The Influence of Working Memory on Second Language Learning

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Abstract—**The learning ability of a foreign language means the tendency people present when studying a second language. It is already accepted abroad that the learning capacity of a foreign language is one of the factors to predict the individual differences of the language learning results. Working memory is the important concept of cognitive psychology, and has great influence on many aspects of language learning (vocabulary acquisition, language understanding, language performance, reading comprehension and so on). So working memory is regarded as the important element of learning ability of a foreign language. As to the research at home so far, the concentration has been purely on academic reasoning as well as the introduction to research abroad during a selected period. The author of the paper is, having experimented with the psychological research mode, trying to analyze the individual differences in the foreign language learning because of their working memory which affects their vocabulary acquisition.**

Index Terms—**learning capacity of a foreign language, working memory, vocabulary acquisition**

I. INTRODUCTION

Working memory, as an important concept of cognitive psychology, has great influence on many aspects of language learning including vocabulary acquisition, language understanding, language performance, reading comprehension and so on. So it is regarded as an important element of learning ability of a foreign language.

The learning ability of a foreign language means the tendency people present when studying a second language. Lots of researches have proved that it's one of the best factors which predict the result of foreign language learning. It's generally taken as a measure of the individual differences in learning a second language. The modern researches indeed began with an American psychologist named Carroll. He held the opinion that the acknowledgement of the learning ability to learn a foreign language as one of the factors influencing learning a second language includes the understandings as follows: 1. The learning ability of a foreign language and the marks got in tests are different concepts. They are unrelated at the beginning of the teaching while related at the end, which has been proved through lots of researches. 2. The learning ability of a foreign language and the motivations of study are different. 3. The learning ability of a foreign language is a relatively stable, inherent and less changeable factor. 4. The learning ability of a foreign language should be regarded as the speed and level of learning a second language, instead of the prerequisite. 5. The learning ability of a foreign language is different from general intelligence.

Vocabulary is the fundamental part of a language and is considered as one of the factors to measure the learning ability of a foreign language. Vocabulary acquisition of a second language has the marginal feature of cross-discipline. But till now there have been only some specific models like process model and vocabulary knowledge model, instead of generally accepted complete theories or models for it. Many theories or models on learning a second language can't be put into practice because their objects are mainly grammars and patterns. The vocabulary has its own characters, which means that there is a need to conduct a specific research on or make adjustments to the acquisition theory, such as the usage of the input hypothesis "i+1" by Laufer and Krashen. Researchers take advantage of psychological model to explain the vocabulary acquisition, which gets influence of the psychology. For example, it's helpful to understand the learning process of a language through cognitive and linguistic psychology. Compared with that, the function of linguistics is limited, which is represented through the description of the morphology and collocations. The researches on vocabulary acquisition of a second language can improve the theory of linguistics, cognitive science and psychology while making use of them so as to form a theory of vocabulary acquisition. The growing theory of vocabulary acquisition can draw lessons from the experimental methods of philological depiction and the test model of psychology, and in turn, help to cognize processing and explain the overall process of acquisition, storage, withdrawal and the rest.

Nowadays in China it's very common that the students at college are not very good at English, especially in vocabulary acquisition and reading comprehension. Sometimes they can't deal with the long and complex sentences, trapped in trouble while learning and reading English. The author of the paper is, having experimented with some psychological research mode, trying to analyze the individual differences in the foreign language learning because of their working memory which affects their vocabulary acquisition.

II. BASIC THEORETICAL FOUNDATION

A. Working Memory

Working memory is generally understood as a limited-capacity processing and storage system that is necessary for carrying out a wide range of tasks (Baddeley, 2003). It's figured out by Baddeley on the basis of research on the short-term working memory. Baddeley proposed three components of working memory: a central executive, which refers to a limited-capacity system responsible for processing information; two sub-components, one of which is the phonological loop temporarily storing phonological or auditory information, and the other is the visual-spatial sketchpad involved in generating and temporarily storing images.

Vocabulary acquisition means the process that a difficult or a new word is becoming familiar to a reader or listener through some amount of information in a linguistic form. If a word has been learnt before, the vocabulary acquisition of it would be much faster with less storage resources used.

B. *"Reading Span" Task by Daneman and Carpenter*

The publication of a seminal paper by Daneman and Carpenter (1980) initiated over the research on the relationship between working memory and language abilities. They developed a "reading span" task in which subjects are required to read aloud increasingly longer sequences of sentences and to recall the final word of all the sentences in each sequence. The Daneman-Carpenter reading span task, and variants thereof, rapidly became the standard method of assessing verbal working memory.

