The Reading Ability Can Be Predicted by a Universal Verbal Working Memory Factor Across Different Writing Systems: Evidence from Reading Span Task

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ABSTRACT

Most Chinese college students have an experience of learning English as second language for more than ten years. To explore whether the ability of reading Chinese script and English script was related to a universal working memory capacity, and whether the working memory capacity can predict a change in reading ability, we measured the general working memory span (via N-back task), verbal working memory span of Chinese and English (via reading span task), and reading comprehension ability of Chinese and English of our participants. We also collected the score of Chinese and English of their College Entrance Exam, which is tested at least half a year before now. Our results showed that both Chinese and English reading ability can be predicted by English reading span, which suggested a universal reading ability across different writing systems. The results also showed that reading span failed to predict the past reading score, and Chinese reading span failed to predict the reading comprehension of either Chinese and English, the possible reasons were discussed.

Keywords: Reading span, Reading cqomprehension ability, Working memory

1. INTRODUCTION

Reading is of vital importance in today's information-driven society. Reading comprehension as an indicator of reading ability has been widely researched in many topics, such as supervising the development of children's ability, diagnosing reading disorder promptly, and exploring psychological models. In order to measure the ability of reading comprehension, researchers have developed accurate assessment methods. For example, Classic standardized assessments of reading ability, represented by the Neale Analysis of Reading (NARA), require participants to read a set of stories and answer questions related. Reading comprehension ability is measured by the number of questions answered correctly. Despite different details and some disputes in suitability, this paradigm has a wide range of applications.

Working memory(WM) is defined as the mental system that is responsible for both information storage and information processing, in contrast to short-term memory(STM), a passive storage system for short periods of time[1]. As reading comprehension task engage the procedure of temporarily storing and manipulating information simultaneously, reading comprehension is closely connected with working memory. For instance, when reading a text and comprehending the meaning, a person should process the word into a visual message, then compare the word with vocabulary and grammatical structures in the long-term memory, and then contact all these representations with the context, with the combination of which the comprehension of the text is constructed. And working memory plays an important role in this process, including holding up information of the text in the short-term memory, searching information from long-term memory and making comparison, and exporting an overall comprehension[2]. As a theory proposed by Just and Carpenter explains, both processing and storing are mediated by activation, the amount of which, in working memory, is limited and differs among individuals. Therefore, people tend to assume that the individual difference in working memory explains the difference in reading comprehension[3].

However, the strong theoretical bond does not make stable predictions. Daneman and Merikle[4] noticed that the relation between working memory and reading comprehension was stronger than that between short-

term memory and reading comprehension in their meta-analytic review. Savage et al., with systematic meta-analysis of substantial studies, came to conclusions that working memory matters more for reading comprehension than foundational reading process such as decoding[5]. In contrast to Savage et al., Peng et al. proved that the correlation of working memory and comprehension is as strong as that of working memory and foundational reading skills[6].

As is widely recognized, working memory is an central mental construct, which acts as an indispensable role in contemporary cognitive models. In the meantime, working memory capacity(WMC) has been a reliable predictive factor that is related to many intellectual ability and cognitive tasks[7-12].

From the perspective of the original theory of Baddeley[1], researchers designed working memory span task to measure working memory capacity, which emphasized the functional role that the memory system played, that is, stressing the limited information was stored for being processed. Therefore, working memory span test requires stimuli that should be remembered by the participants, and also cognitive task that should be processed simultaneously[13]. And the reading span test(RST) was the first task designed to achieve requirements above[14].

In the original version of reading span test, participants were asked to read aloud sentences on index cards and keep the last words of the sentences in mind for later recall. After a series of sentences, they would be asked to recall the words supposed to be remembered in order. Furthermore, Daneman and Carpenter also introduced an cognitive task in their later design. Participants were asked to judge true or false of sentences they read, which guaranteed the reading span test carried out without a strategy of remembering last words only. Subsequent experimental studies designed by other researchers improved the original reading span test in different aspects, but the general framework remains.

