

The Role of Working Memory in the Comprehension of Relative Clauses by Chinese Dyslexic Children

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ABSTRACT---- *Previous psycholinguistic studies on the processing of relative clauses delineate the importance of working memory in sentence comprehension. This study further investigates the role of working memory in the comprehension of Chinese relative clauses by dyslexic children who have reading and writing difficulties in Chinese. In this study, a computerized sentence listening and reading comprehension test was designed to assess to what extent dyslexic children comprehend Chinese sentences consisting of three types of relative clauses. The results of the test indicate that dyslexic children were significantly worse than their non-dyslexic counterparts with comparable educational level, age and IQ in both listening and reading comprehension of relative clauses. Dyslexic children had great difficulty in comprehending the subject-extracted relative clauses, which involve heavy working memory load in restructuring the word order for comprehension. The findings of the study highlight the importance of working memory in sentence comprehension by dyslexic children, and shed light on the enhancement of sentence comprehension of dyslexic children. It is proposed that language games and computerized language tasks can be used for training the working memory of dyslexic children, which in turn will facilitate the sentence comprehension that is essential for text comprehension.*

Keywords-- Chinese dyslexia, working memory, sentence comprehension, relative clauses

1. INTRODUCTION

While previous research on Chinese dyslexia emphasized learning difficulties in character or word recognition and pronunciation, relatively little attention has been paid to problems with sentence comprehension (Chung & Ho, 2010; Ho, Chan, Tsang & Lee, 2002; Ho, Chan, Lee, Tsang, Luan, 2004; Ho, Chan, Tsang, Lee & Chung, 2006; Ho, Chan, Chung, Lee & Tsang, 2007). The present study emphasizes sentence comprehension by Chinese dyslexic children, with a focus on the comprehension of relative clauses (RCs). Relative clauses are complex structures which have received increasing attention in those previous psycholinguistic studies which evaluate sentence processing theories (Hsiao & Gibson, 2003; Lin and Bever, 2006). In line with previous studies, this study delineates the complexity of the comprehension of Chinese relative clauses. It further indicates the difficulty in the comprehension of subject-extracted relative clauses by Chinese dyslexic children.

It was pointed out by a number of researchers that although there may not be a definite answer on whether dyslexic children have poor working memory, the working memory of dyslexic children is weaker than that of non-dyslexic children (Pickering, 2006; Reilly, 1997; Young & Tyre, 1983). In the Chinese context, Leong, Hau, Tse & Loh (2007) found that verbal working memory plays a significant role in reading comprehension by less competent Chinese readers. More research has to be done on exploring the relationship between working memory and dyslexia in the Chinese setting. The present study is an attempt to investigate this relationship. A close relationship between working memory and comprehension of relative clauses by Chinese dyslexic children is shown in this study.

2. AIMS OF THE STUDY

Based on the previous studies on Chinese dyslexia, this study focuses on the comprehension of relative clauses by Chinese dyslexic children. It aims to:

- (1) Investigate Chinese dyslexic children's ability in listening and reading comprehension concerning relative clauses;
- (2) Compare dyslexic and non-dyslexic children's ability in the listening and reading comprehension of Chinese relative clauses;
- (3) Analyze the relationship between working memory and the comprehension of Chinese relative clauses by dyslexic children.

3. RESEARCH METHODS

3.1 Participants

The experimental group included Year 3 to Year 6 Chinese dyslexic children from five primary schools in Hong Kong, while the control group consisted of age-, educational year-, and IQ-matched non-dyslexic counterparts. The relevant information of the participants is given in Table 1.

