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Effects of Structural Priming and Lexical Residual Activation on the Acquisition of the English "Noun + Relative Clause" by L1 Chinese Learners

Xueli Li[a], Nattama Pongpairoj[b,*]

[a] lixueli85068@hotmail.com, English as an International Language Program, Graduate School, Chulalongkorn University, Thailand
[b] pnattama@gmail.com, English as an International Language Program, Graduate School, Chulalongkorn University, Thailand
[*] Corresponding author, pnattama@gmail.com

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ABSTRACT

This study investigated L1 Chinese learners' acquisition of the English "Noun + Relative Clause（N + RC）" based on Structural Priming (SP)(Bock,1986; Bock & Griffin, 2000) and Lexical Residual Activation (LRA)(Cleland, 2003). It was hypothesized that, based on SP, when L1 Chinese learners were primed by the English "N+ RC", when the priming and the target structures shared different head nouns, they would produce more "N+ RC" than when they were primed by the English "Adj + Noun (Adj + N)", and the priming effect was significant. Also, based on SP and LRA, when the priming and the target structures shared the same head noun, the increasing priming effect would be enhanced. The participants were 90 first year non-English major Chinese students attending Guizhou University of Finance and Economics, and 10 native English speakers. A picture description task was used to elicit data. The results confirmed the hypotheses. The study also found that there were different SP and LRA effects for L1 speakers and L2 speakers in that, while L2 speakers were significantly affected, L1 speakers were not. A long-term priming effect was found indirectly after the priming "Simple Sentence". The study contributed to Second Language Acquisition in that SP and LRA would facilitate L1 Chinese learners' acquisition of the English "Noun + Relative Clause", although this structure is non-existent in the learners' L1. The study also gave pedagogical implications in that the application of SP and LRA would facilitate the acquisition of the L2 structures.

Keywords: structural priming, lexical residual activation, the English noun + relative clause, L1 Chinese learners

Introduction

There is a common phenomenon in that people prefer to reuse sentence structures that they have heard or used previously, and we call this structural priming (SP) (Bock, 1986). The sentence appearing previously is called the priming sentence, and the latter sentence is called the target sentence.

In the past decades, SP has been widely scrutinized. Such studies concerning SP were mainly focused on four directions: SP and mental representation of syntactic knowledge (Bock, 1989), SP and language comprehension (Nitschke & Kidd, 2013), SP and language production (Chang et al., 2003), and SP in different populations (Schoonbaert et al., 2007). Most of these studies employed dative structures (Prepositional Dative and Double-Object Dative, e.g. She gave a book to Susan. She gave Susan a book.) and transitive structures (Passive and Active, e.g. The cat was chased by the dog. The dog chased the cat.) Only a few studies focused on noun phrases ("Adj + N" and "N + RC") (Bernolet et al., 2007; Cleland, A. 2003; van Beijsterveldt & van Hell, 2009). The participants of the previous studies that focused on "Adj + N" and "N + RC" structures were native English speakers and native Dutch speakers, and both languages included "Adj + N" and "N+ RC" structures. However, since Chinese is a left branch language, the "Adj + N" and "RC + N" structures are existed. Previous studies have shown that L1 Chinese learners produce less English "N + RC". The reasons for this have been attributed to avoidance (Schachter, 1974), a lower proficiency in relative clauses in Chinese (Bley-Vroman & Houng, 1988), and language transfer at the discourse level, pragmatic level, and the syntactic level (Chiang, 1980; Chang, 2004; Yip & Matthews, 2000). If SP can help L1 Chinese learners produce more "N + RC", it could be meaningful for their acquisition of English.

Previous studies have shown that if the priming and target sentences shared the same verb, the priming effect was enhanced (Cleland & Pickering, 2006). This effect is referred to as lexical boost and is attributed to lexical residual activation (LRA) (Pickering & Ferreira, 2008). However, there have been only a few studies conducted in native English and Dutch speaker contexts that focused on noun repetition between the priming structure and target (van Beijsterveldt & Hell, 2009; Cleland & Pickering, 2003).

To the best of our knowledge, there has been no study focused on the context of L1 Chinese speakers' acquisition of "N+ RC" based on SP and LRA. Therefore, the present study aimed to investigate the effect of SP on the acquisition of English "N+ RC" by L1 Chinese learners when the priming and the target shared the same noun and different nouns based on the two accounts. Two hypotheses were therefore formulated:

1. L1 Chinese learners produce more "N+ RC" phrases when they are primed by the English "N+ RC" structure, and the priming effect is significant.

2. When the priming "N + RC" and the target share the same noun, L1 Chinese learners produce more "N+ RC" phrases, and the priming effect is enhanced based on the LRA.

Literature review

Lexical residual activation

Lexical residual activation means that once a word is used, then the properties and structures linked to the word are activated. In the following language production process, if the same word occurs again, then the residual of the activated word would activate the same properties and structures linked to the word. Speakers would probably reuse the same structure that linked to the word as the previous sentence. It is short-lived. (Pickering & Ferreira, 2008)

According to the findings of Pickering and Branigan (1998), the frequent use of a specific syntactic representation is attributed to the residual activation of combinatorial nodes. These nodes connect individual lexical items to represent the various ways in which these items can be combined in a sentence. The authors also suggest that structural priming can be facilitated by the

repetition of content words, leading to enhanced priming effects. This enhancement is thought to occur due to the residual activation of both combinatorial and lemma nodes, as well as the links between them (Pickering & Ferreira, 2008). Specifically, when the priming sentence and the target sentence differ in their verbs, the increased priming effect is attributed to the residual activation of the combinatorial nodes, such as in the NP-PP NP-NP structure. Conversely, when the priming sentence and the target sentence share the same verb, the heightened priming effect is a result of residual activation in the lemma node and its connections with the combinatorial node, known as lexical residual activation.

Implicit learning

The theory of lexical residual activation can easily clarify the short-term priming effects, but it falls short in justifying the long-term priming effects. As a result, the error-based implicit learning theory has been suggested (Chang et al., 2006; Jaeger & Snider, 2013; Dell & Chang, 2014). According to implicit learning, when speakers unconsciously predict the upcoming input but are unable to meet their prediction, it leads to structural priming. The errors in their prediction enable them to modify their implicit knowledge and skills, which could help them acquire the construction in the long run. Implicit learning is an inherent characteristic of SP.

Previous studies have found that SP could last after several intervals, one day, or even after a week (Bock & Griffin, 2000; Bock et al., 2007), which has presented convincing proof that SP is an exemplar of the implicit learning mechanism.

Inverse preference effect and cumulative priming effect

According to the inverse preference effect, when participants are primed with a rarer structure, they tend to produce more instances of that structure (Scheepers, 2003) This finding has been supported Jaeger and Snider (2008).

The cumulative priming effect signifies that the intensity of the priming effect is amplified with each successive prime that precedes it (Jaeger & Snider, 2013; Fine & Jaeger, 2016; Tooley & Traxler, 2018). Shin and Christianson (2012) observed marginal enhancement in grammaticality judgment tests after structural priming sessions. On the other hand, Kim and McDonough (2016) discovered that the priming effect persisted even after two weeks in L2 learners' comprehension of English passives, indicating that implicit learning mechanisms apply to both language production and comprehension. These findings provide evidence for the significance of the implicit learning mechanisms in both aspects of language.

Structural Priming and L2 learning

The study of structural priming has mainly focused on monolingual speakers in various contexts and modes of communication. However, there is a growing interest in investigating structural priming in second language acquisition to gain insights into how non-monolingual speakers use language and its implications for language instruction.

Factors that have been claimed to modulate the SP effects are lexical repetition, proficiency level, frequency, and duration.

Various studies have shown that lexical repetition is present with both monolingual and L2 speakers, indicating that it has a role to play. Mahowald et al. (2016) confirmed this finding, suggesting that the lexical repetition effect is not specific to any particular type of speaker.

The frequency of using one's L1, L2, or a combination of both in second language speech production has been a major focus of research. Studies on highly proficient L2 English speakers have found that the presence or absence of a particular structural alternative in their L1 had little effect on the strength of their L2 priming (Nitschke et al., 2014; Shin & Christianson, 2012). The results of these studies indicate that, for individuals who are highly proficient in their second

language, the influence of their native language experience on within-language structural priming in their second language is not significant.

