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Short-term Working Memory and Chunking in SLA*

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***Abstract*—After elaborating the definition of working memory, the relationship between short-term memory and working memory, chunking in SLA and the relationship between short-term memory and chunking, this paper proves the importance of chunking through the experiment: the students' capacity in fast reading, reading in depth, listening and cloze from experimental group was affected by vocabulary depth through learning the theory of chunking and states how to apply chunking to second language acquisition.**

***Index Terms*—chunking, short-term memory, working memory, SLA (second language acquisition)**

I. The Origin of Working Memory

The type of early memory Baddeley stated actually contains a specialized component of LTM but also has some characteristics of STM. This type of memory is named working memory, which is conceptualized as a system that temporarily stores and controls information as we carry out cognitive tasks. Baddeley and Hitch (1974) put forward the evolution of a single short-term memory into working memory.

Working memory can be defined as a type of workbench in which new and old information is constantly being changed, integrated, and changed. Working memory disputes the view that STM is only another "box" in the head – a simple station along the way to either being forgotten or transmitted on to LTM — in which information is not actively stored. It suggests that our working memory is coordinating with activity.

The idea of working memory also disputes the concept that the capacity of STM is restricted to about 7 items. Baddeley proposes that the span of memory is decided by the speed with which we practise information. Concerning verbal material, he assumed that we have an articulatory loop in which we can retain as much information as we can practice in an unchanging duration. Working memory holds a phonological loop that is a rehearsal circuit which retains inner speech for verbal comprehension. There is also a visuospatial scratchpad that is obliged to practise images and maintain them transiently. These processes are controlled by a central executive, which teams attentional activities and controls responses. The central executive behaves much like a supervisor who determines which issues need attention and which will be neglected.

II. The Relationship between Short-term and Working Memory

The study of short-term memory, the storage of small amounts of information over transient time intervals, constituted a main part of the development of cognitive psychology during the 1960s. The effort to form information-processing models of short-term memory (STM) resulted in some main arguments. Unluckily, solving these issues clearly proved beyond the ability of the methods available at the time, leading to a decrease of interest in STM during the 1970s, and afterwards even to a declaration of its death (Growder, 1982). Nevertheless, as the old idea of STM was losing support, it became integrated within a more complicated framework, working memory (WM), which assumed that the older idea of a unitary store be substituted by a multicomponent system that used storage as component of its function of helping complicated cognitive activities such as learning, understanding, and concluding (Baddeley & Hitch, 1974). Keen interest in WM went on to boost through the 1980s, though with little different focuses on different sides of the Atlantic. During the 1990s, the whole area has achieved a further boost from the development of functional imaging techniques, with the parts of working memory presenting a suitable level of complicatedness for the processing techniques of brain scanning. This development was helped by the very productive relationship between cognitive psychology and the neuropsychology of working memory, which offered hypotheses as to which areas of the brain might be most easily to be engaged in particular tasks, as well as concepts that help the relating of the neuroanatomy to a related cognitive framework.

The traditional concept of STM depicts a more or less passive temporary memory retention, the capacity of which is typically evaluated through the immediate serial recall of lists of information (e.g., Atkinson & Shiffrin, 1968). The concept of WM, as well as being chronologically newer, describes a more energetic system, concerned with the temporary retention and transformation of information to support cognitive activity (Baddeley & Hitch, 1974). Although STM and WM unequivocally have a intimate relationship, both referring to brief memory, it has been debated

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on both empirical and conceptual bases that there are nevertheless important differences to be made.

III. Chunking in SLA (Second Language Acquisition)

The term "chunking" was invented by George Miller in his classical review of short-term memory (Miller 1956). It is the development of everlasting sets of coherent connections in long-term retention and is the process that forms the attainment of automaticity and fluency in language. Newell (1990) reasons that it is the overarching principle of human cognition (Ellis, 1996):

A chunk is a unit of memory organization, formed by bringing together a set of already formed chunks in memory and welding them together into a larger unit. Chunking implies the ability to build up such structures recursively, this leading to a hierarchical organization of memory. Chunking appears to be a ubiquitous feature of human memory. Conceivably, it could form the basis for an equally ubiquitous law of practice. (p.7)

Its role in language acquisition is reexamined by McLanghlin (1987) and Schmidt (1992) (Ellis, 1996).