Table 1: Information about the participants

Year of study	Age range	Experimental group-	Control group-
		Number of dyslexic students	Number of non-dyslexic students
Year 3	8;4 – 8;7	11	11
Year 4	9;1- 9;9	17	17
Year 5	10;3-11;5	10	10
Year 6	11;9-12;5	5	5
Total number of students		43	43

Table 2: Comparison of IQ scores of the dyslexic and non-dyslexic groups

Year of Study	Dyslexics / Non-dyslexics	Mean scores of Raven's SPM	S. D.	T-test result of the comparison of the IQ scores of dyslexics and non-dyslexics
Year 3	Dyslexics	34.56	7.002	p>0.05 (No significant difference)
	Non-Dyslexics	35.60	7.892	
Year 4	Dyslexics	36.72	8.259	p>0.05 (No significant difference)
	Non-Dyslexics	36.43	8.382	
Year 5	Dyslexics	41.75	6.751	p>0.05 (No significant difference)
	Non-Dyslexics	42.89	7.271	
Year 6	Dyslexics	41.00	5.967	p>0.05 (No significant difference)
	Non-Dyslexics	40.33	7.727	

In the selection of the students involved in the study, the IQ of the participants was the control variable of this study. The students involved in this study had to complete the standardized non-verbal IQ test, Raven's Standard Progressive Matrices (Raven 2006), which was used to assess the IQ of all the participants. This test required the participants to identify the missing element that completed a pattern in each test item: there were 64 test items in the test. The students did the test at their own pace, spending 25 to 30 minutes to complete the test. Only those students whose IQ scores fell within the average score range were selected to do the sentence comprehension test. The IQ mean scores in each age group of the dyslexic and non-dyslexic students were compared by conducting a t-test. The IQ mean scores of the dyslexic students were not significantly different from those of the non-dyslexic students in each age group, which ensured that the differing performance of dyslexic and non-dyslexic students, which might appear in this study is not due to the differing IQ of the two groups of students. The descriptive and t-test results of the IQ scores of the two groups of students selected for this study are given in Table 2.

3.2 Test Instruments

Each student involved in this study completed a computerized sentence comprehension test which required them to listen and read Chinese sentences. This test consisted of four subtests, and a specific testing method was used in each sub-test. The testing methods of these four subtests in order were:

- (1) Subtest 1: Students listened to a sentence while watching four pictures shown on the screen of the computer, and then pressed the key to choose the picture showing the meaning of the sentence.
- (2) Subtest 2: Students listened to a sentence first, and then pressed a key to watch four pictures shown on the screen of the computer. After this, they pressed the key to choose the picture showing the meaning of the sentence.
- (3) Subtest 3: Students read a sentence while looking at four pictures. The sentence and the four pictures were shown on the screen. They then pressed a key to choose the picture showing the meaning of the sentence.
- (4) Subtest 4: Students read a sentence shown on the screen first, and then pressed a key to watch the next page - which showed four pictures. After this, they pressed a key to choose the picture showing the meaning of the sentence.

Each test item in these four subtests included a sentence embedded with a relative clause. The test was designed to investigate the participants' comprehension of three types of relative clauses, consisting of: (1) Subject-extracted relative clauses; (2) Object-extracted relative clauses; (3) Passivized subject-extracted relative clauses. All the embedded relative clauses were in the subject position of the main sentence. There were six test items for testing each of the three types of relative clauses, a total of 18 test items, in each of the four subtests. In total, in the whole test, there were 72 test sentences investigating the students' comprehension of relative clauses.

In addition, in order to avoid the participants being aware of being tested on the comprehension of the sentences with relative clauses, an equal number of filler sentences with simple Subject-Verb-Object (+adverbial) structures, a total of 18 test items, were added to each subtest. The target test sentences and filler sentences were randomized in each subtest. The results of filler sentences will not be reported.

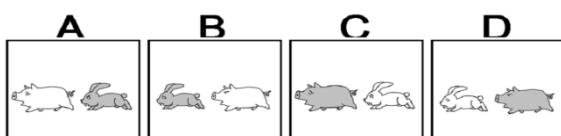
Examples of target test sentences embedded with subject-extracted, object-extracted, and passivized subject-extracted relative clauses, and an example of a filler sentence, are given below.

