Article ID:1002 - 1175(2004)01-0135-05

EXCERPT OF DISSERTATION

Priming for New Associations and its Brain Mechanisms *

YANG Jiong-Jiong [1,2] GUAN Lin-Chu [1]
KUANG Pei-Zi [1] WENG Xu-Chu [1]

(1 *Institute of Psychology, Chinese Academy of Sciences, Beijing* 100101, *China*;
2 *Department of Psychology, Peking University, Beijing* 100871, *China*)

(Received 17 January 2003)

Abstract Priming for new associations, also called associative priming, refers to the implicit memory for newly formed associations between different stimuli or the features. By now, there are still many unsolved issues on associative priming. This dissertation used cognitive neuroscience approach that combines the study of cognitive psychology, near-infrared spectroscopy (NIRS) and neuropsychology to investigate associative priming effects and its brain mechanisms systematically. The priming tasks used in this dissertation were process dissociation paradigm, perceptual identification task and speeded naming task. The experiments on normal subjects showed both level of processing and unitization affected associative priming effects, which was different from other kinds of implicit memory (such as item priming, supported by perceptual representation system). However, when the associative strength was strong enough, subjects could manifest associative priming effects even under shallow encoding conditions. NIRS study showed the activation of both sides of prefrontal lobe under deep encoding conditions was stronger than under shallow condition when subjects encoded unrelated word pairs. It suggested prefrontal lobe participate in memory for new associations. Furthermore, medial temporal lobe (MTL) and frontal lobe lesioned patients were tested using methods of perceptual identification task and speeded naming task. Both brain regions participated in associative priming. MTL mediated unitization between unrelated items. Frontal lobe contributed to priming for new associations by elaborative processing, inhibiting irrelevant information and selective attending to tasks. In addition, normal subjects needed to be aware of the relationship between study and test to form associative priming and densely memory deficit patients could not form memory for new associations. In conclusion, this dissertation demonstrated that associative priming needs the interaction between perceptual representation system and other memory systems. Both MTL and frontal lobe played important roles in priming for new associations, but with different mechanisms; and there were some relations between associative priming and conscious retrieval processing.

Key words priming, new associations, memory, medial temporal lobe, frontal lobe
CLC B842

Priming is an important technique for assessing implicit memory that does not require conscious retrieval

* supported by Foundation for the Author of National Excellent Doctoral Dissertation of China (200207)

processes[1,2]. There are two major types of priming effects: item priming, and priming for new associations, also called associative priming. Item priming is hypothesized to reflect the operation of perceptual representation systems that are independent of episodic or declarative memory system. In contrast, associative priming should reflect the formation of a new association, which has no prior existence in the memory system and is encountered for the first time during a study episode. To form new associations, subjects must integrate individual items or components, by processing the co-occurrence and/or relations between them. In the test session, memory for the new association can facilitate the retrieval of other information. For example, in the stem completion test, after learning some unrelated word pairs (e.g. *window - reason*, *apple - kite*, *fish - nurse*), subjects are asked to complete the stem of the second word of old pairs (*window - rea--*), recombined pairs (*apple - nur--*) and new pairs (*bottle - stu--*) with the first words that come to mind. If the proportion of completions of the old pairs is higher than that of the recombined ones, the difference of them is regarded as an effect of priming for new associations. Superior performance for word completion within recombined pairs relative to new pairs is regarded as a single word, or item priming, effect. The common paradigms for testing priming for new associations include stem completion, speeded naming, lexical decision and perceptual identification[2].

There are still many unsolved issues on priming for new associations[3\~7]. The central debate issues are whether perceptual representation systems can support priming for new associations independently; whether there is relation between associative priming and conscious retrieval; and what are the neurals of associative priming. For example, whether the medial temporal lobe plays a role in associative priming, and whether other brain regions mediate in associative priming. A series of experiments were done to explore the cognitive mechanisms and the neural basis of priming for new associations, using the cognitive neuroscience approach that combines the study of cognitive psychology, near-infrared spectroscopy and neuropsychology.

