was able to produce sound. In the recognition phase, the participants determined whether the Chinese character was one that had been studied in the study phase. They responded to the trials using a response controller. They were prompted to avoid unnecessary eye blinking and body movements to lessen movement-related artifacts during the experimentation.




*Note: 貓 means cat; 桌 means desk*




*Note: 貓 means cat; 球 means ball*

**Figure 1.** Schematic view of 2 trials in study and recognition phases.

### Electroencephalogram

Electroencephalograms (EEGs) were gathered from 128 scalp sites using the SynAmps2 amplifier, Quikcap system, and Acquire 4.3 software (Compumedics Neuroscan, Charlotte, North Carolina, USA). The impedance levels were kept below 10 kΩ in all the scalp locations. A left mastoid reference was used. Vertical and horizontal electrooculograms (EOGs) were gathered for later data processing. The EEGs and EOGs were sampled at 1,024 Hz with a low pass filter set at 200-Hz.

Data obtained at study phase were pre-processed using Edit 4.3 software (Compumedics Neuroscan, Charlotte, North Carolina, USA). Data were re-referenced to linked mastoids. Then, digital band pass filtering with zero-phase shift from 0.1 Hz to 30 Hz (24 dB/oct) was applied. Ocular artifacts were corrected afterwards. EEG data was cut into epochs from 200 ms prior to and 1200 ms post stimulus onset. All epochs were baseline corrected to the pre-stimulus interval. If there was a site in any epochs with an amplitude over ± 75 μV, the particular epoch was excluded from averaging. The epochs were sorted and averaged depending on whether they were correctly identified or missed.

### Data analyses

The SPSS version 17 (IBM, Chicago, Illinois, USA) was utilized to compute and analyze the behavioral (reaction time, accuracy, and d-prime) and ERP data. The d-prime (d') measure is used as it provides a more accurate indication of recognition memory performance.

For the ERP data, repeated-measure ANOVAs were conducted. The twelve sites selected were left anterior inferior F7, left anterior superior F3, right anterior superior F4, right anterior inferior F8, left central inferior T7, left central superior C3 right central superior C4, right central inferior T8, left posterior inferior P7, left posterior superior P3, right posterior superior P4, and right posterior inferior P8. The sites were subjected to 4-way comparisons among Response (2 levels; correctly identified or missed), Anterior–Central–Posterior site

(A/C/P) (3 levels; anterior or central or posterior), Hemispheric site (2 levels; left or right), and Inferior–Superior site (I/S) (2 levels; inferior or superior). For any significant interaction effect, post-hoc tests would follow. If there were any results that did not meet sphericity requirements, the Greenhouse-Geisser correction would be applied. Significance results were established at $P<0.05$. sLORETA (standardized low resolution brain electromagnetic tomography) procedure was employed to supplement investigation on the neural sources and networks underlying the SMEs [8].

## RESULTS

### Behavioural results

At study phase, participants identified 81.1 ± 5.5% of trials correctly with an average reaction time of 998.5 ± 325.5 ms. At recognition phase, participants identified 61 ± 22.7% of trials correctly. The calculated d' was 0.87±0.7.

### ERP results

Significant SME was not identified in both P550 and LPC intervals in this group of MCI participants. There were visible SMEs at F4, F8, T7 and T8. However, none of which reached a significant level. Figure 2 displays ERPs from the 12 sites analysed.

### sLORETA results

Images computed by the sLORETA method are displayed in Figure 3. In the P550 window, a number of regions were involved. The left anterior frontal temporal and the posterior parietal regions were the most prominent. In the LPC window, scattered regions were shown. The bilateral frontal temporal lobes displayed the strongest sources.

## DISCUSSION

The focus of this investigation was to examine whether people with MCI may produce robust SMEs at P550 and LPC windows and engage in similar encoding processes when learning new information semantically. Behavioural and ERP data were obtained in order to understand their encoding processes.