Jackson and Ruf (2016) conducted a study with L2 German speakers and found that in a post-priming task, they were more influenced by fronted temporal phrases instead of fronted locative phrases because the former was used more commonly in German. Kaan and Chun (2018) also conducted a similar study with L2 English speakers, whereby they were primed with the double object construction since they had a preference for the prepositional construction in a baseline task. Although the preference for prepositional construction remained, the number of double object constructions increased, indicating that L2 speakers are more influenced by the construction that is most frequently used in their L2. Unlike monolingual speakers, L2 speakers tend to show a frequency effect rather than an inverse frequency effect.

Until now, only a few studies have investigated the long-term effect of structural priming on language learning. Jiang and Huang (2015) and Shin and Christianson (2012) have shown promising results in this field. Jackson (2018) emphasized the need for more research on different L2 structures and languages to assess the usefulness of structural priming as a pedagogical tool.

Although research has examined various English structures, such as passive and active, prepositional dative structure and double object structure. limited studies have explored "N + RC". Therefore, this study aims to investigate how intermediate L1 Chinese-L2 English speakers acquire the "N + RC" construction in English using both SP and LRA. This research is expected to make a valuable contribution to language acquisition of intermediate L2 learners and provide insights into the pedagogical implications of second language acquisition.

Methodologies

Participants

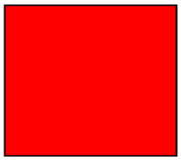
The participants were ninety native Chinese speakers and ten native English speakers. The native Chinese speakers were first-year students from Guizhou University of Finance and Economics, Guiyang, Guizhou, China, with an age range from 18 to 21 years (*M=19.34, SD=0.90*). Eighty-three females and 7males. They were all intermediate English proficiency level students according to the Quick Placement Test (Syndicate, 2001), with scores ranging from 30 to 46 (*M=39.03, SD=5.40)*. With respect to English educational experience, 32.9% have learned English for 6 to 8 years, 67.1% for more than 8 years, and none had experiences of learning English in an English-speaking country. Regarding the native English speakers, they were people from New Zealand, the USA, and England. They had a bachelor's degree and received their education in their respective country. They were aged from 35 to 49, with a mean age of 44.

Materials

The materials for the experiment consisted of a set of pictures and a set of spoken sentences. Regarding the pictures, 16 place-holder pictures were included, which could be described with a simple sentence, a compound sentence, or other structures other than "N + RC" and "Adj + N" phrases (See example in Picture 1). Twenty-four target pictures were also included, which could be described with a "N + RC", "Adj. + N", or other structures, such as a simple sentence "there is a square" (See example in Picture 2).

Picture 1
Example of a place-holder picture

Picture 2
Example of a target picture



With respect to spoken sentences, there were three groups of priming phrases consisting of 24 "Adj + N" structures, 24 "N + RC" structures (the priming phrase and target picture had a different head noun), and 24 "N + RC" structures (the priming phrase and target picture shared the same head noun). Sixteen simple English sentences were used as the place-holder sentences, and half were repeated for the sake of making the experiment appear as a memory test. The place-holder sentences and the priming phrases were read by a native English speaker at normal speed and recorded by an audio microphone.

Table 1

Example of place-holder sentences for the experiment

The teacher went to school.
The boy is drinking water.
The girl loves cats.

Table 2

Examples of the priming structures for the experiment

"N + RC" structure	A square that is blue
	A cake that is yellow
	A car that is black
"Adj + N" structure	A blue square
	A yellow cake
	A black car

Design of the experiment

Latin Square Design was employed in the current study, as shown in Table 3:

Table 3

The Latin Square Design in the current study

Groups	Materials					
Group One	1a 2b 3c 4d	5a 6b 7c 8d	9a 10b 11c 12d	13a 14b 15c 16d	17a 18b 19c 20d	21a 22b 23c 24d
Group Two	1b 2c 3d 4a	5b 6c 7d 8a	9b 10c 11d 12a	13b 14c 15d 16a	17b 18c 19d 20a	21b 22c 23d 24a
Group Three	1c 2d 3a 4b	5c 6d 7a 8b	9c 10d 11a 12b	13c 14d 15a 16b	17c 18d 19a 20b	21c 22d 23a 24b
Group Four	1d 2a 3b 4c	5d 6a 7b 8c	9d 10a 11b 12c	13d 14a 15b 16c	17d 18a 19b 20c	21d 22a 23b 24c

Note: 1, 2, 3, 4…represent the sequence of items; a, b, c, d represent "Adj + Noun", "Noun + RC (The priming and target shared different noun DN)", "Noun + RC (priming and target shared the same noun SN)", and "Simple Sentences", respectively.

As shown above, this is a 4*4 Latin Square Design, which means that there are four rows and four columns, and in each row and each column "a", "b", "c", "d" appears only once. There were twenty-four items, and each item had four conditions "a", "b", "c" and "d", so there were six 4*4 Latin Squares. The reason why the Latin Square Design was used is that it ensured that the experiment was random and balanced all the factors that may affect the experiment, such as the sequence of the materials that the participants received, and the format of the materials. Each group received all the four priming phrases, one condition of each of the four items. For example, see Table 4.

Table 4

*An example of the 4*4 Latin Square Design in the current study*

Groups	Treatment			
Group One	A red square	A star that is blue.(DN)	A man who is fat.(SN)	Tom is a student.
Group Two	A square that is red (DN)	A star that is blue.(SN)	Mike is good at jumping.	A black bird.
Group Three	A square that is red (SN)	Lucy like animals.	A fat man.	A bird that is black.(DN)
Group Four	Jack is playing football.	A blue star.	A man who is fat. (DN)	A bird that is black.(SN)

Table 4 shows one example of the 4*4 Latin Square design which was used in the current study. Each group received four different priming treatments at random.

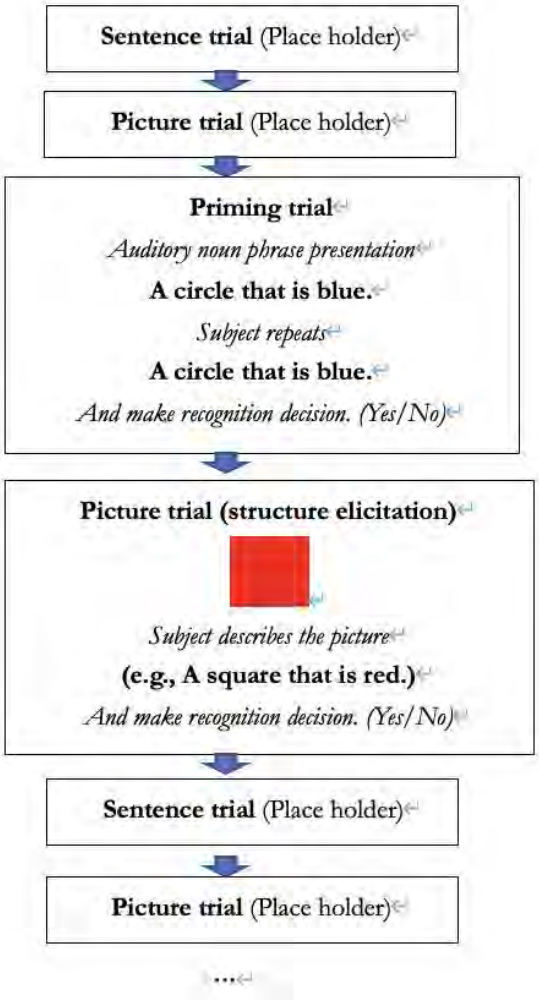
The place-holder sentences and place-holder pictures were used to segment the priming trials, and half of the place-holder sentences and places-holder pictures were repeated in order to ensure that the experiment looked like a memory test. The materials for each group begin with a place-holder sentence and a place-holder picture; then, in the following sequence, the place-holder sentences and place-holder pictures were placed between the successive priming trials.

Procedure

The experiment was conducted in a computer laboratory using the E-prime 2.0 software system. The four groups received similar stimuli. The process began with two consecutive place-holder trials, one was a sentence trial, the other a picture trial, followed by a priming trial and a target picture trial, then a place-holder sentence and picture trial, and so on, until completion of the experiment**.**

Figure 1

Process for the sample structural priming trial for the participants



For each sentence trial, the participants listened to the audio sentence, then repeated it aloud, and made a recognition decision whether it had appeared previously in the experiment or not. The participants were told that repeating the audio sentence aloud can help them to memorize it. The real aim of repeating the audio sentence was to ensure that the subjects had heard the sentence clearly. The same process was used for all the sentence trials, no matter whether the place-holder sentence trial or priming trial, so that the participants could not distinguish the trial's type. For the picture trials, the participants were required to describe the picture, and then make a recognition decision whether the picture had appeared previously in the experiment. Regardless of whether the picture was a place-holder picture trial or a target picture trial, the process was the same to ensure that the trial types were indistinguishable by the participants. What should be mentioned was that the priming sentences were always followed immediately by the target pictures.