Part 1, which was aimed at the cognitive mechanisms of associative priming, included three experiments. These experiments explored whether perceptual representation systems could support priming for new associations independently, by studying the effects of the level of processing and unitization on forming memory for new associations; and explored whether there is some relation between associative priming and conscious retrieval, by applying process dissociation paradigm and analyzing the awareness questionnaires. In experiment 1, subjects studied unrelated word pairs of Chinese character under deep or shallow conditions, and then performed the inclusion and exclusion tasks. The process dissociation procedure was applied to investigate the contribution of automatic and consciously controlled processes to priming for new associations. The results showed that only under elaborative condition, did subjects complete more correct stems of old pairs than that of repaired ones, and both automatic and consciously controlled processes contributed to associative priming. Experiment 2 used perceptual identification task to make further exploration of effects of level of processing on priming for new associations. Effects of unitization, or associative strength were also explored, with concrete and abstract word pairs as within subject variable. After subjects studied the word pairs under deep or shallow encoding conditions, the different word pairs (old pairs, recombined pairs and new pairs) were presented at brief exposure threshold duration. Subjects were asked to identify the word pairs as fast as possible with no error. Finally subjects performed the recognition test, the corresponding explicit memory-test, and filled in the awareness questionnaire. Consistent with experiment 1, the results showed that only in elaborative level was there associative priming effects, with old pairs more identified than the recombined ones. Furthermore, unitization affected associative priming as well, for the concrete pairs could form priming

for new associations even under shallow encoding conditions, thus produced dissociation between implicit and explicit memory. That is, subjects had normal associative priming under shallow condition, but their explicit recognition performance was lower than that under deep condition [4]. Experiment 3 used speeded naming paradigm to further examine the effects of level of processing and unitization with colored abstract words as material, and to compare perceptual priming and associative priming. The results showed level of processing had no effects on associative priming between color and abstract words, either using color naming (associative priming task) or word naming (perceptual priming task). But the performance of recognition was better under deep condition than shallow condition [5]. It further showed when the degree of unitization was strong enough, associative priming could be formed even under shallow encoding condition, and inferred the similarities between perceptual priming and associative priming.

Taken together, **the results of part 1** showed that there was interaction between level of processing and unitization. Semantic encoding was one of the conditions for priming for new associations, but unitization played a crucial role in it. When the degree of unitization was stronger, deep processing was not necessary. Therefore, although perceptual representation system could support the perceptual priming alone, it could not support associative priming independently. Associative priming may need the interaction of perceptual representation system and other memory systems. In addition, the awareness questionnaires used in experiment 2 and 3 were analyzed, and showed that when doing perceptual identification and speeded naming tasks, most of subjects were aware of the relations between study and test, but they did not consciously recollect the studied items. The result of experiment 1 also showed the automatic controlled process mediated in associative priming, thus suggested the involuntary conscious awareness is one of the features of associative priming and there exist some relations between associative priming and conscious awareness.

The aim of part 2 and part 3 was to explore the brain mechanisms of priming for new associations. Part 2 explored the role of the prefrontal cortex during memory encoding process. Forty-eight subjects studied unrelated pairs of Chinese characters that were visually presented under both shallow and deep encoding conditions. The regional blood volume changes related to performance of the cognitive tasks were measured using functional NIRS equipment that was a continuous optical imager [6]. The results showed that the activation of bilateral prefrontal regions was stronger under deep condition than shallow condition and that areas comparable to the dorsolateral prefrontal cortex showed greater blood volume changes, particularly in the left hemisphere [7-10]. This is the first study using NIRS imaging to investigate the role of the prefrontal cortex in deep encoding compared with shallow encoding. It suggested that the prefrontal cortex participates in the elaborative processing of unrelated word pairs and is the neural basis of memory for new associations.

In **Part 3**, the MTL lesioned patients and frontal lobe lesioned patients were examined to explore the brain mechanisms of associative priming. There were 18 MTL patients, 25 frontal lobe patients, and 18 age, gender, and education-matched control subjects. Each subject did the neuropsychological tasks to assess their cognitive deficits, including Mini Mental State Examination, Wechsler Memory Scale--Revised, Wisconsin Card Sorting Test and word fluency task. The assessments demonstrated that MTL patients had lower performance in memory scale, and the main deficits of frontal lobe lesioned patients ware the abstract thinking and inhibiting irrelevant information [11]. Both patient groups had lower word fluency scores.