Behavioural data included reaction times and accuracies. A comparison of reaction times at encoding phase from this study and other similar studies indicated that cognitive processes may be slower in people with MCI [4, 9]. It has been suggested that the speed of cognitive processes may be associated with the number of activated nodes in the semantic memory [10]. Faster processing correlates with more activation and vice versa. Therefore, reaction time findings may suggest information to be learned has fewer opportunities of connecting with

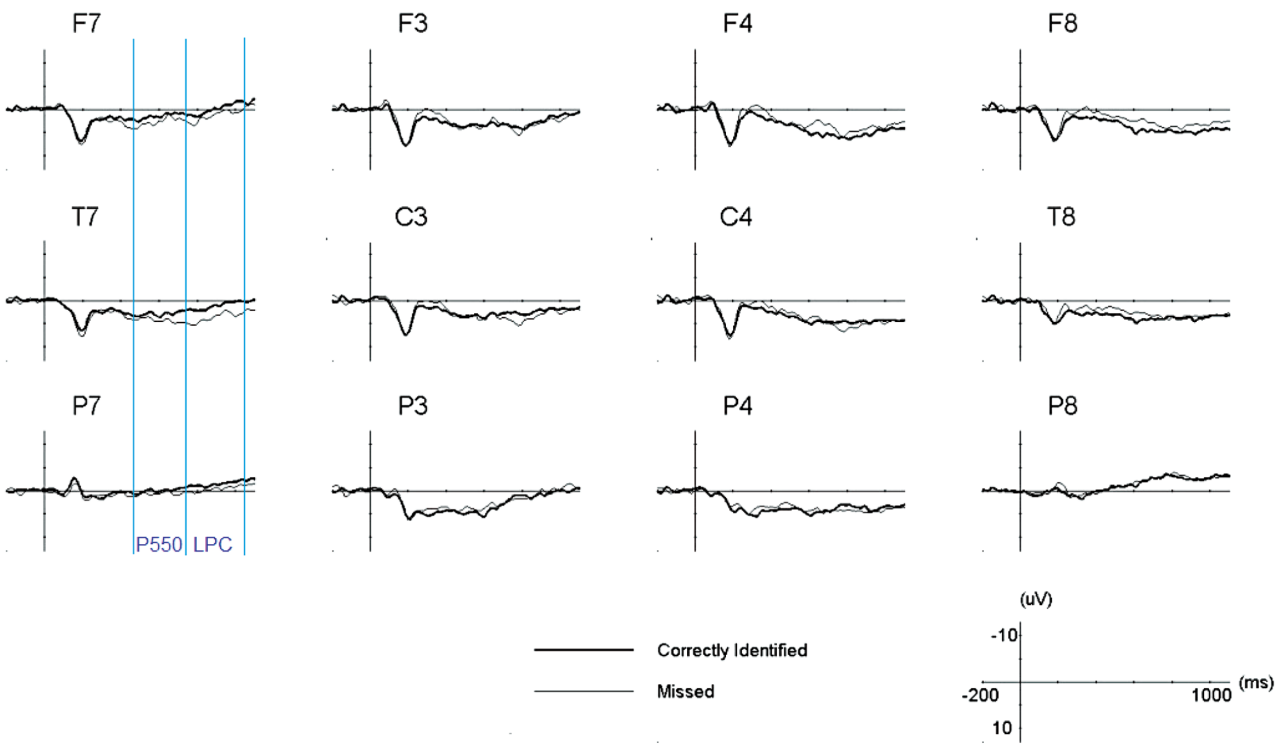
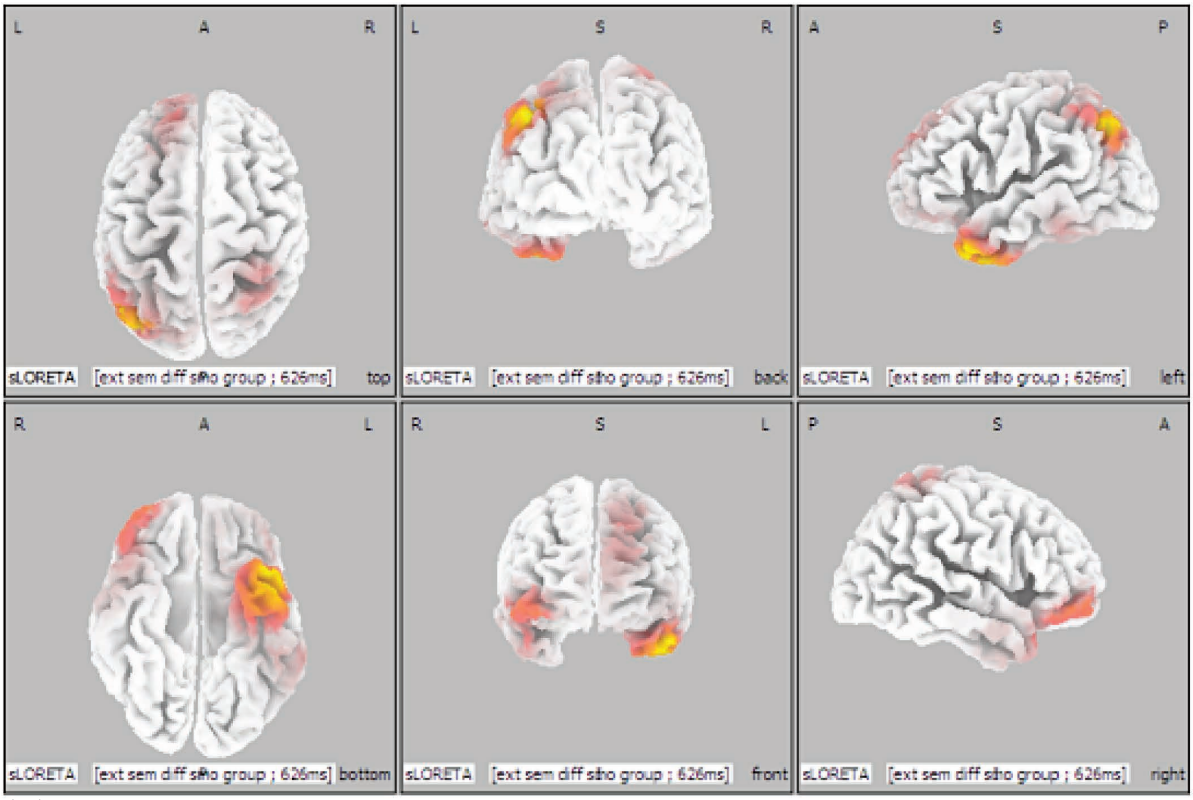
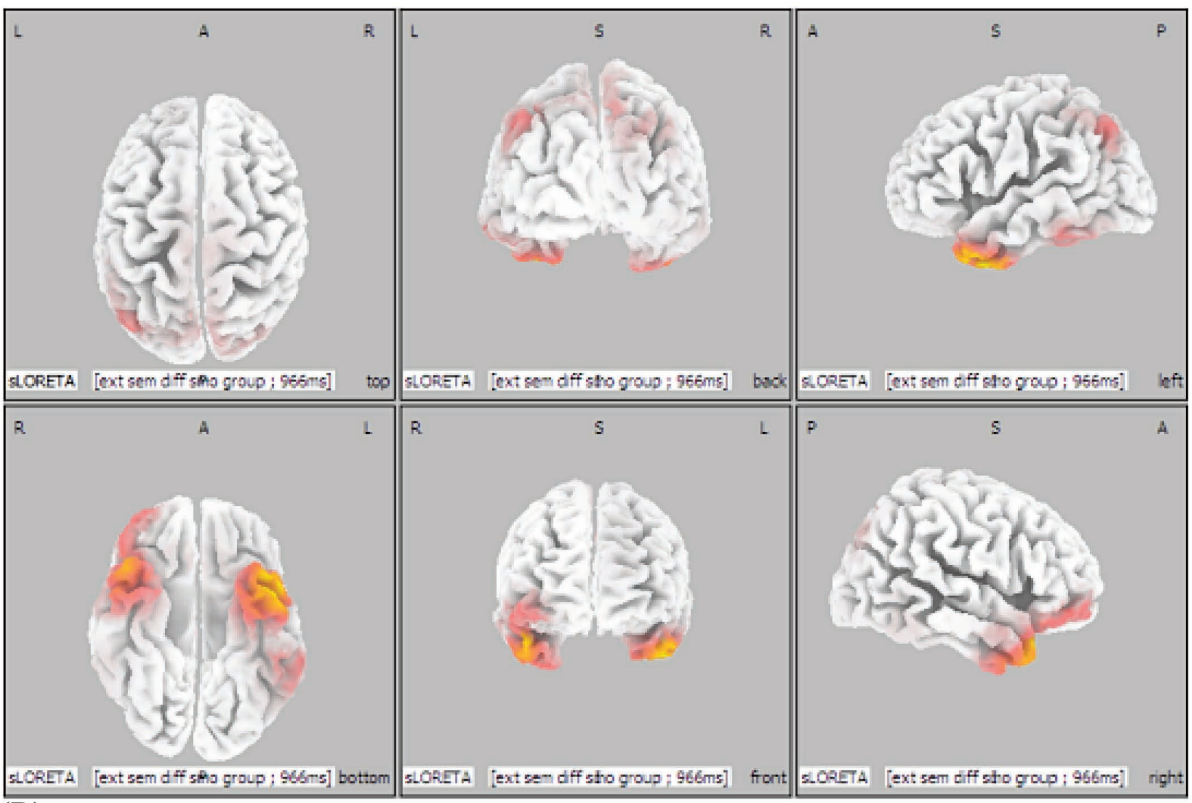