Despite its popularity, the Daneman-Carpenter task has several features that cause questions about its appropriateness as a measure of the resources involved in language processing. One of these features is that the memory load imposed in the Daneman-Carpenter task is unrelated to the computations that the sentence processing task requires. In contrast, most language comprehension tasks require storage of verbal material that is relevant to ongoing computations. A second difference between the Daneman-Carpenter task and the language comprehension process is that the former requires controlled processing and conscious retrieval of the items held in memory. Though this type of processing is needed in some aspects of the total sentence comprehension process, these controlled and conscious processes are not required to the same degree in many language comprehension processes (Marslen-Wilson & Welsh, 1978).

C. *Waters-Caplan Reading Span Measures*

Although Daneman and Carpenter have given empirical researches about the differences of low- and high-span readers, there are some criticisms of their theory. In their theory, they didn't consider some other factors which can make influences in the memory or cognitive processes. They didn't pay much attention on the individual differences of comprehension. Waters and Caplan (1996) criticized Daneman and Carpenter's (1980) Read Span task, and they think it should not be used as a measure of working memory on language comprehension. It could also be a measure of storage. But Daneman and Carpenter didn't have the evidence or data to prove that The Read Span has connections between text difficulty and other external processing loads. Therefore, this measure fails to illustrate individual differences in verbal working memory abilities. It means that a single measure of storage is an inadequate measure of the size of this working memory resource, since it does not reflect the tradeoff between processing and storage during the working memory task (Waters & Caplan, 1996). In the Waters-Caplan Reading Span Measures, one of the most obvious differences is that the participants are required to remember the final words and also understand the meaning of the sentences given.

Waters and Carpenter adopted the domain-specific view of working memory in the Comprehension Constraint Capacity theory (CCC theory). They stated that individuals' abilities on coordinating the processing and storaging the functions are various. Specifically, the more inefficient the individuals have the smaller temporary storage capacity they have. Waters and Carpenter (1980) argued that a functionally smaller storage capacity would lead to deficits in comprehension, particularly in the processes that integrate successively encountered words. Unfortunately, they have yet to make developments in assessing working memory in reading (i.e., Reading Span task by Daneman & Carpenter, 1980).

The two theories have something in common which is also their goal in setting a connection between human beings' higher level cognition and the nature of the memory system. To achieve this goal, different theories proposed have different characteristics and emphases. And the relationship between the processing and the storage is still controversial, leading to different types of tests and conclusions.

III. THE RESEARCH DESIGN

A. *Introduction to Software*

The software used in the test is E-prime. E-prime, short for Experimenter's Prime /Best, is a cross platform system which can realize the computer-administered behaviors. It supports the data collection as well as the primary analysis. It specializes in psychological experiments, improving the accuracy on time counting. The accuracy on time counting does help the experiment and verify the reaction. And at last there will come up with the charts to show the data collected, convenient for the further analysis.

The main tasks for the subjects to do in the test are to verify whether the sentences, grammars as well as meanings, are proper, and to remember the last word of every sentence. There are altogether 80 sentences mixed, divided into 20 groups. The 1-4 groups consist two sentences each; the 5-8 groups, three; the 9-12 groups, four; the 13-16 groups, five; and the 17-20 groups, six. The software records the reaction time. After the judgment of one group is over, subjects are

to write down the final words in order. To assure the reference value, all the final words are notional words instead of empty words or mixture of them. And to make sure the distinguishability, the words in the sentences are not too hard to remember, just around the level of CET4.

The results of the test are shown in two charts, one recording the judgment of sentences and the other, the final words remembered. Each of them has the operative process, complex though, making the test run to the purpose of the design.

B.   The Tests

1) The Selection of Test Subjects

Since the more a person reads, there will be more resources for the episodic buffer. And the person could get a better processing system. So the hypothesis of test is the person with a better working memory will have much better advantage in processing system than the storage system. And in this way he will do a better reading comprehension, which plays a bigger role in learning a second language. The purpose of the experiment is to prove the existence of difference in individual working memory, and explain it through the difference in a second language learning and processing. Other than that, the ability of reading comprehension represents their reading span.

Because of the budget limitation and the imperfect background the test runs in, there are altogether 70 subjects in this experiment. All of them are chosen randomly from undergraduates as well as graduates. They are from different majors (except English majors) and have different levels of English. At the very beginning of the test, they are required to write down their gender, major, grade and level of English (mainly the scores of their CET4 or CET6), taken as the reference.

2) The Test of Vocabulary Acquisition

There are two parts in the test.