Melton made his conclusion on data about the learning of letter or digit sequences: The more stimuli are repeated in STM, the greater the LTM for these items and, in succession, the easier they are to repeat as sequences in STM. But the process is much more omnipresent: If we are concerned with the acquisition of form either as perceptual units or as motor programs for output, then the pervasive quantitative law, *the power law of practice*, applies (Anderson, 1982). The crucial feature in this relationship is not just that performance, typically time, increases with practice, but that the relationship is concerned with the power law in which the amount of improvement declines as a function of improving practice or frequency. Anderson (1982) demonstrated that this function is relevant to a variety of tasks, involving, for instance, cigar rolling, syllogistic reasoning, book writing, industrial production, reading inverted text, and lexical decision. As for language acquisition, Kirsner (1994) demonstrated that lexical recognition processes (for both speech perception and reading) and lexical production processes (articulation and writing) are controlled by the relationship $T=BN^{-\alpha}$, where T is some measure of latency of response and N is the number of trials of practice. Newell (1990; Newell & Rosenbloom, 1981) formally showed that the following three assumptions of chunking as a learning mechanism could result in the power law of practice: (a) People chunk at a changing rate: Every time they get more experience, they establish extra chunks; (b) performance on the task is faster, the more chunks that have been built that are linked to the task; (c) the structure of the environment hints that higher level chunks happen again more rarely (Ellis, 1996).

IV. The Relationship between STM and Chunking

That STM retains seven units no matter whether the type of data concerned seems contradictory. Evidently, a string of words holds greater information content than a string of letters. Nonetheless, by examining the amount of information recall (at least according to letters), it is evident that more information is remembered in the latter condition than in the former. Miller (1956b) provided an explanation as to how items are coded in STM. He assumed a model of memory in which seven units of information could be stored. Individual letters symbolized individual pieces of information, and, as such, each letter would occupy a slot. The letters that made up a word, nevertheless, were "chunked" into one word unit, so that each of these word units also took up one slot in STM. Thus the expanded capacity (in terms of numbers of letters) of STM was accomplished through the coding of letter sequences into word units. So, even though our brief memory capacity seems to be restricted to seven units of information, chunking (or coding single units into larger units) greatly increases our capacity. For Miller, this kind of linguistic recoding appeared to be "the very lifeblood of the thought process." At any rate, chunking is crucial because it provides an explanation of how so much information is dealt with through STM, which, if limited to seven units, would create a bottleneck in the information-processing sequence.

The ability of STM to manipulate a vast amount of information, then, is helped by our ability to chunk information. Nevertheless, chunking cannot happen until some information in LTM is stimulated. Our wide-ranging knowledge can put a structure on apparently unrelated material once a match happens between the incoming items and their LTM representation. The capacity of STM, then, may be restricted to seven units, but the density of information in a unit can change to a very great extent.

V. Research Methodology

A. Subjects

The participants in this study were 112 non-English majors placed into two classes, from Qingdao University of Science and Technology. 56 students were in controlled group; while 56 students were in experimental group. The subjects had nearly the same experience in English learning. They had had six years of English learning experience in the secondary school and were in the first term of their freshman period at the time when this study was conducted. They were all students of rubber. In addition, they used the same textbooks. Therefore, they shared the same environment and experience, and their ages were nearly the same, ranging from 18 to 21. In the second semester, 56 students from experimental group will be taught theory of working memory, short-term memory and chunking besides

being taught the textbooks while 56 students from control group were only taught the textbooks (Xu, 2009).