**Figure 2.** Grand average of the event-related potentials elicited by correctly identified and missed trials.




(A)




(B)

**Figure 3.** Outcome of the ERP sLORETA analyses at (A) P550 and (B) LPC

existing semantic knowledge in people with MCI. Even so, these MCI participants completed the encoding task in an accurate fashion.

ERP results indicated that robust SMEs at P550 and LPC were not significantly revealed. In other words, trials correctly identified and missed were not differentiated under semantic encoding in this group of MCI participants. SMEs at these time windows were normally reliably identified in healthy adults [5]. However, it has been shown that results can vary in older adults [4]. Therefore, these results indicated that people with MCI may have problems enriching new information with semantic memory. Specifically, they might have difficulties accessing semantic memory and updating working memory as these processes are what P550 and LPC index [5, 11, 12]. The undifferentiated SME at LPC might also suggest a problem of binding. Weyerts, Tendolkar (12) studied SMEs at LPC. The encoding conditions required their participants to produce semantic associations among two words (also known as associative encoding where binding happens between two closely related concepts) or to remember the two words shown separately (non-associative encoding). Only in the associative encoding condition a significantly SME was found at LPC window. Their investigation suggested that binding concepts together may be a vital process indexed by SME at LPC time windows. Although in the present experiment associated encoding was not overtly required, the presence or absence of consistent SME at LPC should nonetheless indicate whether such binding process had taken place. As people with MCI did not show differentiated ERPs, the results suggested that they may have deficits forming the associations (binding) needed for effective encoding. sLORETA results also confirmed their difficulties with semantic encoding as the pattern seemed to astray from those associated typically [13].

These results might have clinical implications. Some researcher have examined the effects of memory training and memory performance in the context of MCI [14-17]. A few of these mnemonic techniques are categorisation, method of loci, mental imagery, and semantic association. Memory training was associated with increased performance in subjective measures (e.g., memory appraisal) [15, 16] and objective measures (e.g., immediate recall, delayed recall) [14, 17]. As studies on memory training usually include several techniques, it is not possible to know their relative contributions. However, based on the results of the present study, it might be suggested that future investigations on memory training in MCI may emphasize non-semantic techniques (e.g., mental imagery). Future clinical studies might consider separating strategies into different categories such as perceptual-, location- or association-based strategies and examine their associations with memory performance in the people with MCI.