The patients were further divided into mild or severe memory deficit subgroups, with their memory quotient was 80 as the cut-off. Each patient did the perceptual identification task, color naming and word naming tasks in counterbalanced order. In contrast to the control subjects, the MTL lesioned patients failed to

show superior identification of the old pairs relative to the recombined pairs , and failed to show priming for recently experienced new associations between words and colors. Recognition memory by these patients was severely impaired , but their item priming was normal. The results recorded an absence of priming for new associations , in which the nature of the stimuli was considerably diffe-rent [1,12]. The results indicate a critical role for MTL in forming associations between unrelated items , whether the association concerns two separate items or two aspects of a single stimulus.

As for the frontal lesioned patients , their associative priming effect was lower than that of the control subjects with unrelated word pairs and colored words as material too. The recognition performance of the patients with mild memory deficit was similar to that of the control subjects , but their associative priming was lower than that of the normal controls [13]. The phenomenon of intact recognition but impaired associative priming manifested the dissociation between implicit memory and explicit memory. The correlation between associative priming and preservative response , preservative errors , conceptual level responses and word fluency test was significant in patient group. It indicated the mechanisms of the frontal lobe participating in associative priming were semantic processing , sorting , inhibition and word fluency. The results also showed the severely memory deficit patients could not form memory for new associations , which inferred the relation between associative priming and conscious retrieval.

Both MTL and frontal lobe mediated priming for new associations , but there was some difference in their mechanisms. Medial temporal lobe played a critical role in forming associations between unrelated items or stimuli. Maybe it is the neural basis of unitization. Experiment 3 in part 3 explored this hypothesis with 11 MTL lesioned patients as subjects. When the test did not require retrieving the relations between items to be formed , priming effects in MTL lesioned patients had no difference with the control group , but their recognition performance was still lower. With regard to the frontal lobe , the mechanisms were more abstract. Frontal lobe participated in elaborative processing , which is necessary for associative priming between the word pairs. In addition , the correlation analysis indicated that frontal lobe contributed to associative priming by inhibiting the irrelevant information , attending to the tasks , and establishing some effective strategies.

In conclusion , this study explored the central issues on priming for new associations and the neural basis on which the associative priming depends. The results demonstrated that perceptual representation system could not support priming for new associations alone. Associative priming may need the interaction of perceptual representation system and other memory system. There existed some relations between associative priming and conscious awareness ; the awareness of the relation between study and test may be one of the features of associative priming that different from perceptual priming. MTL played critical role in priming for new associations. Frontal lobe contributed to associative priming as well , by different mechanisms from MTL , such as semantic encoding , inhibition , attention and strategy using.

References

[1] Yang J , Weng X , Guan L , Kuang P , Zhang M , Sun W , Yu S , Patterson K. Involvement of the medial temporal lobe in priming for new associations. *Neuropsychologia* , 2003 ,41(7) :818 - 829

[2] Yang J , Weng X , Guan L , Kuang P. Progress in study of brain mechanisms of associative priming. *Progress in Physiological Science*(**生理科学进展**) , 1999 , 30 (3) : 263 - 265

[3] Yang J , Guan L , Weng X , Kuang P. Current status of priming effects and its brain mechanisms. *Psychological Science* (**心理科学**) , 1999 , 22 (3) : 250 - 253

[4] Yang J, Weng X, Guan L, Kuang P. Effects of level of processing and word type on forming memory for new associations. *Acta Psychological Sinica* (心理学报), 1999, 31: 257 - 265

[5] Yang J, Weng X, Guan L, Kuang P. Associative priming and perceptual priming effects. *Acta Psychological Sinica* (心理学报), 2001, 33: 111 - 116

[6] Yang J, Luo Q. Near infrared spectroscopy and its application in neuroscience. *Progress in Physiological Science* (生理科学进展), 2002, 33 (3): 265 - 268