The first part of the test (The content of the test is detailed in the appendices.) is the working memory. In the task, subjects were presented with a series of sentences. Rather than read the sentences aloud, as in the Daneman-Carpenter task, the subjects were required to make a judgment about the acceptability of each sentence in the series. The largest number of the words remembered in the first half of the test is defined as the reading span. The subjects read the sentences silently and decide whether they are unacceptable. As soon as a decision about one sentence had been made, they should move to the next one in the series. When the subjects had made a decision about the last sentence in the series, they should recall the final word of each sentence at once. They were instructed not to put down the last word first, instead to perform as well as they could on the recall task after reading the whole sequence of the sentences. The working memory span could be measured through the reading span test. For the individuals who have a larger reading span, they will save more capacity to store the sentence-final words because the resources of the working memory used in the processing for the comprehension of the sentences are less. On the other side, the ones with a smaller reading span will have little resource to remember the words, since a large proportion of their working memory is consumed for the processing task.

There are four different types of stimulus materials which vary in complexity in the task. The order of presentation of the four sets of materials is counterbalanced across subjects. All of the sentences in each set are of the same syntactic structure. The four sets of stimulus materials have the following structures:

1. It was the gangsters that broke into the warehouse. (cleft subject: CS)
2. It was the broken clock that the jeweller adjusted. (cleft object: CO)
3. The man hit the landlord that requested the money. (object subject: OS)
4. The meat that the butcher cut delighted the customer. (subject object: SO)

These sentences vary along two dimensions: 1. the number of propositions; 2 syntactic complexity. CS and CO sentences have one proposition, and OS and SO sentences have two. CS and OS sentences are considered to be syntactically simpler than CO and SO sentences, as thematic roles are assigned canonically in these sentences (i.e. the first noun is the agent and the second is the theme).

There are 8-11 words in every sentence, altogether 20 in each type, with the span ranging from 2 to 6. Each span has 4 series. The 80 sentences are put according to the length, difficulty and acceptability. The statistics are shown in Chart 1:

CHART 1

span set	one	two	three	four
2	CS	CO	OS	SO
3	CS	CO	OS	SO
4	CS	CO	OS	SO
5	CS	CO	OS	SO
6	CS	CO	OS	SO

In the chart half of the sentences are right while others are wrong. The difference of the span between the sentences from different series is less than one. This part lasts about 30-40 minutes.

3) The Test of Reading Comprehension

The Second part of the test is reading comprehension in which subjects are required to read four passages in 35 minutes and then finish 20 multiple choices. It's not an independent test, the result of which must be put together with the first part in the analysis. The test is designed to measure subjects' reading vocabulary, reading comprehension and

the reading speed. It is divided into two sections and each one has its own time design.

The vocabulary section of the test contains the items from the passages and subjects are required to complete as many items as they can. Here is what the question looks like: A *calamity* is a: (a) storm (b) party (c) conference (d) disaster.

The comprehension section of the test is made up of four short passages and after each there are multiple-choice comprehension questions to answer. The passages are chosen from Humanities, Science, and Social Science texts. The questions test both a subject's literal and inferential comprehension abilities.

IV.   DATA ACQUISITION AND ANALYSIS

A.   Data List

The data recorded in the test are the number of sentence-final words, the number of right judgments as well as the reaction time. More than that, the basic information of the subjects, like the score of their CET4 or CET6, is also collected as a reference. It's to be noticed that although all of the subjects have taken either CET4 or CET6, but not all of them have passed it. To make the data more comparable, we make use of Z score to process them. Here is part of the result after the processing:

CHART 2

Label	Sentence-final Words Recalled	Correct Number	Reaction Time
a1	-0.61717	-0.81272	-1.34182
a2	0.302972	1.30887	-0.67567
a3	-0.1571	0.934472	0.420338
a4	0.763041	1.558468	0.765083
a5	1.959219	1.558468	1.358068

The data is analyzed with the method of SPSS and the results can be seen in the following charts:

CHART 3
DESCRIPTION OF STATISTICS

	N	Minimum	Maximum	Average	SD
Accuracy	41	.54	.98	.8115	.10822
Effectual N (List of Status)	41				

NB: This is the data list about accuracy based on the sentence-final words recorded.
N : the number of the valid data got in the test;
Minimum: the lowest accuracy rate;
Maximun: the highest accuracy rate;
Average: the average level of all accuracy rate;
SD: standard deviation.