## CONCLUSION

This is a preliminary study with a relatively small sample size. As MCI population is anticipated to demonstration more within-group variations, future studies should be conducted with a larger sample. In addition, inclusion of other encoding conditions would allow comparisons and understanding why certain strategies could be more effective in MCI.

## ACKNOWLEDGEMENTS

The work was supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (Project No. PolyU 5620/07M) awarded to Dr. K.P.Y. Liu. The author wishes to thank Dr. K.H. Ting for his technical support.

## REFERENCES

1. Petersen RC. Mild cognitive impairment: Aging to Alzheimer's disease. Oxford: Oxford University Press; 2003.
2. Clément F, Belleville S, Mellah S. Functional neuroanatomy of the encoding and retrieval processes of verbal episodic memory in MCI. Cortex. 2010;46:1005-15.
3. Hudon C, Villeneuve S, Belleville S. The effect of semantic orientation at encoding on free-recall performance in amnestic mild cognitive impairment and probable Alzheimer's disease. J Clin Exp Neuropsychol. 2011;33:631-8.
4. Kuo MCC. Intentional Encoding in Elderly Adults: An Event-Related Potential Study. Archives of Neuroscience. [Research Article]. 2016:e39145.
5. Cansino S, Trejo-Morales P, Hernández-Ramos E. Age-related changes in neural activity during source memory encoding in young, middle-aged and elderly adults. Neuropsychologia. 2010;48:2537-49.
6. Wagner AD, Koutstaal W, Schacter DL. When encoding yields remembering: Insights from event-related neuroimaging. Philos Trans R Soc Lond B Biol Sci. 1999;354:1307-24.
7. Gauthier S, Reisberg B, Zaudig M, Petersen R, Ritchie K, Broich K, et al. Mild cognitive impairment. Lancet. 2006;367:1262-70.
8. Pascual-Marqui RD. Standardized low-resolution brain electromagnetic tomography (sLORETA): technical details. Methods Find Exp Clin Pharmacol. 2002;24:5-12 Suppl D.
9. van Deursen JA, Vuurman EF, Smits LL, Verhey FR, Riedel WJ. Response speed, contingent negative variation and P300 in Alzheimer's disease and MCI. Brain Cogn. 2009;69:592-9.

10. Salthouse TA. Initiating the formalization of theories of cognitive aging. Psychol Aging. 1988;3:3-16.
11. Mangels JA, Picton TW, Craik FIM. Attention and successful episodic encoding: An event-related potential study. Cognitive Brain Research. 2001;11:77-95.
12. Weyerts H, Tendolkar I, Smid HG, Heinze HJ. ERPs to encoding and recognition in two different inter-item association tasks. Neuroreport. 1997;8:1583-8.
13. Visser M, Jefferies E, Lambon Ralph MA. Semantic processing in the anterior temporal lobes: a meta-analysis of the functional neuroimaging literature. J Cogn Neurosci. 2010;22:1083-94.
14. Belleville S, Gilbert B, Fontaine F, Gagnon L, Ménard E, Gauthier S. Improvement of episodic memory in persons with mild cognitive impairment and healthy older adults: Evidence from a cognitive intervention program. Dement Geriatr Cogn Disord. 2006;22:486-99.
15. Rapp S, Brenes G, Marsh AP. Memory enhancement training for older adults with mild cogntive impairment: a preliminary study. Aging Ment Health. 2002;6:5-11.
16. Troyer A, Murphy K, Anderson N, Moscovitch M, Craik FI. Changing everyday memory behaviour in amnestic mild cognitive impairment: A randomised controlled trial. Neuropsychol Rehabil. 2008;18:65-88.
17. Wenisch E, Cantegreil-Kallen I, De Rotrou J, Garrigue P, Moulin F, Batouche F, et al. Cognitive stimulation intervention for elders with mild cognitive impairment compared with normal aged subjects: preliminary results. Aging Clin Exp Res. 2007;19:316-22.