All the tasks for the experiment were controlled by the E-prime 2.0 software. The experiment began when the participant pressed the button on the screen. For the sentence trial, after pressing the "Listen" button, the participants heard the audio sentence. By pressing the "Repeat" button, the participants can repeat and record their spoken repetition. Then, by pressing the space key, the message "Have you heard this sentence in this test?" was displayed on the screen. Below the sentence, there were two buttons, "Yes" and "No". The participants made the recognition decision by pressing "Yes" if they had heard the sentence before, or "No" if they had not heard the sentence. For the picture trial, the picture appeared on the screen, the "Describe" button was placed beneath the picture. The subjects were asked to record their description by

pressing the "Describe" button. Then by pressing the space key, the question "Have you ever seen the picture in this test?" appeared on the screen, with the buttons "Yes" and "No" blow. The participants pressed the "Yes" button if they had seen the picture previously, and the "No" button if they had not seen the picture. The participants' descriptions and repetitions were recorded by headset microphones connected to the computers. The audio sentences were also played through the same headset microphones.

Scoring

In the scoring of the production, omission of any articles and the use of the definite article and indefinite article was allowed (van Beijsterveldt & Janet G van Hell, 2009). If the production included "Adj + Noun", it was categorized as "Adj + Noun", if the production consisted of a "Noun + Relative Clause", it was categorized as "Noun + Relative Clause", and any other kind of production was categorized according to its structure, respectively.

Data analysis

The measurement of each structural type was calculated, as shown in below:

$$\frac{\text{Number of N+RC}}{\text{Number of (N+RC)+(Adj+N)+(Others)}} \times 100\% = \text{N + RC (\%)}$$

$$\frac{\text{Number of Adj+N}}{\text{Number of (N+RC)+(Adj+N)+(Others)}} \times 100\% = \text{Adj + N (\%)}$$

$$\frac{\text{Number of Others}}{\text{Number of (N+RC)+(Adj+N)+(Others)}} \times 100\% = \text{Others (\%)}$$

The number of "N+ RC" divided by the sum of the number of "N+ RC", "Adj. + N", and other sentence structures multiplied by 100% was the percentage proportion of the "N + RC" phrases. For example, if the total number of "N +RC" was 36, and the sum of the number of "N + RC", "Adj + N", and other sentence structures was 72, the calculation was (N + RC) %=36/72 × 100%=50%. For the proportion of "Adj + N", and other sentence structures, the calculation process was the same.

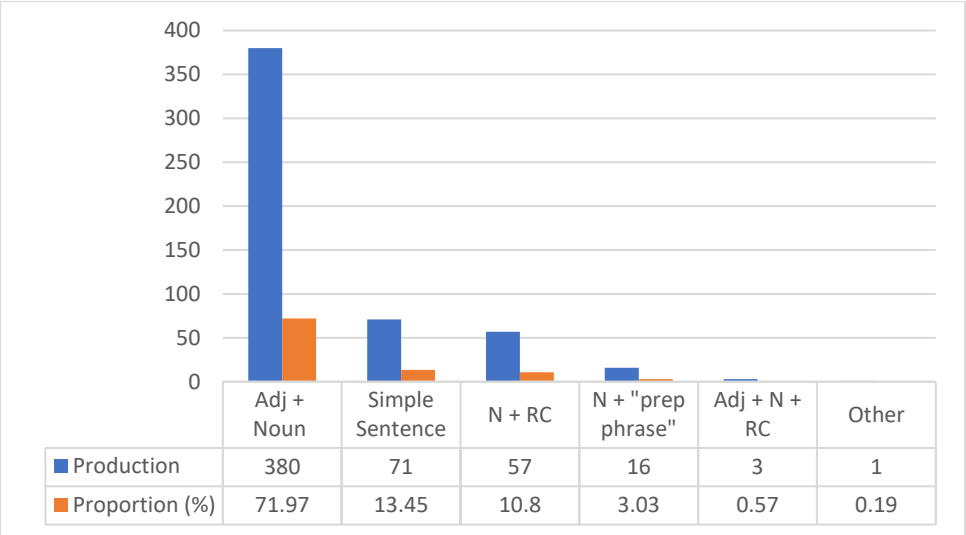
The IBM SPSS Statistic 23 process were employed, and the two-way ANOVA process used to analyze the variance of the production under different stimulus situations. The effect was treated as significant if the probability related to each was less than .05.

Findings and data analysis

Findings and data analyses of L1 Chinese learners' production of English sentences and phrases

Figure 2

Different structure types produced by L1 Chinese Learners when the priming was the English "Adj + N"

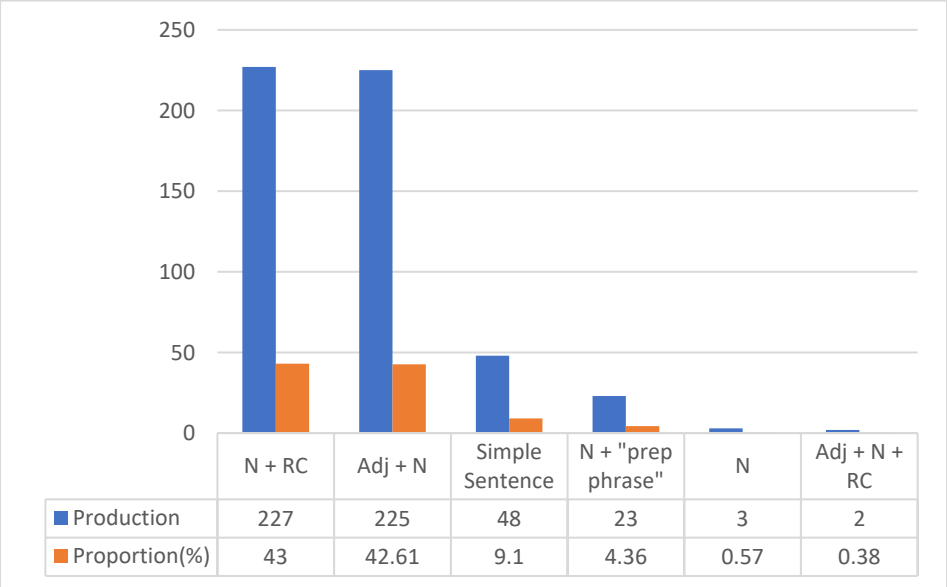


	Adj + Noun	Simple Sentence	N + RC	N + "prep phrase"	Adj + N + RC	Other
Production	380	71	57	16	3	1
Proportion (%)	71.97	13.45	10.8	3.03	0.57	0.19

Figure 2 shows the different structure types produced by the L1 Chinese participants when primed by the English "Adj + N". The top three productions were 380 "Adj + N" structures, 71 "Simple sentences", and 57 "N + RC". The percentages were 71.97%,13.45%, 10.80%, respectively.

Figure 3

Different structure types produced by L1 Chinese Learners when the priming was the English "N + RC" when the priming and target shared different nouns

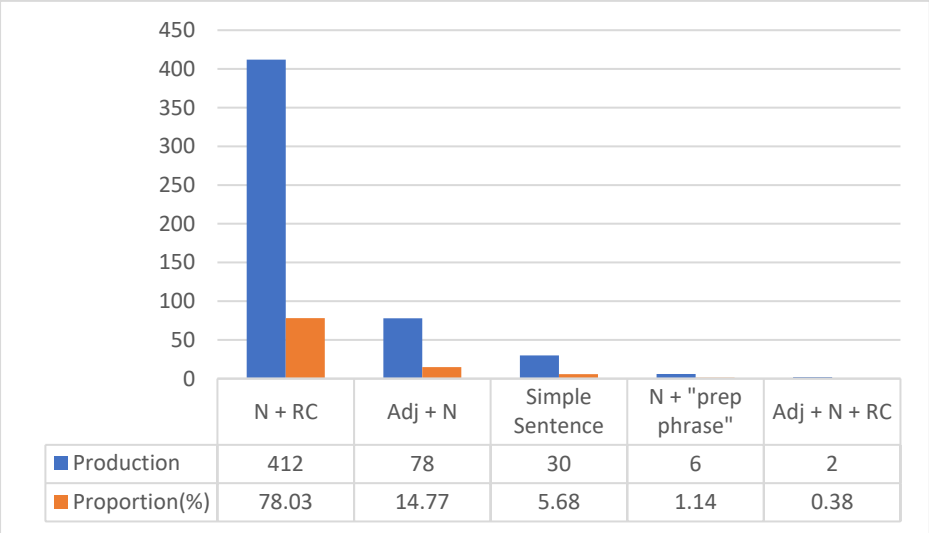


	N + RC	Adj + N	Simple Sentence	N + "prep phrase"	N	Adj + N + RC
Production	227	225	48	23	3	2
Proportion(%)	43	42.61	9.1	4.36	0.57	0.38

Figure 3 shows different structure types produced by L1 Chinese learners when the priming was the English "N + RC", and the priming and target shared different nouns. The L1 Chinese participants produced 528 sentences and phrases in total. The top three structures produced were 227 "N+ RC", 225 "Adj + N", and 48 "Simple sentences". The percentages were 43%, 42.61% and 9.1%, respectively.