CHART 4
CORRELATION

		Number of Sentence-final Words	Correct Number
Number of Sentence-final Words	Pearson Correlation	1	.706[**]
	Significance (Double Side)		.000
	N	41	41
Correct Number	Pearson Correlation	.706[**]	1
	Significance (Double Side)	.000	
	N	41	41

NB: Chart 4 is the analysis on the relationship between the number of the sentence-final words and the right judgment on the acceptability.
Number of Final Words: the number of sentence-final words recalled;
Correct Number: the number of right judgment on the acceptability.

CHART 5
CORRELATION

		Reaction Time	Scores of CET4
Reaction Time	Pearson Correlation	1	-.145
	Significance (Double Side)		.366
	N	41	41
Scores of CET4	Pearson Correlation	-.145	1
	Significance (Double Side)	.366	
	N	41	41

CHART 6
CORRELATION

		Reaction Time	Scores of CET6
Reaction Time	Pearson Correlation	1	-.192
	Significance (Double Side)		.230
	N	41	41
Scores of CET6	Pearson Correlation	-.192	1
	Significance (Double Side)	.230	
	N	41	41

CHART 7
CORRELATION

		Accuracy	Scores of CET4
Accuracy	Pearson Correlation	1	-.010
	Significance (Double Side)		.950
	N	41	41
Scores of CET4	Pearson Correlation	-.010	1
	Significance (Double Side)	.950	
	N	41	41

CHART 8
CORRELATION

		Accuracy	Scores of CET6
Accuracy	Pearson Correlation	1	.203
	Significance (Double Side)		.202
	N	41	41
Scores of CET6	Pearson Correlation	.203	1
	Significance (Double Side)	.202	
	N	41	41

NB: Charts 5, 6, 7 and 8 are about the relationship between the reaction time, accuracy, the scores of CET4 and CET6.
Reaction Time: the time taken to verify the acceptability of sentences;
Accuracy: referring to the sentence-final words remembered.

B. Data Analysis

In Chart 3, among the data of 41 subjects (other data are not qualified for analysis), the highest of the accuracy is 0.98, very close to 1. The lowest is 0.54, almost half. It's clear that the disparity of individual learning result is obvious. The highest sentence-final words recalled is 78while the lowest 37, which means the scope of working memory is relatively big. The average 0.8115 and the sigma 0.10822 show that the general accuracy is relatively high and the general difference is not that big.

Chart 3 helps to understand the relationship between the number of sentence-final words and the right judgment on the acceptability. Partly they represent the relationship between the features of processing and storage system. The data shows that the relativity between them is obvious and it's showing the positive association, that is to say, the person who has a higher working memory span gets better processing system and storage system.

Charts 5, 6, 7, 8 put the scores of CET4 and CET6 in consideration. Here, the Scores of CET4 and CET6 are taken as the result of learning ability at the end of a learning process. We are trying to find out which one, the processing and storage system, has closer relationship with the result of learning. First, the relationship between the reaction time and the scores of CET4 and CET6 is relatively obvious and negative, which means the reaction time is shorter when the scores are higher. And the relationship between the reaction time and the scores of CET6 seems to be closer. Second, the relativity between accuracy and the scores is relatively not so outstanding, compared with that between the reaction time and the scores. The scores of CET4 have almost nothing to do with the accuracy. But it is weakly relative to the scores of CET6, which means the data of them impact each other in an opposite direction.

The hypothesis at the beginning of the test has some rationality. The person with higher working memory span does much better in processing sentences, which plays a relatively important role in the second language learning.

C. Arguments

All of the data above show that the reaction time can better represent the individual difference in working memory than the accuracy. Through the analysis on the data, it's clear to find that the result of the test has something to do with the foundation of English knowledge, that is to say, the ability the subjects hold will influence the working memory span.

And the result of the graduates and undergraduates compared, it's no wonder that the graduates get the upper hand at not only the number of the sentence-final words remembered but also the right judgment. Interestingly, however, the disparity of the latter is much bigger than the former, which means that the graduates do a much better job at the processing, instead of remembering words, than the undergraduates. The condition of the graduates take as the future of

the undergraduates, it's sure that their operating system gets a faster development than the undergraduates'. But limited by the small amount of subjects, other factors, which perhaps also play a role in the working memory, may not have been missed. So it may be perfunctory to get the conclusion so fast.

V. CONCLUSION

According to the data analysis above, there comes the conclusion as follows:

1. The duration of the memory may better represent the individual difference in working memory than the accuracy of memory;

2. In the same condition, the person who has better working memory will finish remembering faster and at a higher accuracy and who also has the tendency to get better scores while learning English;

3. In the whole growth of the working memory (Some psychologists believe that the working memory is a born ability which will keep stable all the time.), the short-term memory will keep relatively stable while the operating system will improve at a faster speed.