B. Instruments

1. Pretest

The listening material for the pretest was a listening model test from Public English Test System 3 (PETS-3). It contained 2 parts. They were all multiple-choice questions. (See Appendix 1) (Xu, 2009).

The pretest was a part of language proficiency test. Thus it was administered simultaneously by two teachers and the author herself in the language lab. Before the test began, the testers told the subjects in Chinese: "You are going to listen to the tape. The tape will be played once from the beginning to the end. Please listen to the tape and write down the answers on the answer sheet. The test will last 25 minutes." After the instruction, the testers handed out test papers to the subjects. When time was up, the testers required the subjects to stop at once and hand in their answer sheets (Xu, 2009).

According to the scores of the pretest, the 112 subjects were divided into 3 groups of high, medium and low listening proficiency levels. The high listening proficiency level, with scores from 80-90, contained 3 subjects. Scores from 60 to 79 were considered the medium listening proficiency level, including 63 subjects. The low listening proficiency level consisted of 46 subjects, the scores ranging from 30 to 59 (Xu, 2009).

2. Post-test Questionnaire

After pre-test, the testers distributed the questionnaires to the testees. The requirements were read aloud to the testees in Chinese as follows: "This questionnaire is to investigate whether the content of the test is familiar to you or not. As you may notice, on it are some multiple-choice questions. Please read them carefully and tick the best answer." (Xu, 2009).

The post-test questionnaire for the test (see Appendix 2) involved multiple-choice questions constructed to investigate whether the subjects had done the pretest listening comprehension test or not. If someone ticked A (Yes), or B (most of them), he/she was thought to have done the material before, while if he/she ticked C (few of them) or D (Never), he/she was thought to have not done the material before. The post-test questionnaire indicated that no one chose A, B and C for the pre-test—120 students ticked D, demonstrating that all the subjects were unfamiliar with the test (Xu, 2009).

3. Lectures on working memory, STM and chunking

In the first semester, 112 students used the same textbooks. They had the same lessons. In the second semester, 56 students from experimental group will be taught theory of working memory, short-term memory and chunking besides being taught the textbooks while 56 students from control group were only taught the textbooks. In the experimental group, the author lectured on the theory of working memory, STM and chunking; taught testees how to recognize chunks and how to memorize set phrases, proverbs, collocation, etc..

The theory of working memory, STM and chunking was also applied to listening comprehension and speaking. Thus, testees grasped how to chunk in their listening comprehension.

The testees were required to hand in their compositions after each unit by using comprehensible phrase, patterns, collocation as much as possible. At the same time, they were asked to recite much more proverbs related to the textbooks.

4. Two final examinations

The first semester and the second semester final examinations were analyzed. They included: vocabulary, cloze, fast reading, reading in depth and listening tests. The examination pattern is the same as College English Test Band 4(CET Band 4). All these tests were objective questions and were calculated by the computer.

Vocabulary test mainly examined the testees' depth of vocabulary knowledge (DVK). According to Levelt (1989) and Nation (1990), vocabulary's syntax and semantic characteristics are main contents of vocabulary depth.

C. Results

1. English proficiency prior to the experiment

All the statistical procedures were completed with the help of the statistical package for social sciences (SPSS), a package of computer programs for statistical purposes. The results were analyzed according to the students' first semester final examination, including fast reading, listening, reading in depth, cloze and vocabulary. The mean score for each part and mean scores of total scores are displayed in **Table 1**. From **Table 1**, we can see the mean scores of cloze and vocabulary from students in control group are little bit higher than students in experimental group while the mean scores of fast reading, listening, reading in depth and total scores from students in experimental group are higher than students in control group. The results from T-test show that the scores of students' each part and total scores reveal no significant difference from two groups (Sig.>.05). Therefore, we think that the students from two groups prior to the experiment are similar in English proficiency.