- (1) An example of a test sentence embedded with a subject-extracted relative clause:

追著小兔的那隻小肥豬是淺灰色的。

Chasing little rabbit complementizer demonstrative classifier little fat pig is light grey color particle
(The little pig which is chasing the little fat rabbit is in light grey color.)

The four pictures provided:

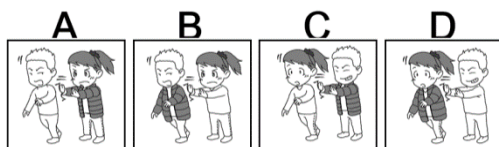


- (2) An example of the test sentence embedded with an object-extracted relative clause:

小男孩推著的那個女孩穿著灰色的外套。

Little boy pushing complementizer demonstrative classifier girl wearing grey color particle jacket
The girl who is pushing the little boy is wearing a grey jacket.

The four pictures provided:

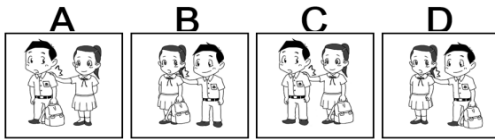


- (3) An example of the test sentence embedded with a passivized subject-extracted relative clause

被小女孩拍著的那個男孩拿著一個書包。

Case marker little girl patting complementizer demonstrative classifier boy carrying one classifier schoolbag
(The boy who is being patted by the little girl is carrying a schoolbag.)

The four pictures provided:



(4) An example of a filler sentence:
兩個小孩子在草地上高興地踢足球。

Two children on the grass happily kick football
(Two children are kicking football on the grass happily.)

The four pictures provided:



3.3 Administrative Procedures

The students whose IQ scores fell within the average score range for their age group were selected to do the sentence comprehension test. The IQ test and the sentence comprehension test were conducted with the students on two separate days within one week. At the beginning of each sentence comprehension subtest, three trials were used to make sure that the students understood how to complete the subtest with the instructions provided. There was a break of at least 5 minutes between the subtests. All the subtests were self-paced. The time spent on the whole test was about one hour and 30 minutes.

3.4 Methods of scoring and data analysis

For the sentence comprehension test, one was scored for each correct answer, and zero for each incorrect answer. The descriptive results in terms of mean scores of each subtest and each type of relative clause in the whole test were calculated. A t-test was conducted to investigate whether the results of the dyslexic students were significantly different from those of their non-dyslexic counterparts.

4. RESULTS

In the following section, the results of the four subtests using different types of testing methods, and the results of the comprehension of three types of relative clauses in the whole test by dyslexic and non-dyslexic students, will be presented. The performance of the two groups of students will also be compared.

4.1 Results of the four subtests

Two groups of students performed better in reading comprehension than in listening comprehension, since listening comprehension involves heavier working memory. They all did worse in subtests 2 and 4 than in subtests 1 and 3. This is because in subtests 2 and 4, the students needed to keep each sentence in their working memory before looking at the pictures, while subtests 1 and 3 did not involve temporary storage of sentences in working memory.

A t-test was conducted to compare dyslexic and non-dyslexic students' performance in each of the four subtests. The results show that dyslexic students did significantly worse than non-dyslexic students in all the subtests, in both reading and listening comprehension (subtest 1: $t = -5.47$, $df = 86$, $p < 0.001$; subtest 2: $t = -5.14$, $df = 86$, $p < 0.001$; subtest 3: $t = -4.9$, $df = 86$, $p < 0.001$; sub-test 4: $t = -5.35$, $df = 86$, $p < 0.001$).