These conclusions above will help in learning a second language (mainly English here). The result of learning depends on the capability of working memory. Since the operating system developing faster, it may be helpful to practice more reading to cultivate the so-called language sense. All in all, the learner should pay attention to improving the ability to handle the relationship between the two recourses while learning to find a proper way to get their studying promoted.

APPENDIX

Here is the test as follows:
1-1 It was the gangster that broke into the bank.
1-2 It was the handsome man that shaved the razor.
2-1 It was the pills that the patients healed.
2-2 It was the young teacher that the computer assisted.
3-1 The investor supported the company that located near the river.
3-2 The article composed the journalist that reported the process.
4-1 The jewelry that the store showed coveted that woman.
4-2 The accident that the girl saw triggered the criminal.
5-1 It was the climber that encountered the big snow.
5-2 It was the princess that set up the school.
5-3 It was the match that broke off the judgment.
6-1 It was the crops that the human fed.
6-2 It was the beautiful girl that the car rode.
6-3 It was the drunkard that the wine poisoned.
7-1 The diamond purchased the actor that performed at the movie.
7-2 The policeman carried the pistol that injured the thief.
7-3 The medicine swallowed the patient that lay on the bed.
8-1 The trial that the media covered confused the lawyer.
8-2 The loan that the banker refused worried the mayor.
8-3 The chemical that the factory produced patented the scientist.
9-1 It was the horse that burdened the goods.
9-2 It was the green hands that messed up the file.
9-3 It was the painter that worked in the gallery.
9-4 It was the inventor that struck the new idea.
10-1 It was the dirty floor that the housekeeper swept.
10-2 It was the elephant that the water cooled.
10-3 It was the fresh grass that the cow cushioned.
10-4 It was the strong horse that the load carried.
11-1 The spy encoded the message that predicted the event.
11-2 The child scalded the water that boiled in the span.
11-3 The farmer cut the plant that attracted the insect.
11-4 The game excited the golfer that fevered all the sports.
12-1 The waiter that the boss blamed broke the dish.
12-2 The donkey that the man rode burdened the load.
12-3 The fire that the fireman fought burned the boy.
12-4 The farmer that the crops fed ran over the tractor.
13-1 It was the wind that blew down the girl.
13-2 It was the drunkard that poisoned the liquid.

13-3 It was the car that got off the lady.

13-4 It was the wool that wound the black cat.

13-5 It was the boy that ran over the bus.

14-1 It was the broken clock that the jeweler adjusted.

14-2 It was the blue ball that the girl threw.

14-3 It was the huge tree that the boy shaded.

14-4 It was the famous chef that the dinner cooked.

14-5 It was the precious tiger that the cage held.

15-1 the expert helped the machinery that worked in the plant.

15-2 The stick cast the warrior that protected the country.

15-3 The rain cooled the lions that lay under the tree.

15-4 The child loaded the gun that scared the youth.

15-5 The engineer lifted the rocket that rushed into the sky.

16-1 The man that the girl called washed the car.

16-2 The knife that the mother hid brandished the child.

16-3 The ship that the people rode carried the pirate.

16-4 The editor that the writer angered tore the book.

16-5 The car that the sun burned cooled the water.

17-1 It was the signal that sent out the guard.

17-2 It was the heavy work that suppressed the doctor.

17-3 It was the robot that assisted the worker.

17-4 It was the net that slipped out the fish.

17-5 It was the green color that took on the snake.

17-6 It was the flood that flushed away the solider.

18-1 It was the new table that the madam destroyed.

18-2 It was the mad dog that the gun shot.

18-3 It was the big fish that the lure attacked.

18-4 It was the magnificent feast that the duke prepared.

18-5 It was the boiling water that the woman scalded.

18-6 It was the naughty boy that the plane flew.

19-1 The bus ran over the boy that played on the road.

19-2 The fort occupied the soldiers that saved the city.

19-3 The girl tickled the feathers that floated in the air.

19-4 The instrument frustrated the student that learned the song.

19-5 The student educated the school that located near the park.

19-6 The car crashed the man that broke into the house.

20-1 The meat that the butcher cut delighted the customer.

20-2 The pillow that the woman bought clenched the baby.

20-3 The athlete that the coach supported won the football game.

20-4 The girl that the cold wind blew rubbed the match.

20-5 The fish that the man caught attracted the lure.

20-6 The actor that the merchant supported delighted the play.

After the verification at each set of sentences, the participants are required to recall the sentence-final words of all the set.

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