Compared with other specific components of working memory, reading span has stronger relationship with L2 learning. The reading span test, which is classified as the "complex" span task, in contrast to "simple" span task which just measure the store and rehearse ability, requires storing information and processing cognitive information both. This distinction is reflected in many aspects, including reading comprehension. As is revealed by Daneman and Merikle in 1996, complex span tasks predicted L1 reading comprehension better. While in L2 learning, working memory span tasks also have certain effect. Jared et al. have reported a meta-analysis indicating that, complex working memory span tasks, including reading span test, have larger effect sizes than simple ones.

However, there is one point to be noted that correlation between working memory performance and L2 is uncertain in the direction. Some evidence might demonstrate a causality that greater reading span cause greater L2 performance[4,15,16]. But opposite evidence from bilingual-advantage articles infers causation in reversed direction. The complicated relationship between two variables need further investigation.

Considering background study above, we assume that reading span and working memory can predict the reading comprehension ability. Further, we suppose that reading span and working memory can predict the decline of the reading comprehension score after absence of practice.The experiment includes four parts. Chinese native speaker participants first were surveyed through a questionnaire about their past Chinese and English performance, which are measured by scores in college entrance exams. Then there were assessments on the present Chinese and English reading comprehension performance. The working memory and reading span were designed to be measured separately then. The reading span were measured by reading span test based on Daneman and Carpenter. And the general working memory were measured by N-back test.

2. METHOD

2.1. Participants

27 native-Chinese speakingers (Mean Age: 21.2, 4 males, 23 females) participated in the study. They were university students from Beijing Normal University and have an experience of leaning English for at least 10 years. All participants gave oral informed consent.

2.2. Materials

2.2.1. Reading comprehension

The reading materials consisted of one Chinese and one English expository reading comprehension articles. The Chinese reading article was selected from the National Civil Servant Examination, which is a way for the government to recruit the staff, and is highly representative of the quality assessment for adults. This article has 952 Chinese characters, and there are five multiple choice comprehension questions following the article. The English reading article was selected from the college English level test (College English Test Band 3). This article has 371 words in total, and there are also 5 multiple choice comprehension questions following it.

2.2.2. Reading comprehension

The sentences for reading span test were modified from Hong 2007. For either Chinese or English sentences, there were 3 lists of testing sentences. Each

list was comprised of 5 reading span groups of 2, 3, 4, 5, 6 sentences to test the reading span varied from 2 to 6 respectively. Thus there 60 sentences for each language

For Chinese sentences, the length of each sentences is controlled between 15 and 20, and the last two characters form a meaningful word, the frequency of which in every million words is controlled referred to Modern Chinese dictionary(1986)(M=1268, SD=680). Each sentence has been standardized with two verbs. For example:

1.他想起临行时父亲和母亲对自己的嘱咐。(He remembered what his father and mother had told him when he left.)

2.耳边飘来的乐声是牧童悠然吹奏的短笛。(The music floating in my ears is the piccolo played by a shepherd boy.)

As for English sentences, each sentence has 9 to 11 words, and the last word of each sentences is common words of CET4 level. Each sentence also has been standardized with two verbs with the structure of attributive clause, object clause or subject clause. For example:

1.The one who won the prize is a visiting scholar.

2.He's a millionaire who has a large number of properties.

2.3. Procedure

2.3.1. Reading comprehension

Participants were asked to complete a questionnaire first. In the questionnaire, they provided personal information as well as the score of Chinese and English in the College Entrance Exam. Then they read the reading comprehension materials and answered the multiple choice comprehension questions.

2.3.2. Reading span test

The reading span test were present on a laptop screen coded with Phychtoolbox (Brainard, 1997).The procedure of CHN and ENG test were the same.

In the reading span test, participants saw the sentences on screen and were asked to read aloud sentences and keep the last words of the sentences in mind for later recall, which were recorded as the target word. After they finished read one sentence, they pressed the space button to proceed to the next question. After a group of sentences were presented, they were required to recall the target words of each sentences in the reading span group. They were not required to recall the final words in order, except that the latest target words cannot be recalled first. If they recalled the final target word first, the experimenter would ask them to

recall it again after they finished the other target words. Only in case they successfully recalled this time, this target word could be considered as being achieved.