TABLE 1
MEAN SCORE, STANDARD DEVIATION AND T-VALUE

	Control Group n=56		Experimental Group n=56				
	Mean	SD	Mean	SD	t	df	Sig.(2-tailed)
fast reading	5.8393	1.17205	5.8571	1.35417	.075	110	.941
listening	9.3929	3.27347	9.5357	3.50565	-.223	110	.824
reading in depth	20.7143	4.86066	20.7143	5.31794	.000	110	1.000
cloze	6.0625	1.34185	5.8661	1.71488	.675	110	.501
vocabulary	8.3214	2.91146	8.1607	2.66135	.305	110	.761
total score	49.9732	10.06904	50.0446	10.03416	-.038	110	.970

2. Results after the experiment

After one semester's experiment, the results were analyzed according to the students' final examination in the second semester, including fast reading, listening, reading in depth, cloze and vocabulary. The mean score for each part and mean scores of total scores are displayed in **Table 2**. From Table 2, we can see that mean scores of fast reading, reading in depth, vocabulary, listening, cloze and total scores from students in experimental group are higher than students in control group. The results of T-test show that the students' scores reveal a significant difference from two groups (Sig.<.05), that is to say, the students from experimental group have stronger capacity in fast reading, reading in depth, vocabulary, listening and cloze than the students from control group.

TABLE 2
MEAN SCORE、STANDARD DEVIATION AND T-VALUE AFTER THE EXPERIMENT

	Control Group		Experimental Group				
	Mean	SD	Mean	SD	t	df	Sig.(2-tailed)
fast reading	4.9821	1.58104	5.8214	1.40269	-2.972	110	.004
listening	11.2857	3.88804	13.2500	3.50714	-2.807	110	.006
reading in depth	17.8571	4.29557	19.5357	4.39820	-2.043	110	.043
cloze	3.2768	1.81639	3.8750	1.23307	-2.039	110	.044
vocabulary	7.5268	2.34214	8.7143	1.92792	-2.929	110	.004
total score	44.9464	8.08572	51.1607	7.66759	-4.173	110	.000

3. Correlation Analyses

TABLE 3
CORRELATION ANALYSES FROM THE EXPERIMENTAL GROUP N=56

		fast reading	listening	reading in depth	cloze	vocabulary	total score
fast reading	Pearson Correlation	1					
	Sig.(2-tailed)						
listening	Pearson Correlation	.113	1				
	Sig.(2-tailed)	.408					
reading in depth	Pearson Correlation	.193	.220	1			
	Sig.(2-tailed)	.155	.104				
cloze	Pearson Correlation	.108	.226	-.122	1		
	Sig.(2-tailed)	.429	.094	.372			
vocabulary	Pearson Correlation	.307*	.359**	.351**	.285*	1	
	Sig.(2-tailed)	.021	.007	.008	.033		
total score	Pearson Correlation	.414**	.709**	.729**	.258	.631**	1
	Sig.(2-tailed)	.002	.000	.000	.054	.000	

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

From **Table 3**, it can be seen that vocabulary is positively correlated to fast reading, reading in depth, listening, cloze and total score respectively. They are p= 0.021; p= 0.007; p= 0.008; p=0.033; p= 0.000. Variables' sig values are all less than .05, which shows that the students' capacity in fast reading, reading in depth, listening and cloze from experimental group was affected by vocabulary depth through learning the theory of chunking.

VI. MAKING USE OF CHUNKING IN SKILL BUILDING

The idea of chunking is mainly due to the work of Miller (1956) who differentiated between bits and chunks of information. Chunking is the process of arranging and grouping bits of information into familiar units or chunks. The capability to chunk information helps an individual to memorize more and gives a means of using the information that is finally held in his or her memory. More importantly, chunking improves "the amount of information we can process" (Miller, 1956: 95). Miller also assumes that we recode information very often in an attempt to absorb new information with existing knowledge. Thus, the process of chunking also appears to function as a mechanism for emphasizing information. For example, as we learn new information, if it seems well known or if it fits into a current category, we

are likely to memorize and link the new information to the current category (Higham, 1997; Gobet & Simon, 1996b). This permits more powerful connections to be made by the learner. (Bodie, Graham D., & Powers, William G., & Fitch-Hauser, Margaret, 2006)