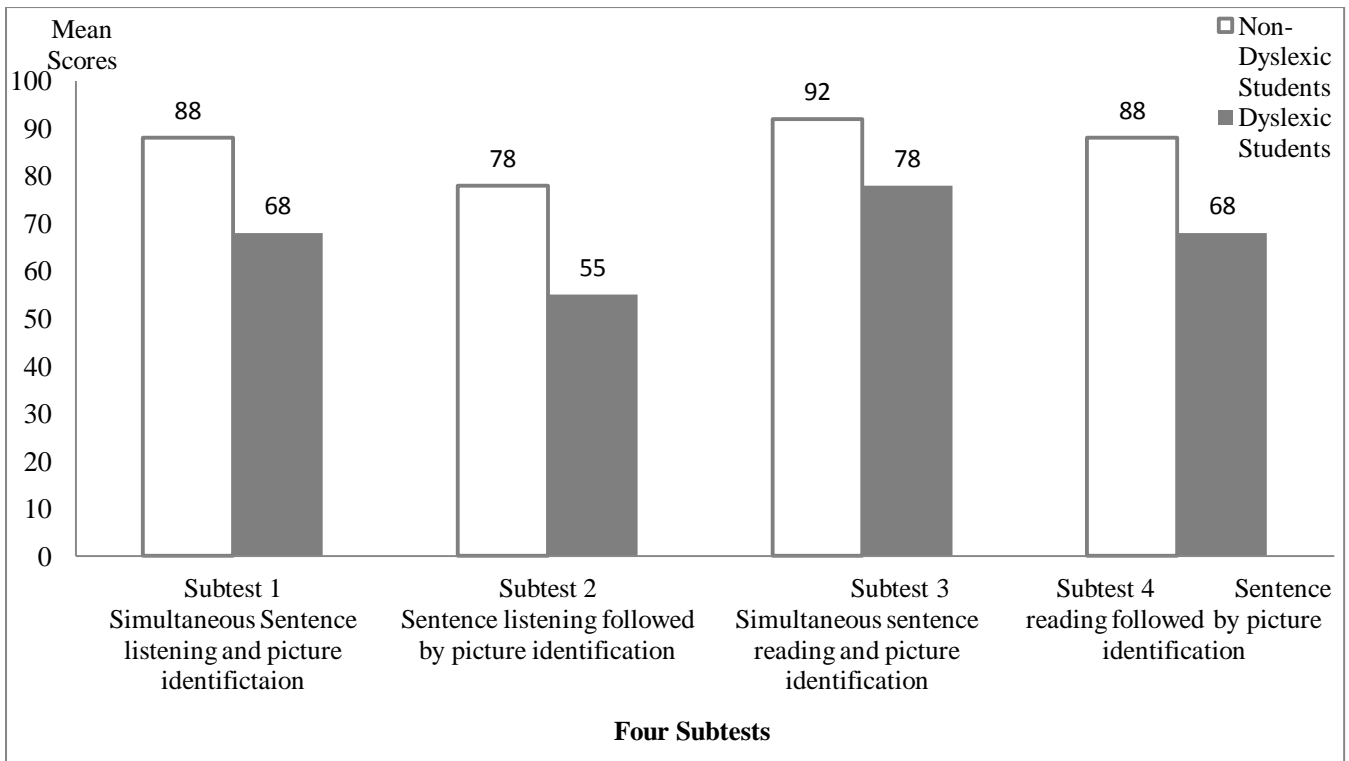


Figure 1: Results of the four subtests

4.2. Results of the comprehension of the three types of relative clauses

As presented in Section 3.2, there were three types of relative clauses included in each of the four subtests, including subject-extracted relative clauses, object-extracted relative clauses, and passivized subject-extracted relative clauses. The results of the comprehension of each type of relative clause for the dyslexic and non-dyslexic groups are given in Figure 2.