Figure 4

Different structure types produced by L1 Chinese Learners when the priming was the English "N + RC" with the priming and target shared the same noun

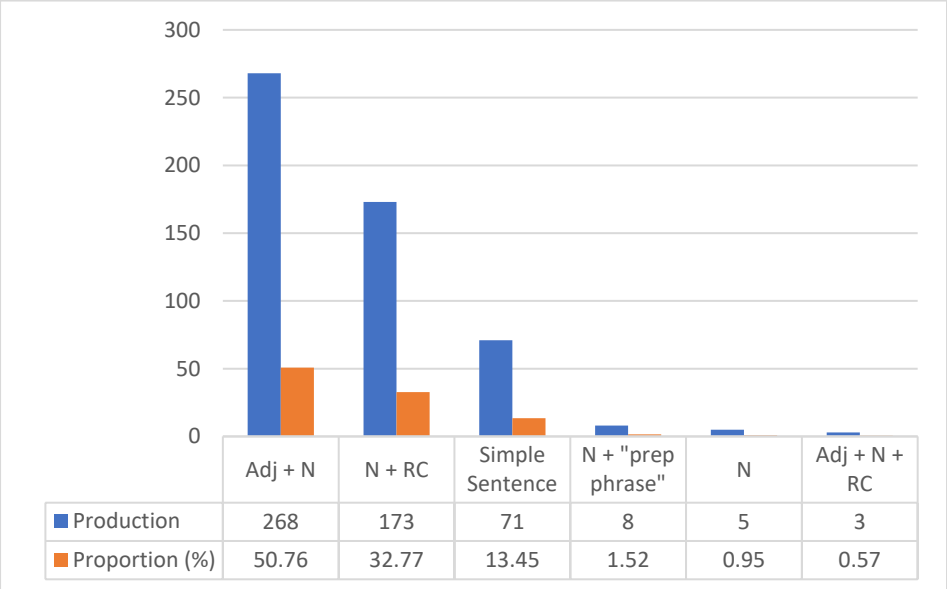


	N + RC	Adj + N	Simple Sentence	N + "prep phrase"	Adj + N + RC
Production	412	78	30	6	2
Proportion(%)	78.03	14.77	5.68	1.14	0.38

Figure 4 shows the number of different structural types of production after the L1 Chinese Learners had been primed by the English "N + RC(SN)". The top three productions were 412 "N + RC", 78 "Adj + N", and 30 "Simple sentences". The proportions were 78.03%, 14.77%, and 5.68%, respectively.

Figure 5

Different structure types produced by L1 Chinese Learners when the priming was the English "Simple Sentence"



	Adj + N	N + RC	Simple Sentence	N + "prep phrase"	N	Adj + N + RC
Production	268	173	71	8	5	3
Proportion (%)	50.76	32.77	13.45	1.52	0.95	0.57

Figure5 shows the number of different types of structures produced when the priming structure was the English "Simple Sentence". The top three were 268 "Adj + N", 173"N + RC", and 71 "Simple Sentence". The proportions were 50.76%, 32.77%, 13.45%, respectively.

Table 5

Descriptive Statistics of L1 Chinese Learners' production

Dependent Variable: N + RC				
Group	Priming	Mean	SD	N
Group One	Adj + N	4.33	1.966	6
	N + RC (DN)	**13.33**	**4.676**	**6**
	N + RC (SN)	**21**	**4.382**	**6**
	Simple Sentence	12.33	2.16	6
	Total	12.75	6.867	24
Group Two	Adj + N	4	1.789	6
	N + RC (DN)	**13.67**	**5.645**	**6**
	N + RC (SN)	**24**	**6.512**	**6**
	Simple Sentence	10.33	3.933	6
	Total	13	8.653	24
Group Three	Adj + N	1.67	1.366	6
	N + RC (DN)	**10.83**	**5.565**	**6**
	N + RC (SN)	**24.17**	**6.616**	**6**
	Simple Sentence	6.67	3.882	6
	Total	10.83	9.631	24
Total	Adj + N	3.33	2.029	6
	N + RC (DN)	**12.61**	**5.158**	**6**
	N + RC (SN)	**23.06**	**5.765**	**6**
	Simple Sentence	9.78	4.023	6
	Total	12.19	8.398	24

Table 5 shows that, when the priming was "Adj + N", "N + RC (DN)", "N + RC (SN)" and "Simple Sentence", the mean production of "N + RC" by Group one was 4.33, 13.33, 21, and 12.33, respectively. With respect to Group two, the mean production of "N + RC" was 4, 13.67, 24, and 10.33, respectively. Considering Group three, the mean production of "N + RC" was 1.67, 10.83, 24.17 and 6.67, respectively.

It could be seen that, L1 Chinese learners produced "N + RC" the most after having been primed by the "N + RC (SN)". The mean numbers were 21, 24, and 24.17 for Group one, Group two and Group three, respectively. After having been primed by "N + RC (DN)", they produced "N + RC" as the top two, and the mean numbers for Group one, two three were 13, 13.67, 10.83, respectively. The L1 Chinese Learners produced fewer "N + RC" after having been primed by "Adj + N" and "Simple Sentence".

Table 6

Tests of the Between-Subjects Effects for L1 Chinese Learners

Tests of Between-Subject Effects				
Dependent Variable: N + RC				
	df	MS	F	Sig.
Priming type	3	1214.981	61.927	.000
Group	2	33.722	1.719	.187

According to the two-way ANOVA, as Table 6 shows, the priming effect between the groups was not significant (*p.>0.05*), which means the three L1 Chinese learner groups produced similar types and numbers of production after having been primed by the four types of structures. The priming effect between the priming types was significant (*p.< 0.001*), which means different priming structures lead to different productions, as shown in Table 5.

Table 7

Multiple Comparisons Between the Priming Types for L1 Chinese Learners

Multiple Comparisons

Dependent Variable : N + RC

LSD

(I) Priming	(J)Priming	MD(I-J)	SE	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Adj + N	N + RC (DN)	-9.28*	1.476	.000	-12.23	-6.33
	N + RC (SN)	-19.72*	1.476	.000	-22.67	-16.77
	Simple Sentence	-6.44*	1.476	.000	-9.39	-3.5
N + RC (DN)	Adj + N	9.28*	1.476	.000	6.33	12.23
	N + RC (SN)	-10.44*	1.476	.000	-13.39	-7.5
	Simple Sentence	2.8*	1.476	.049	-.11	5.78
N + RC (SN)	Adj + N	19.72*	1.476	.000	16.77	22.67
	N + RC (DN)	10.44*	1.476	.000	7.5	13.39
	Simple Sentence	13.28*	1.476	.000	10.33	16.23
Simple Sentence	Adj + N	6.44*	1.476	.000	3.5	9.39
	N + RC (DN)	-2.83*	1.476	.049	-5.78	.11
	N + RC (SN)	-13.2*	1.476	.000	-16.23	-10.33

*The mean difference is significant at the .05 level

Table 7 shows that the priming effect between each priming type was significant (p. < 0.01). This means that after having been primed by different structures L1 Chinese learners' production was not achieved by chance. More specifically, after having been primed by "N + RC (SN)" and "N + RC (DN)", the L1 Chinese Learners produced the top amount of "N + RC", as shown in Table 5, because of the priming structure.