Chunking functions as both a triggering device and as a code-building device for our memory. The triggering aspect of chunks depends on the strength of a chunk or group of associative chunks. Since chunks are organized in a hierarchical style, the most memorable will be made up of information that is most connected to the individual effort to learn (Servan-Schreiber & Anderson, 1990). Code-building is often achieved through replication of chunks or relevant information that lets the participant to remember chunks for future use. As students establish a system of codes (i.e. chunks) patterns begin to occur with which they are able to associate with other chunks and finally develop larger and larger stores of information (Koch & Hoffmann, 2000). At last, students are capable of building skills that are more complicated than simple rules yet easy enough to be retained in memory improving skill in a given capacity. (Bodie, Graham D., & Powers, William G., & Fitch-Hauser, Margaret, 2006)

Another point that must be contained in any effective instructional effort is repetition. Just as our memories are arranged and retained in chunks, they are emphasized through repeated exposure to an ides, concept or expertise. In one aspect chunking offers a way for repetition to the extent that the chunks are developed as bits of information and put or combined into a chunk. This is especially obvious in observations of a variety of ritualistic behaviors, such as many compulsive behaviors (Graybiel, 1998). Although message production and reception are not ritualistic behaviors, it is obvious to everyone that we are concerned in these acts often enough (see Wolvin & Coakley, 1996) that much of the skills considered vital for communicative competence are carried out in chunks. As we learn more skills, we seem to establish cognitive and neural sequences that may help with the use of these expertise. (Bodie, Graham D., & Powers, William G., & Fitch-Hauser, Margaret, 2006)

APPENDIX 1. TAPE SCRIPTS FOR PRETEST

Listening Test

NAME_____ CLASS_____NO_____

Directions**:**

You will hear a selection of recorded materials and you must answer the questions that accompany them. There are two parts in this section, Part A and Part B..

Part A

You will hear 10 short dialogues. For each dialogue, there is one question and four possible answers. Choose the correct answer--A, B, C or D. You will have 15 seconds to answer the question and you will hear each dialogue ONLY ONCE.

1. Why can't the woman get the size she wants?
   [A] Because the white shirts are too long.
   [B] Because she wants a special style.
   [C] Because the size she wants is not available.
   [D] Because all the leather shoes are sold out.
2. What is the woman's reply?
   [A] She knows Professor Arnold has come.
   [B] She thinks Professor Arnold has checked in.
   [C] She is sure that Professor Arnold has arrived.
   [D] She doesn't know whether Professor Arnold arrived.
3. How much will the woman pay for the chairs?
   [A] $150 [B] $85 [C] $115 [D] $170
4. When does the conversation take place?
   [A] On Friday [B] On Thursday [C] On Tuesday [D] On Monday
5. Why is the man calling the campus newspaper office?
   [A] Because he wants to buy a walkman.
   [B] Because he wants to contribute an article to the newspaper.
   [C] Because he wants to advertise a sale.
   [D] Because he wants to buy a newspaper.
6. What did the woman say about the weather?
   [A] It was very cold.
   [B] It snowed in December.
   [C] It snowed all winter.
   [D] The temperature was below zero.
7. Where did the conversation take place?
   [A] In a shop [B] At the office
   [C] In a friend's home [D] In the hospital
8. What does the man think about Jane.

[A] She will quit her job.
[B] She will be sorry if she quits her job.
[C] She will not quit her job.
[d] She will not accept his present.

9. What is the man's profession?
[A] A waiter [B] A cook
[C] A salesman [D] A shop-assistant

10. What could be concluded from the conversation?
[A] Jim is a poor typist.
[B] Jim types better than David.
[C] David is a better typist.
[D] Jim is too busy to help.