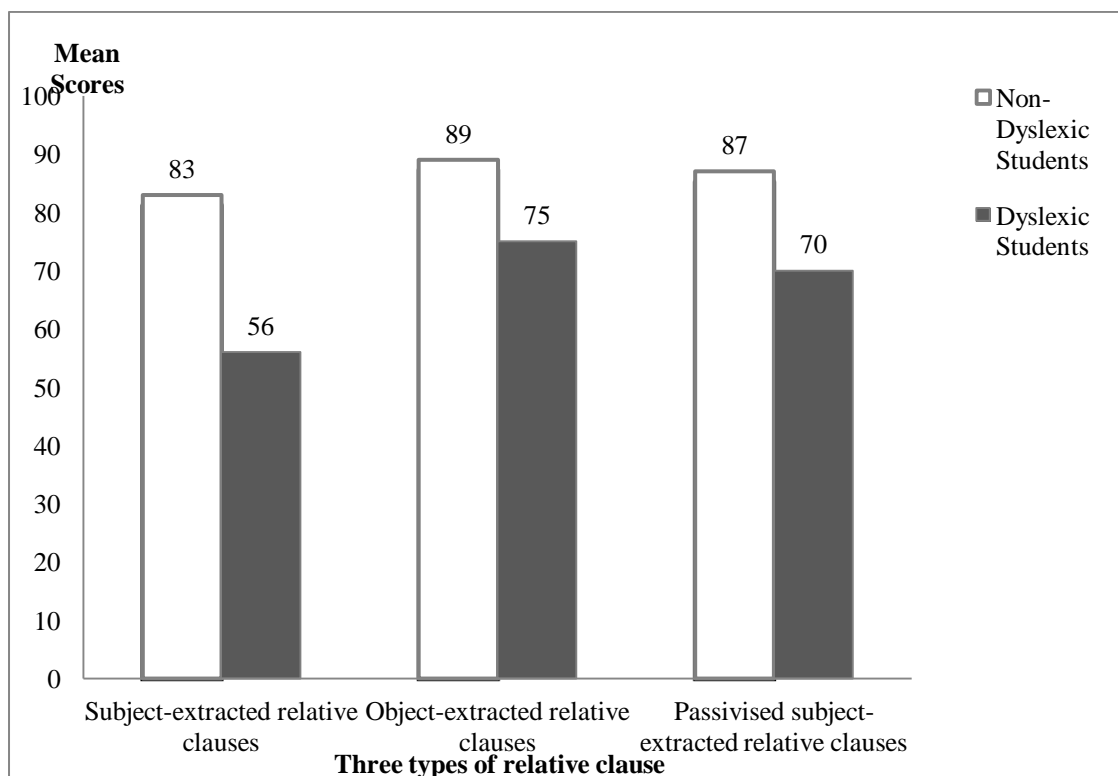


Figure 2: Results of the comprehension of three types of relative clause in the whole test

Figure 2 shows that all students scored lowest on the comprehension of subject-extracted relative clauses, and highest on object-extracted relative clauses. Dyslexic students did not comprehend all three types of relative clauses similarly well as non-dyslexic students. T-test results show significant differences between the two groups in the comprehension of passivized subject relative clauses ($t=-2.49$, $df=86$, $p<0.05$) and object relative clauses ($t=-1.82$, $df=86$, $p<0.05$), and the most significant difference was shown in the comprehension of subject-extracted relative clauses ($t=-2.57$, $df=86$, $p<0.001$), due to the heaviest working memory load being involved in this type of relative clauses. The important role of working memory in the comprehension of relative clauses by dyslexic students will be discussed in the following section.

5. DISCUSSION

The results of this study indicate that Chinese dyslexic children have difficulty in the listening and reading comprehension of relative clauses. Their ability is significantly lower than their non-dyslexic counterparts', not only in reading comprehension, but also in listening comprehension. We argue that there is a close relationship between working memory and sentence comprehension by dyslexic children, regardless of reading or listening comprehension abilities.

The significant role that working memory plays in sentence comprehension is reflected in this study. In both the listening and the reading comprehension of sentences, the participants need to keep all the sentential elements in their working memory, and connect and relate them for comprehension. If children have better working memory, the sentential elements can be kept, connected and related better, which will facilitate sentence comprehension. In contrast, a weaker working memory will adversely affect the proper storage and connection of sentential elements by dyslexic children, which will cause them sentence comprehension difficulty.