It should be noted that while the priming effect between other priming types was .000, it was significant p=.049 between "N + RC (DN)" and "Simple Sentence", which implies that after having been primed by "Simple Sentence", the L1 Chinese Learners also produced many "N + RC".

Table 8

Multiple Comparisons Between the Groups for L1 Chinese Learners

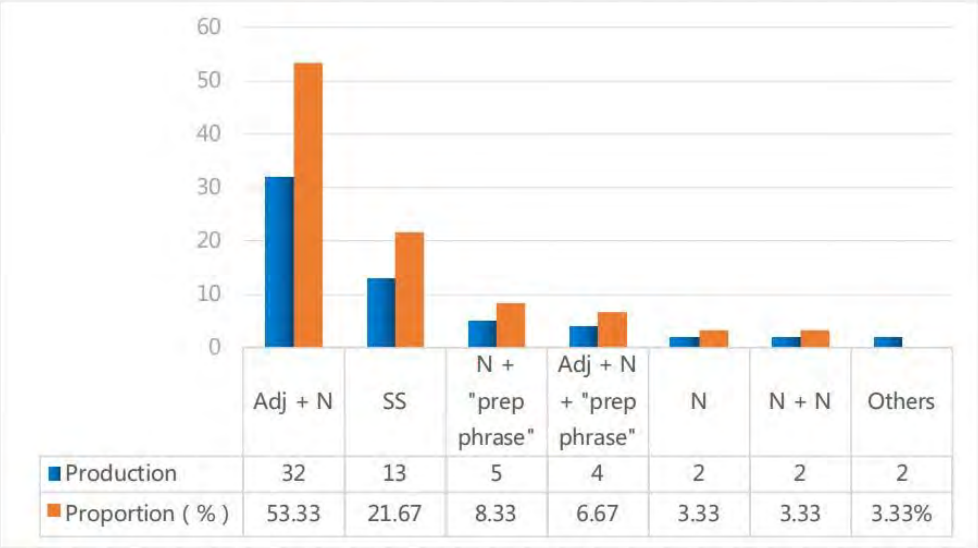
Multiple Comparisons						
Dependent Variable: NRC						
LSD						
					95% Confidence Interval	
(I)Group	(J) Group	MD	SE	Sig.	Lower Bound	Upper Bound
Group One	Group Two	-.25	1.279	.846	-2.80	2.30
	Group Three	1.95	1.279	.139	-.64	4.47
Group Two	Group One	.25	1.279	.846	-2.30	2.80
	Group Three	2.17	1.279	.095	-.39	4.72
Group Three	Group One	-1.92	1.279	.139	-4.47	.64
	Group Two	-2.17	1.279	.095	-4.72	.39

Table 8 shows "Multiple Comparisons between Groups for L1 Chinese Learners". The priming effect between each group was not significant ($p > 0.05$), which means that there was no significant difference among the three groups of L1 Chinese Learners' production.

Findings and data analyses of Native English speakers' production of English sentences and phrases

Figure 6

Different structure types produced by native English Speakers when the priming was the English "Adj + N"



After priming by the English "Adj + N", the native English participants produced the "Adj + N" phrases with the highest percentage (53.33%), the "Simple sentence" second (21.67%), and the "N + prep phrase" third (8.33%). Figure 7 above shows the results in detail.

Figure 7

Different structure types produced by native English Speakers when priming with the English "N + RC" with the priming and target shared different nouns

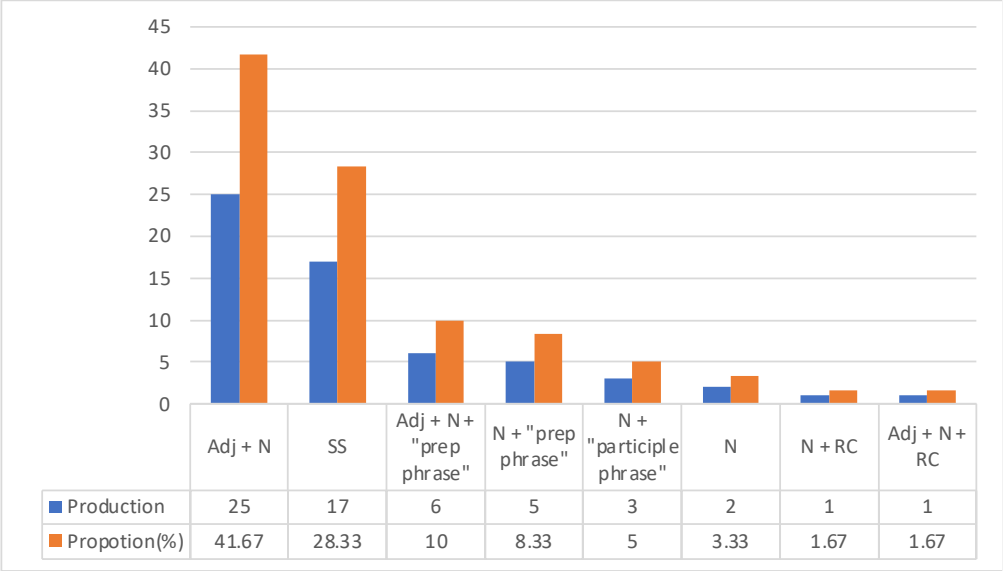
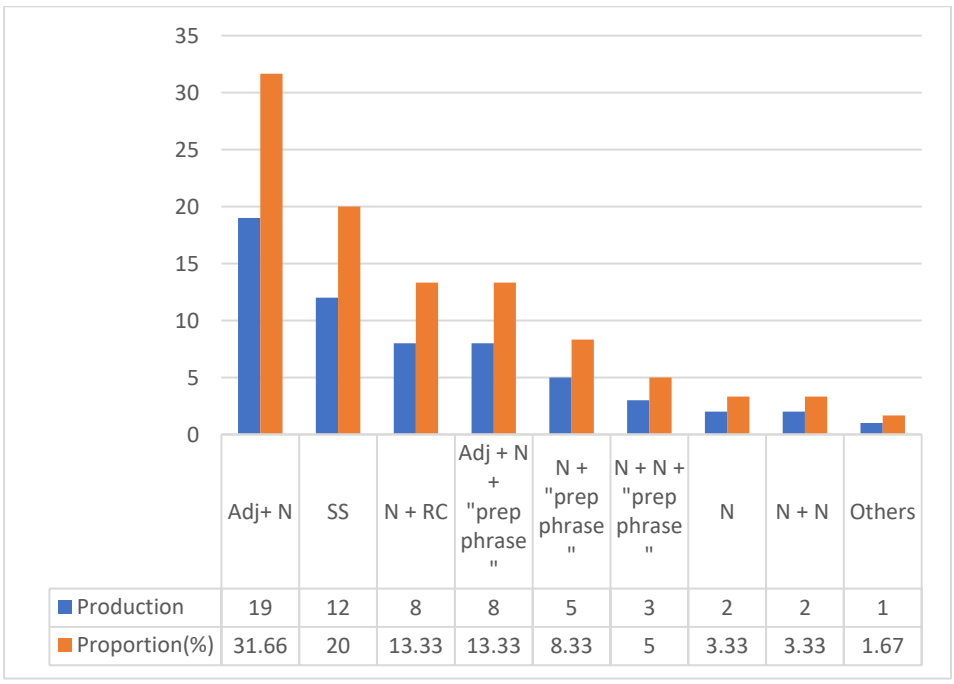


Figure 7 shows that the native English speakers produced 60 sentences and phrases in total, when the priming structure was the English "N + RC", and when the priming and target shared different nouns. The top three were 25 "Adj + N" (41.67%), 17 "Simple Sentences" (28.33%), and 6 "Adj + N + prep phrase" (10%).

Figure 8

Different structure types produced by native English Speakers when the priming was the English "N + RC" with the priming and target shared the same noun



As Figure 8 shows that, having been primed by "N + RC" with the priming and target sharing same nouns, the native English speakers produced "Adj + N", "Simple Sentence", and "N+ RC", "Adj + N + prep phrase", as the top three structural production types. The percentage of each structural type of production was "Adj + N" 19(31.66%), "Simple sentence" 12 (20%), "N + RC" 8 (13.33%) and "Adj + N + prep phrase" 8 (13.33%), respectively.