Part B

You are going to hear four conversation or talk, before listening to each conversation or talk, you will have 5 seconds to read each of the questions which accompany it. After listening, you will have time to answer each question by choosing A, B, C or D. You will hear each conversation ONLY ONCE. Mark your answers in your test booklet.

Questions 11--13 are based on a conversation about robots.

11. What kind of robots is Paul going to discuss?
[A] The ones that walk and talk like human being
[B] The ones that are used in industry
[C] The ones that are built to resemble human beings
[D] The ones that are often shown in the movies

12. Which of the following is NOT important for robots to perform a task?
[A] A head shaped like a human being
[B] A computer brain
[C] Signals in the form of electrical impulses
[D] A claw

13. What is NOT the advantage of the new robots?
[A] They can perform different tasks.
[B] They are easy to reprogram.
[C] They increase productivity.
[D] They perform a single operation at a time.

Questions 14--17 are based on the following dialogue.

14. Where is the Bank of English created?
[A] At the University of Buckingham
[B] At the Oxford University
[C] At the Cambridge University
[D] At the University of Birmingham

15. How many words are there in the Bank of English?
[A] 120 million [B] 112 million [C] 7 000 [D] 20 million

16. Which of the following is NOT mentioned in the use of the Bank of English?
[A] The way ordinary people use English
[B] The way language is developing
[C] The way people communicate
[D] The way psychologists treat the mentally diseased people

17. What does Professor John Sinclair say about one of the findings coming out of studies?
[A] "Ex" and "former" are often associated with "lover".
[B] "Her lover" is more often used than "his lover".
[C] English language is used wittily and lively.
[D] Ordinary people use English language more frequently.

Questions 18--21 are based on a talk by Mary Raffety.

18. At what point in the semester does this talk take place?
[A] At the beginning [B] In the middle
[C] Near the end [D] During the final exam

19. Which of the following is NOT the duty of the lab instructor?
[A] Taking care of the students' safety.
[B] Grading their lab notebooks.
[C] Helping set up the experiments.
[D] Giving them lectures on physics.

20. Why does the speaker tell the story about Newton?

[A] To illustrate what a great scientist he was.
[B] To explain why lab equipment must be cleaned carefully.
[C] To emphasize the need for proper precautions.
[D] To show how theoretical chemistry has advanced.

21. What will the students probably do after the talk?
[A] Leave the room.
[B] Hand in their lab notebooks.
[C] Go to Professor Kaplan's office.
[D] Work on an experiment.

Questions 22--25 are based on a conversation between Irene, a secretary and her boss Mr. Jerome S. Buck. They are talking about Buck's trip to Europe.

22. How long will the sales conference in London last?
[A] From Tuesday to Wednesday
[B] From Tuesday to Thursday
[C] From Wednesday to Thursday
[D] From Thursday to Friday

23. What are they going to discuss at the meeting on Friday morning?
[A] The trade in Scotland
[B] The industry in Scotland
[C] The new factory in Scotland
[D] The site of their new plant in Scotland

24. Where is Mr. Buck going to see Mr. Chambery, the European Manager?
[A] In London [B] In Paris [C] In Rome [D] In Madrid

25. Why must Mr. Buck be back on Friday?
[A] It's his daughter's birthday.
[B] It's his son Sharon's birthday.
[C] It's his wife's birthday.
[D] It's his friend Sharon's birthday.

APPENDIX 2. POST-TEST QUESTIONNAIRE

QUESTIONNAIRE

The purpose of this questionnaire is to investigate whether you have done the listening material of pretest or not. You are required to choose the answer that best suits you to complete the following statements.

I have done the listening material before.

A. Yes B. Most of them
C. Few of them D. Never

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Ms. Xu's paper "Short-Term Memory, Listening Comprehension and Input Hypothesis" won the third prize from China English Language Education Association**.**