In the comprehension of the three types of relative clauses, the dyslexic children comprehended all types of RCs significantly less accurately than non-dyslexic children. The most significant difference between the two groups was found in the comprehension of subject-extracted RCs, which involves the most demanding working memory when compared with the other two types of RCs, which is explained below.

As shown in the following sentence with a subject-extracted relative clause, a Chinese relative clause is right-branching, with the head noun at the right of the clause. The linear surface structure of the subject-extracted relative clause is VOS, with the Verb as Action, the Object as Patient, and the Subject as Agent. To process the subject-extracted relative clauses, the participants need to: (1) keep the VO structure in the initial part of the relative clause in working memory until they reach the subject of the clause; and (2) restructure the VOS order to SVO order to comprehend the meaning of the clause. Following this, they connect the RC with the remaining part of the sentence in order to comprehend the meaning of the whole sentence.

[V (action) O (patient) S (agent)] RC

追著小兔的那隻小肥豬是淺灰色的。

Chasing little rabbit complementizer demonstrative classifier little fat pig is light grey color particle
(The little pig which is chasing the little rabbit is in light grey color.)

In contrast, as indicated in the object-extracted relative clause given below, the surface structure of the RC is SVO. In the comprehension of object-extracted relative clauses, unlike in subject-extracted relative clauses, storage of VO structure in working memory for restructuring is not needed.

[S (agent) V (action) O (patient)] RC

小男孩推著的那個女孩穿著灰色的外套。

Little boy pushing complementizer demonstrative classifier girl wearing grey color particle jacket
The girl who is pushing a little boy is wearing a grey jacket.

With regards to the passivized subject-extracted relative clause shown below, although the surface linear structure is OVS, instead of SVO, the object is an agent, and the subject is the patient. The semantic roles of the three sentential elements in order are Agent-Action-Patient, an ordinary semantic word order in Chinese, and therefore it is not difficult to process this type of RC. Unlike the subject-extracted relative clause, the passivized subject-extracted relative clause does not require storage of sentential elements in working memory for re-structuring. As a result, both of the two participant groups comprehend passivized subject-extracted relative clauses better than subject-extracted relative clauses.

[O (agent) V S (patient)] RC

被小女孩拍著的那個男孩拿著一個書包。

Case marker little girl patting complementizer demonstrative classifier boy carrying one classifier schoolbag
(The boy who is being patted by the little girl is carrying a schoolbag.)

With regard to the comprehension of object-extracted and passivized subject-extracted relative clauses, the latter structure includes the additional meaning of passivation, and therefore, the participants scored lower on the comprehension of the latter structure than the former one. However, despite the fact that the additional meaning of passivation is included in passivized subject-extracted relative clauses, they are comprehended better than subject-extracted relative clauses involving demanding working memory load. We argue that as dyslexic students have weaker working memory in comparison with non-dyslexic students, they have greater difficulty in processing and comprehending subject-extracted relative clauses.

6. CONCLUSION

To sum up, the results of this study show that there is a close relationship between working memory and sentence comprehension by Chinese dyslexic children. In this study, Chinese dyslexic students, in comparison with non-dyslexic counterparts, are weaker in the comprehension of relative clauses not only in reading, but also in listening. Working memory plays an important role in sentence comprehension by dyslexic children, regardless of reading or listening comprehension. Furthermore, subject-extracted relative clauses, compared with object-extracted relatives and passivized subject-extracted relatives, require demanding working memory for restructuring the sentential elements, and therefore cause comprehension difficulties among dyslexic children.

The findings of this study shed light on the enhancement of sentence comprehension by Chinese dyslexic children. It is suggested that not only the training of reading comprehension, but also the enhancement of listening comprehension, is required in the teaching of dyslexic students. The training of working memory is beneficial to the enhancement of sentence comprehension in reading and listening by dyslexic students. Language games and computerized language tasks, such as word repetition, word connection, or sentence repetition, could be designed for the training of verbal working memory.

7. ACKNOWLEDGMENT

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