Figure 9

Different structure types produced by native English Speakers when priming with the English "Simple Sentence"

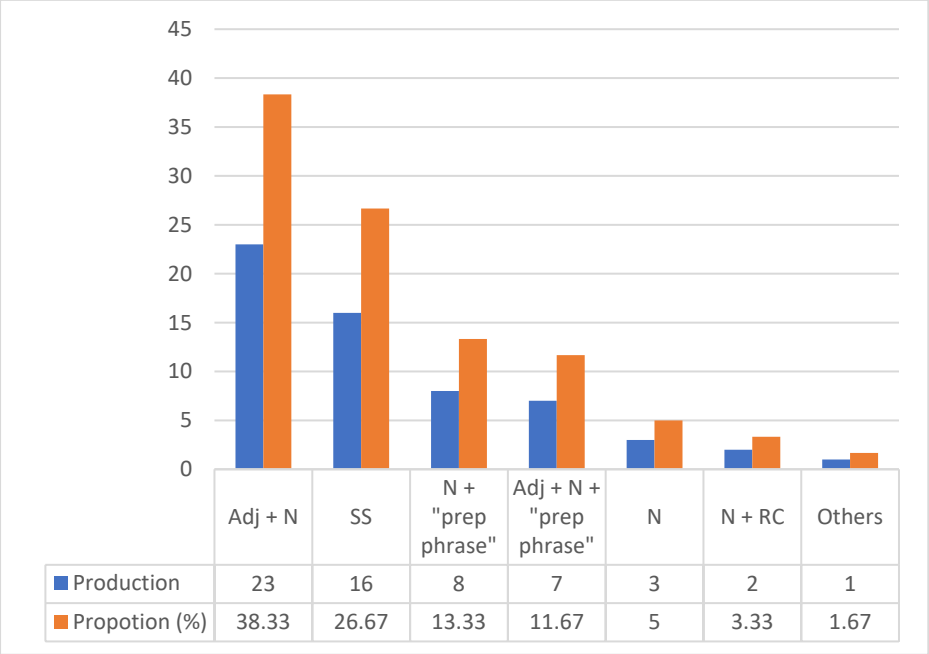


Figure 9 shows that, when the priming structure was the "Simple Sentence", the top three structural types produced were "Adj + N" (23/38.33%), "Simple sentence" (16/26.67%), and "N + prep phrase" (8/13.33%).

Table 9

Descriptive Statistics for the Native English Speakers

Dependent Variable: N + RC			
Priming	Mean	SD	N
Adj + N	.00	.000	6
N + RC (DN)	.17	.408	6
N + RC (SN)	1.33	1.506	6
Simple Sentence	.67	1.633	6
Total	.54	1.179	24

Table 9 shows that after priming by "Adj + N", "N + RC (DN)", "N + RC (SN)", and "Simple Sentence", the mean productions of "N + RC" achieved 0, 0.17, 1.33 and 0.67, respectively.

Table 10

Tests of Between-Subjects Effects for Native English speakers

Tests of Between-Subjects Effects						
Dependent Variable: N + RC						
Source	Type III Sum of Squares	df	MD	F	Sig.	Partial Eta Squared
Corrected Model	6.458[a]	3	2.153	1.688	.202	.202
Intercept	7.042	1	7.042	5.523	.216	.216
Priming type	**6.458**	**3**	**2.153**	**1.688**	**.202**	**.202**
Error	25.500	20	1.275			
Total	39.000	24				
Corrected Total	31.958	23				
a. R Squared = .202 (Adjusted R Squared = .082)						

According to the one-way ANOVA, as shown in Table 11, the priming effect between the priming types was not significant (*p = 0.202)*, which means although different priming structures led to different productions, the difference was not significant as shown in Table 9.

Table 11

Multiple Comparisons between Priming Structures for Native English Speakers

Multiple Comparisons						
Dependent Variable: N + RC						
LSD						
					95% Confidence Interval	
(I)Priming	(J) Priming	MD(I-J)	SE	Sig.	Lower Bound	Upper Bound
Adj + N	N + RC (DN)	-.17	.652	.801	-1.53	1.19
	N + RC (SN)	-1.33	.652	.054	-2.69	.03
	Simple Sentence	-.67	.652	.319	-2.03	.69
N + RC (DN)	Adj + N	.17	.652	.801	-1.19	1.53
	N + RC (SN)	-1.17	.652	.089	-2.53	.19
	Simple Sentence	-.50	.652	.452	-1.86	.86
N + RC (SN)	Adj + N	1.33	.652	.054	-.03	2.69
	N + RC (DN)	1.17	.652	.089	-.19	2.53
	Simple Sentence	.67	.652	.319	-.69	2.03
Simple Sentence	Adj + N	.67	.652	.319	-.69	2.03
	N + RC (DN)	.50	.652	.452	-.86	1.86
	N + RC (SN)	-.67	.652	.319	-2.03	.69

Table 11 shows the "Multiple Comparisons between Priming Structures for Native English Speakers", and the priming effect between different priming structures was not significant ($p > 0.05$), which means that the priming effects for native English speakers was not significant.

Discussion

Results and Discussion of Hypothesis 1 and Hypothesis 2

According to the findings (Figure 3), L1 Chinese learners produced more "N + RC" when the priming structure was "N + RC (DN)", and the priming effect was significant (p. < 0.001) (See Table 7).

The results of this study were consistent with previous research by Bernolet et al. (2007), van Beijsterveldt & van Hell (2009), and Cleland (2003), which demonstrated that priming with a specific structure increased its production. This could be ascribed to LRA. As a result, Hypothesis 1 is confirmed, suggesting that SP can work in both the L1 and L2 contexts. Specifically, this study's findings indicate that SP is effective for intermediate level L2 speakers.

It is worth discussing that the participants produced many "Adj + N" structures after having been primed with the English "N + RC (DN)". This pattern can be explained by two linguistic phenomena known as SP and LRA. Additionally, the frequency and preference of the first language (L1) may also contribute to this phenomenon. For instance, Chinese learners, who primarily use "Adj + N" structures in their L1, are likely to prefer this structure over "N + RC," which does not exist in Chinese. Moreover, "Adj + N" appears more frequently in the Chinese language than "N + RC." These two factors make it more probable for L1 Chinese-L2 English learners to use "Adj + N" following priming with the English "Adj + N" structure (Nitschke et al. ,2010, 2014; Shin and Christianson ,2012; Flett et al., 2013). However, it is difficult to say to what extent these factors affect SP. Future research should focus on this factor.

According to Hypothesis 2, when the priming "N+ RC" and the target share the same noun, L1 Chinese learners produced more "N + RC" phrases, and the priming effect was enhanced based on the LRA.

In accordance with the findings (Figure 4; Table 7), after the L1 Chinese learners had been primed by "N + RC (SN)", the production of "N + RC" was enhanced more than when they were primed by "N + RC (DN)", and this enhancement was significant (p. <0.001).

The results were in line with Cleland (2003), Bernolet et al. (2007) and van Beijsterveldt and van Hell (2009) in that, when priming by a specific structure, and the priming and the target shared same content word, the priming effect was enhanced, and the enhancement was significant (p. < 0.05). The results of the study could be explained through the LRA model proposed by Pickering and Branigan (1998), as discussed in the literature review. The input frequency of the noun appeared to have a significant impact on the priming effect observed, as the noun was frequent in both the prime and target stimuli. Due to the LRA, the activation frequency of the "noun" node was higher than that of other nodes, resulting in an accumulative priming effect for the "N+RC" structure. So, L2 input frequency played an important role in L2 priming. This is in line with Kaan and Chun (2018), in which L2 speakers tended to show a frequency effect rather than an inverse frequency effect.

In contrast to the results of this study, Bernolet et al. (2007) found that bilingual L1 Dutch participants produced more "N+RC" structures when primed with English "N+RC(SN)" than with English "N+RC(DN)", but the enhancement was not significant. The difference in word order between Dutch and English "RC" structures played a crucial role in this effect. When the priming and target structures shared the same word order, the priming effect was more apparent. However, if there were differences in the word order, the priming effect would be less significant. Due to these factors and short-term lexical residual activation, the impact of L1 Dutch "N+RC" on the English production was diminished, resulting in a non-significant enhancement.

The results from the current study, therefore, supported lexical residual activation in that the repetition of the content words could enhance the priming effects. Thus, Hypothesis 2 was supported.

Based on the data presented in Figures 2 and Figure 3, we observed that the production of the English "Adj + N" construction was higher after priming with the "Adj + N" stimulus (380), compared to the "N + RC (DN)" stimulus (225). However, it is noteworthy that production of the "Adj + N" still remained relatively high even after priming with "N + RC (DN)". The decline in production from the prime "Adj + N" to "N + RC (DN)" was significant, but not to a large extent. Therefore, it can be inferred that, while L1 frequency and preference may have some impact on L2 sentence production, the effect is not statistically significant.