The size of the group would begin from 2, and increased according to the performance of the participants. There were 3 different but equivalent lists of materials for each group size. If a participant succeeded in 2 lists continuously or succeeded in 2 out of 3 lists, the group size would increase. Otherwise, the test was over.

Meanwhile, a question based on the content of questions in each group would follow the recalling part. The participants were asked to press the button to answer yes or no.

2.3.3. Working memory test

In N-back test, letter A and letter B randomly appeared on the screen, and from the third letter or the fourth letter, participants should compare it to the letter appeared 2 or 3 positions back in the sequence. For example, as for 2-back test, the third letter should be compared with the first letter, and the fourth letter should be compared with the second letter. Participants should response by pressing the button F in case the letters were same, or button J in case not. The stimulus letter would last 2s on the screen and duration between stimuli was 500ms. There were 30 formal trials for both 2-back and 3-back test, with 10 trials for practice.

2.4. Scoring

2.4.1. Reading span test

The reading span was calculated by two parts, the base span and the addition, calculated through the number of words or characters the participants could remember. The experiment continued until the participant failed to completely recall at least two groups of sentences out of three, and the base span should be the number of sentences of current item minus one, that is, number of sentences for the last item, which the participant succeeded in all of the 3 groups. As for current item, words or characters the participants recalled were counted. If the sum was more than a quarter of all the sentences in the item and less than two quarters, than add 0.25 to the base span. For instance, if a participants had a base span of 3, and he recalled 4 words in the 4-span item, then his final reading span would be calculated as 3.25. The same scoring rules was executed when the sum was between two and three quarters, and when more than three quarters.

2.4.2. Working memory

The genaral working memory was meausured by N-back test accuracy. Both 2-back test and 3-back test

were carried out under the experiment, and we sum the data in a weigted way. Considering the majority had a better performance on the 2-back, we calculated the general accuracy as one third of 3-back test accuracy and two thirds of 2-back test accuracy.

Descriptive statistics for Chinese reading span and English reading span are provided in table 1. With interquartiles as the cut-pff points, the reading spans for each participant are converted to grade variable from 1 to 4.

We examined our hypothesis with regression analyses, with the college entrance exam score, reading comprehension score converted into a hundred percent system and their difference as dependent variables, and gender, age, reading spans, working memory accuracy as well as response time as the factors. Table 2 presents the result of the regression analyses. We found that both span have little predictive effect on college entrance exam score($p>0.1$). English span has a significant positive prediction on both English comprehension ($p=0.027$) and Chinese comprehension ($p=0.017$), while Chinese reading span barely explains any of the reading comprehension performance ($p>0.1$). Furthermore, the English reading span also negatively predicts difference between past and present scores($p=0.025$ for Chinese, $p=0.031$ for English). Moreover, the working memory accuracy has a predictive effect of significance on Chinese reading comprehension($p=0.067$) and difference($p=0.062$).

In general, English reading span has significant predictive effect on two reading comprehension task, which verifies the hypothesis we proposed and means that higher reading span predicts stable reading comprehension ability.

Furthermore, predictive effect of English reading span on both language, instead of English reading comprehension only, also indicates that reading span might has consistency across languages. The consistency implies that both L1 and L2 language reading comprehension share a mutual factor that influence their performance, and reading span for one language could be the incarnation of this factor, showing effect on the comprehension of this language and the other.

The college entrance exam scores show little relationship with individual general abilities, which could have two possibilities. On one hand, all participants from different provinces in China does not share same examinations and the distribution of scores for each provinces lack. Thus, the college entrance exam might not be representative measure. On the other hand, the entrance exam requires more education and practice rather than personal abilities, under which circumstance the difference between the entrance exam and present reading comprehension score effactually assess the difference between the individual abilities and practice skills. The neglect prediction implies that students with fewer reading span and working memory benefit more from education and practice.

Another notable result is that Chinese reading span shows little predictive effects, which is not consistent with our hypothesis. One possible explanation might be that Chinese native speakers are much more familiar with Chinese reading, which allows them to generate a memorizing strategy on the spot, and makes the results not a proper representation for Chinese reading span. Thus, the Chinese reading span demands more elaborate design.