[7] Yang J, Zeng S, Luo Q, Guan L, Kuang P, Gong H. Role of left prefrontal lobe in encoding unrelated word pairs-A study using near-infrared spectroscopy. *International Symposiums of Industrial Laser and Biomedical Optics*. SPIE, 1999, 3863: 124 - 128

[8] Yang J, Zeng S, Luo Q, Guan L, Kuang P, Gong H, Chance B. Left prefrontal lobe contributed to semantic encoding of unrelated word pairs: A near-infrared spectroscopy study. *Acta Psychological Sinica* (心理学报), 2001, 33: 48 - 54

[9] Zeng S, Yang J, Gong H, Chance B. Observing prefrontal activation during semantic encoding with infrared diffusive imaging. *Acta Photonica Sinica* (光子学报), 2000, 29 (1): 1 - 4

[10] Li P, Gong H, Yang J, Zeng S. Left prefrontal cortex activation during semantic encoding accessed with functional near infrared imaging. *Space Medicine and Medical Engineering* (航天医学与医学工程), 2000, 13 (2): 79 - 83

[11] Yang J, Weng X. Role of prefrontal lobe in memory: studies in functional brain imaging. *Journal of Developments in Psychology* (心理学动态), 1999, 7 (2): 13 - 18

[12] Yang J, Weng X, Guan L, Kuang P. Brain mechanisms of priming for new associations. *International Journal of Psychology*, Abstract for XXVII International Congress of Psychology. Sweden。2000。169

[13] Yang J, Weng X, Guan L, Kuang P, Zhang M, Sun W, Yu S. Frontal lobe participated in priming for new associations: an evidence from frontal lesioned patients. *Acta Psychological Sinica* (心理学报), 2002, 34 (1): 3 - 42

联想启动效应及其脑机制研究

杨炯炯[1,2]　管林初[1]　匡培梓[1]　翁旭初[1]

(1 中国科学院心理研究所,北京 100101;2 北京大学心理学系, 北京 100871)

摘　要　联想启动效应,又称作对新异联系的启动效应,是指对新近形成的联系的内隐记忆。目前关于联想启动效应的研究争论颇多。研究中采用认知实验、脑成像技术和多种神经心理学测验方法相结合的认知神经科学途径,对联想启动的认知机制和脑机制进行了探讨。测定联想启动的方法包括过程分离、知觉辨认和快速命名等。对正常大学生的研究结果表明,加工水平和联结共同作用影响联想启动,这与知觉表征系统所支持的项目启动等其他内隐记忆有所不同。当项目间的联系足够强时,被试可以在浅加工条件下形成联想启动。这提示,知觉表征系统单独并不能支持联想启动,还需要其他记忆系统的参与。采用近红外光学成像的研究显示,左右前额叶均参与非相关词对的语义编码过程,与新异联系的形成密切相关。对内侧颞叶和额叶损伤病人的知觉辨认和快速命名测查发现,这两个脑区均参与了联想启动。其中,内侧颞叶参与了联想启动所必需的联结过程,额叶则与语义加工、抑制无关信息和选择性注意等有关。另外,正常被试形成联想启动需要意识到学习和测验的关系,重度记忆障碍的被试不能形成联想启动,提示联想启动需要有意识回忆的参与。总之,研究表明,联想启动需要知觉表征系统和其他记忆系统的共同作用,内侧颞叶和额叶均在联想启动中起重要作用,但它们的作用有所不同。在联想启动和有意识回忆之间存在一定关系。

关键词　启动效应,新异联系,记忆,内侧颞叶,额叶

杨炯炯:攻读博士学位期间,在国内一级学术刊物上发表了 13 篇论文,荣获 1999 年中国科学院地奥奖学金一等奖。2000 年获得一项国家自然科学青年基金项目资助。

导师管林初:研究员,主要从事生物心理学、药物对学习记忆的影响的研究;导师匡培梓:研究员,主要从事生物心理学、学习记忆方面的研究;导师翁旭初:研究员,主要从事认知神经科学,运动、语言和记忆的 fMRI 研究.