L1 Chinese learners' VS Native English Speakers' Performance

The previous results showed that for L1 Chinese learners, the priming effect of "N+RC" was significant regardless of whether the priming and target structures shared the same head noun. When they did share the same head noun, the priming effect was even more pronounced and significant. In contrast, native English speakers showed no significant priming effect, regardless of whether the priming and target had the same or different head nouns.

The results indicate that SP and the LRA model can indeed operate among L2 intermediate level speakers, particularly in short-term or immediate priming effects. This is evident from the study's design, whereby the target pictures immediately followed the priming structures. Native English speakers preferred syntactically simpler structures such as "Adj + N" over "N + RC", particularly when using simple adjectives (Cleland, 2003), which could interpret their performance in the present study.

Language proficiency level can impact priming effect, with lower or intermediate level learners relying more heavily on activated lemmas, nodes, and links (van Beijsterveldt & van Hell, 2009). In this study, the L1 Chinese participants had intermediate English proficiency level and were more influenced by previously activated structures. Additionally, since "N+RC" does not exist in Chinese, they may rely more on imitating structures they had heard previously.

It seems that the results may also be explained by the inverse preference effect (Hartsuiker, et al., 1999; Scheepers, 2003), which is the rarer the structure, the more production the participants would make when primed by that structure. As there is no "N + RC" in Chinese, this structure is unfamiliar for L1 Chinese learners. Therefore, they would be more likely to use the "N + RC" structure that they had recently heard. We have not directly tested the inverse preference effect, making it difficult to determine whether the production of L1 Chinese learners relied on it. While previous studies such as Kaan and Chun (2018) have found that L2 speakers tend to exhibit a frequency effect rather than an inverse frequency effect, further research is still necessary to investigate the presence of the inverse frequency effect in the context of L2 learners.

L1 Chinese learners' performance when the priming structure was the "Simple Sentence"

When the priming structure was the "Simple Sentence", the top three productions by L1 Chinese learners was "Adj + N", "N + RC" and "Simple Sentence". The number and proportion were 268 (50.87%), 173 (36.77%) and 71 (13.45%), respectively.

The results were different from what they should have been according to structural priming and lexical residual activation. Based on these theories, the results should be that, after having been primed by the "Simple Sentence", the L1 Chinese learners should have produced the "Simple Sentence", "Adj + N" and "N + RC" as the top three productions. However, according to Cleland (2003), "Adj + N" is shorter and syntactically simpler than the other two, and so the order should be "Adj + N", "Simple Sentence" and "N + RC".

The results therefore supported the "Accumulate Priming Effect" (Chang et al., 2006; Pickering et al., 2013) and "Implicit Learning" (Bock & Griffin, 2000; Chang, 2006).

According to Pickering and Garrod (2013), the fact that language learners comprehend and produce more structures that they have encountered was mainly because of the accumulation effect. This is because when the participants have heard a structure, the node and the links of that structure are activated. The more times the node and links are activated, the more experiences of that structure are accumulated, and the participants will be more likely to reuse the same structure (Pickering & Garrod, 2013).

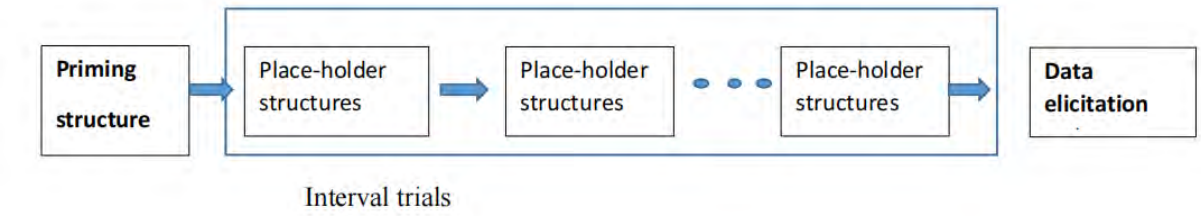
In the current study, each L1 Chinese group received all four types of priming including "Adj+N", "N+RC(DN)", "N+RC(SN)", and the "Simple Sentence". The activation of "N+RC" occurred more frequently than the other two structures, resulting in higher accumulation of this link. This may explain why the participants produced more "N+RC" than "Simple Sentence" after having been primed by the latter.

Bock and Griffin (2000) discovered that structural priming effect can last for fairly long trials without exhibiting any significant decline. These findings align with the idea of implicit learning associated with structural priming. (Chang et al., 2006).

In this study, each group of L1 Chinese learners received an equal number of priming structures, including "Adj + N", "N + RC(DN)", "N + RC(SN)", and the "Simple Sentence". Following the priming of "N + RC(DN)", several space-holder sentences or pictures were presented. After having been primed by the "Simple Sentence", the participants produced more "N+RC" due to the continued effectiveness of the "N+RC" priming effect across multiple interval trials. This is in line with Bock and Griffin (2000), when the process of the task is shown in Figure 10.

Figure 10

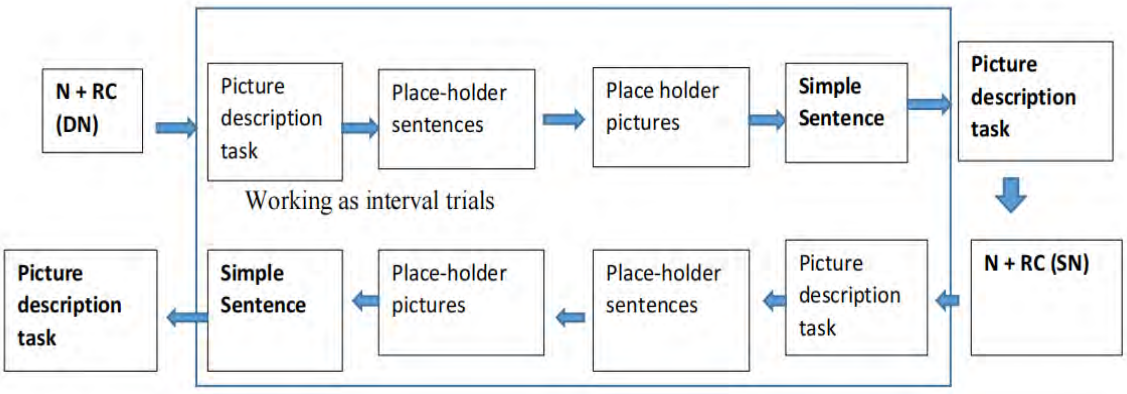
The process of the experiment by Bock and Griffin (2000)



The process of the current experiment is demonstrated in Figure 11:

Figure 11

The process of the experiment in the current study



After several interval trials, the priming effect of "N + RC", no matter with the same noun or different nouns, continued to work. Furthermore, the function of the "Simple Sentence" was part of the interval trials. Therefore, the results supported Bock and Griffin (2000) and Chang (2006) in the L2 context. The results were also consistent with Jiang & Huang (2015), and Shin & Christianson (2012).

The current study, along with previous research by Bock and Kroch (1989), Hartsuiker and Kolk (1998), Boyland and Anderson (1998), Bock (1986), Jiang & Huang (2015), and Shin & Christianson (2011) illustrated those structural priming effects persist over several interval trials. Moreover, Boyland and Anderson (1998) found that priming could remain effective even after a 20-minute delay following multiple repetitions of the priming form. These studies collectively demonstrate that structural priming is not only a short-term activation but also a form of implicit learning (Bock & Griffin, 2000; Chang, 2006).

Conclusions

In this study, the effect of SP and LRA on L1 Chinese learners' acquisition of the English "N+RC" structure was investigated. The findings revealed that priming with "N+RC" resulted in more "N+RC" phrase production, especially when the priming and target shared the same noun. These results supported SP and LRA activation. Additionally, the persistence of SP effect over several intervals demonstrated its role as implicit learning.

Utilizing SP and LRA in teaching can enhance the acquisition of the sentence and phrase structures in the target language, as demonstrated by this study with L1 Chinese learners acquiring the English "N+RC" structure. These findings may apply to other English constructions, such as "Passive Construction", "Dative Construction", and "Accusative Verb Construction". Inclusion of SP and LRA in teaching materials can facilitate learners' acquisition of the targeted linguistic features. For example, teachers could design practice materials for reading or writing that provide example sentences of a structure and then give students a picture or some words to use in creating a new sentence. Additionally, they could make the example sentence and the target sentence include same content words. Such exercises would enable students to apply SP and LRA in their language acquisition effort.