As for the working memory ability, which also shows predictive effect on present Chinese reading comprehension score and the difference, could be inferred to have influence on reading comprehension as well, but weaker than reading span

4. CONCLUSION

The experiment measured the past and present reading comprehension ability, the reading span and working memory, and examined relationship between reading span and reading comprehension ability to test the hypotheses. We conclude that reading span has a significant predictive power on reading comprehension and its change with the lack of practice, and has larger effect than working memory. Meanwhile, reading span might has consistency across languages. However, failure of Chinese reading span's predictive power leaves doubt and demands further studies.

Table 1. Chinese reading span and English reading span

		CNSPAN	ENSPAN
N		27	27
M		3.39	2.67
SD		0.88	0.54
σ^2		0.78	0.29
Percentiles	25	2.5	2.25
	50	3.5	2.5
	75	3.75	2.75

Table 2. Chinese reading span and English reading span

		CNCollegeEntranceExam					ENCollegeEntranceExam				
		B	Error	Beta	error	sig	B	Error	Beta	error	sig
College Entrance Exam	constant	65.254	27.844		2.344	0.032	85.805	22.079		3.886	0.001
	Gender	0.987	4.269	0.057	0.231	0.820	3.002	3.385	0.208	0.887	0.388
	Age	-0.232	0.932	-0.062	-0.249	0.807	-0.47	0.739	-0.152	-0.637	0.533
	Cspan	-1.485	1.725	-0.261	-0.861	0.401	-0.669	1.368	-0.141	-0.489	0.631
	Espan	1.492	1.558	0.249	0.957	0.352	0.389	1.235	0.078	0.315	0.757
	WM_acc	2.478	11.544	0.049	0.215	0.833	-3.905	9.154	-0.092	-0.427	0.675
	WM_RT	11.975	8.969	0.370	1.335	0.199	10.784	7.112	0.400	1.516	0.148
		CNComprehension					ENComprehension				
		B	Error	Beta	error	sig	B	Error	Beta	error	sig
Comprehsion	constant	26.742	77.967		0.343	0.736	38.664	81.491		0.474	0.641
	Gender	-17.619	11.954	-0.303	-1.474	0.159	-15.467	12.495	-0.272	-1.238	0.233
	Age	0.363	2.609	0.029	0.139	0.891	0.072	2.727	0.006	0.026	0.979
	Cspan	-3.957	4.829	-0.207	-0.819	0.424	-4.195	5.048	-0.225	-0.831	0.417
	Espan	11.603	4.363	0.577	2.659	**0.017**	11.037	4.560	0.562	2.42	**0.027**
	WM_acc	63.224	32.324	0.369	1.956	**0.067**	40.849	33.785	0.244	1.209	0.243
	WM_RT	17.001	25.115	0.156	0.677	0.508	21.146	26.25	0.199	0.806	0.432
		CNDifference					ENDifference				
		B	Error	Beta	error	sig	B	Error	Beta	error	sig
Difference	constant	38.512	73.461		0.524	0.607	47.141	80.99		0.582	0.568
	Gender	18.606	11.264	0.339	1.652	0.117	18.469	12.418	0.324	1.487	0.155
	Age	-0.595	2.458	-0.051	-0.242	0.812	-0.542	2.710	-0.044	-0.200	0.844
	Cspan	2.473	4.550	0.137	0.543	0.594	3.526	5.017	0.189	0.703	0.492
	Espan	-10.111	4.111	-0.534	-2.46	**0.025**	-10.648	4.532	-0.542	-2.349	**0.031**
	WM_acc	-60.746	30.456	-0.377	-1.995	**0.062**	-44.755	33.578	-0.267	-1.333	0.200
	WM_RT	-5.026	23.664	-0.049	-0.212	0.834	-10.363	26.089	-0.097	-0.397	0.696

AUTHORS' CONTRIBUTIONS

Jin Yan contributed to the conception of the study, performed the experiment and completed the article.

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