The current study has some limitations, including that long-term SP in L2 learning was indirectly observed rather than directly tested. Future research should design experiments specifically to elicit long-term SP data. Additionally, age and gender factors were not considered in relation to SP and LRA effect; therefore, future studies should explore if these factors play a role. Furthermore, interviews were not included in the data collection process of this study; thus, future research should use interviews to obtain more insightful data from the participants.

About the Authors

Xueli Li: A Ph.D. candidate in English as an International Language Program, Graduate School, Chulalongkorn University, Thailand. Her research interests include psycholinguistics, second language acquisition, and English language teaching.

Nattama Pongpairoj: An associate professor in English as an International Language Program, Graduate School, Chulalongkorn University, Thailand. Her research interests lie in second language acquisition, particularly L2 representations and cognitive processing.

References

Bernolet, S., Hartsuiker, R. J., & Pickering, M. J. (2007). Shared syntactic representations in bilinguals: Evidence for the role of word-order repetition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(5), 931–949. https://doi.org/10.1037/0278-7393.33.5.931

Bley-Vroman, R., & Houng, C. (1988). Why do Chinese use few relative clauses in English?. *University of Hawai'i Working Papers in ESL*, *7*, 93-98.

Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive Psychology*, *18*(3), 355–387. https://doi.org/10.1016/0010-0285(86)90004-6

Bock, J. K., & Kroch, A. S. (1989). The isolability of syntactic processing. *Linguistic Structure in Language Processing*, 157–196. https://doi.org/10.1007/978-94-009-2729-2_5

Bock, K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology: General*, *129*(2), 177–192. https://doi.org/10.1037/0096-3445.129.2.177

Bock, K., Dell, G., Chang, F., & Onishi, K. (2007). Persistent structural priming from language comprehension to language production☆☆☆. *Cognition*, *104*(3), 437–458. https://doi.org/10.1016/j.cognition.2006.07.003

Boyland, J. T., & Anderson, J. R. (2022). Evidence that syntactic priming is long-lasting. *Proceedings of the Twentieth Annual Conference of the Cognitive Science Society*, 1205–1205. https://doi.org/10.4324/9781315782416-225

Branigan, H.P., & Pickering, M. J. (2012). Are non-native structural preferences affected by native language preferences? *Bilingualism: Language and Cognition*, *16*(4), 751–760. https://doi.org/10.1017/s1366728912000594

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition*, *75*(2), B13-B25. https://doi.org/10.1016/s0010-0277(99)00081-5

Chang, Y.-F. (2004). Second language relative clause acquisition: An examination of cross-linguistic influences. National Chung Hsing University.

Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. *Psychological Review*, *113*(2), 234–272. https://doi.org/10.1037/0033-295x.113.2.234

Cleland, A. (2003). The use of lexical and syntactic information in language production: Evidence from the priming of noun-phrase structure. *Journal of Memory and Language*, *49*(2), 214–230. https://doi.org/10.1016/s0749-596x(03)00060-3

Cleland, A., & Pickering, M. (2006). Do writing and speaking employ the same syntactic representations? *Journal of Memory and Language*, *54*(2), 185–198. https://doi.org/10.1016/j.jml.2005.10.003

Dell, G. S., & Chang, F. (2014). The P-chain: Relating sentence production and its disorders to comprehension and acquisition. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1634), 20120394. https://doi.org/10.1098/rstb.2012.0394

Fine, A. B., & Jaeger, T. F. (2016). The role of verb repetition in cumulative structural priming in comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *42*(9), 1362–1376. https://doi.org/10.1037/xlm0000236

Hartsuiker, R. J., & Kolk, H. H. (1998). Syntactic persistence in Dutch. *Language and Speech*, *41*(2), 143–184. https://doi.org/10.1177/002383099804100202

Hartsuiker, R. J., Kolk, H. H., & Huiskamp, P. (1999). Priming word order in sentence production. *The Quarterly Journal of Experimental Psychology Section A*, *52*(1), 129–147. https://doi.org/10.1080/713755798

Jackson, C. N. (2017). Second language structural priming: A critical review and directions for future research. *Second Language Research*, *34*(4), 539–552. https://doi.org/10.1177/0267658317746207

Jackson, C. N., & Ruf, H. T. (2016). The priming of word order in second language German. *Applied Psycholinguistics*, *38*(2), 315–345. https://doi.org/10.1017/s0142716416000205

Jaeger, T. F., & Snider, N. E. (2013). Alignment as a consequence of expectation adaptation: Syntactic priming is affected by the prime's prediction error given both prior and recent experience. *Cognition*, *127*(1), 57–83. https://doi.org/10.1016/j.cognition.2012.10.013

Jiang, L., & Huang, K. (2015). The efficacy of structural priming on the acquisition of double object construction by Chinese EFL learners. *Higher Education Studies*, *5*(5), 38–49. https://doi.org/10.5539/hes.v5n5p38

Kaan, E., & Chun, E. (2018). Priming and adaptation in native speakers and second-language learners. *Bilingualism: Language and Cognition*, *21*(2), 228–242. https://doi.org/10.1017/s1366728916001231

Kim, Y., & McDonough, K. (2016). Prime repetition and Korean EFL learners' comprehension and production of passives. *International Review of Applied Linguistics in Language Teaching*, *54*(4). https://doi.org/10.1515/iral-2015-0028

Mahowald, K., James, A., Futrell, R., & Gibson, E. (2016). A meta-analysis of syntactic priming in language production. *Journal of Memory and Language*, *91*, 5–27. https://doi.org/10.1016/j.jml.2016.03.009

Nitschke, S., Kidd, E., & Serratrice, L. (2010). First Language Transfer and long-term structural priming in comprehension. *Language and Cognitive Processes*, *25*(1), 94–114. https://doi.org/10.1080/01690960902872793

Nitschke, S., Serratrice, L., & Kidd, E. (2013). The effect of linguistic nativeness on structural priming in comprehension. *Language, Cognition and Neuroscience*, *29*(5), 525–542. https://doi.org/10.1080/01690965.2013.766355

Pickering, M. J., & Branigan, H. P. (1998). The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and Language*, *39*(4), 633–651. https://doi.org/10.1006/jmla.1998.2592

Pickering, M. J., & Ferreira, V. S. (2008). Structural priming: A critical review. *Psychological Bulletin*, *134*(3), 427–459. https://doi.org/10.1037/0033-2909.134.3.427

Pickering, M. J., & Garrod, S. (2013). An integrated theory of language production and comprehension. *Behavioral and Brain Sciences*, *36*(4), 329–347. https://doi.org/10.1017/s0140525x12001495

Schachter, J. (1974). An error in error analysis 1. *Language Learning*, *24*(2), 205-214.

Scheepers, C. (2003). Syntactic priming of relative clause attachments: Persistence of structural configuration in sentence production. *Cognition*, *89*(3), 179–205. https://doi.org/10.1016/s0010-0277(03)00119-7

Schoonbaert, S., Hartsuiker, R. J., & Pickering, M. J. (2007). The representation of lexical and syntactic information in bilinguals: Evidence from syntactic priming. *Journal of Memory and Language*, *56*(2), 153–171. https://doi.org/10.1016/j.jml.2006.10.002

Shin, J.-A., & Christianson, K. (2011). Structural priming and second language learning. *Language Learning*, *62*(3), 931–964. https://doi.org/10.1111/j.1467-9922.2011.00657.x

Syndicate U. C. L. E. (2001). Quick placement test. Oxford University Press.

Tooley, K. M., & Traxler, M. J. (2018). Implicit learning of structure occurs in parallel with lexically mediated syntactic priming effects in sentence comprehension. *Journal of Memory and Language*, *98*, 59–76. https://doi.org/10.1016/j.jml.2017.09.004

van Beijsterveldt, L. M., & van Hell, J. G. (2009). Structural priming of adjective–noun structures in hearing and deaf children. *Journal of Experimental Child Psychology*, *104*(2), 179–196. https://doi.org/10.1016/j.jecp.2009.05.002

Yip, V., & Matthews, S. (2000). Syntactic transfer in a Cantonese–English bilingual child. *Bilingualism: Language and Cognition*, *3*(3), 193–208. https://doi.org/10.1017/s136672890000033x