项目编号：IPP18114

“第十八期上海交通大学大学生创新实践计划”
项目研究论文

论文题目：数量词线索对汉-英二语者主谓一致加工的影响：来自 P600 的证据

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项目执行时间：2018 年 09 月 至 2020 年 09 月

The impact of quantificational cues on L2 subject-verb agreement processing: evidence from P600

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ABSTRACT

For English second language learners (i.e. Chinese native speakers), subject-verb agreement poses a huge barrier for them to acquire and produce the language. Compared to native speakers, these L2 English learners face greater agreement processing problems. When discussing the acquisition of a new language, scholars tend to focus on the acquisition of specific syntax features. Typically, three claims have been suggested regarding to L2 learners' syntax processing. One is that novel L2 features can be acquired. The second claim suggests that if L1 and L2 share similar morphosyntactic features, L2 learners are able to acquire these features in L2 learning (the Unified Competition Model; UCM). The third claim coincided with the Shallow Structure Hypothesis (SSH), which holds that L2 speakers can never perform an equally effortless sentence processing as native speakers. In this study, we used event-related brain potentials (ERPs)to investigate the impact of quantificational cues on L2 subject-verb agreement processing of Chinese native speakers by two kinds of quantifiers (definite quantifiers and indefinite quantifiers) and an unquantified determiner (the) as a control group. We found that subject-verb agreement violations with quantified cues before the subject noun phrase in L2 learners would lead to a different processing pattern from native English speakers, while subject-verb agreement violations with unquantified cues elicited similar neural responses in L1 Chinese-L2 English speakers as in English native speakers (P600 effects). The absence of P600 in our participants may be evidence for the Shallow Structure Hypothesis, but it can also be attributed to a lexical processing preference and semantic anticipation. However, we didn't detect significant difference between definite quantifiers and indefinite quantifiers.

KEY WORDS： second language learners, subject-verb agreement, quantification, ERP, P600

1. INTRODUCTION

Subject-verb agreement in English requires that the subject and the verb in a sentence must be consistent in number, i.e., a singular verb follows a singular subject and a plural verb follows a plural subject (Shen, Staub, & Sanders, 2013). For example, in *Dog bites woman* (Eberhard, Cutting, & Bock, 2005), the singular number of the subject (*dog*) is reflected by the singular number of the verb (*bites*).

For some English second language (L2) learners (i.e. Chinese native speakers), subject-verb agreement poses a huge barrier for them to acquire and produce the language. Compared to native speakers, these L2 English learners face greater agreement processing problems. For example, in Pratt and Fernández (2016)'s study, the comprehension of English subject-verb agreement was directly compared between English natives and Spanish-English speakers. They found that the Spanish-English speakers had lower accuracies than the natives when comprehending agreement. The L2 participants were more susceptible to attraction. Ojima et al. (2005) investigated agreement among Japanese-English speakers. The results showed a left negative response for both native speakers and Japanese learners with high proficiency. However, P600 was exclusively found for native participants.

When it comes to English L2 learning, China, where English has been popularized within a large population, cannot be ignored. Linguistic researchers have made a lot of efforts in investigating subject-verb agreement among Chinese-English speakers to further understand L2 acquisition (e.g., Chen et al., 2007; Jackson et al., 2018), and the way Chinese learners of English process subject-verb agreement is still receiving growing attention. Before we proceed to discuss this topic, a broader issue of L2 acquisition should be pointed out.

1.1 The acquisition of syntax for L2 learners

When discussing the acquisition of a new language, scholars tends to focus on the acquisition of specific syntax features. Typically, three claims have been suggested regarding to L2 learners' syntax processing.

One holds that novel L2 features can be acquired (e.g., Foucart & Frenck-Mestre, 2012; Steinhauer, 2014; White, 2003; White et al., 2012). In Wei et al. (2018)'s study, similar lexical priming effects were found between Chinese-English L2 learners and L1 English speakers when they were processing reduced relative clauses. In spite of the typological difference of the two languages, L1 and L2 English speakers had similar lexical mechanisms. Frank et al. (2016) investigated how did German and Dutch proficient L2 English speakers process English sentences with double-embedded relative clauses. They suggested that although German and Dutch had the head-final nature the L2 speakers actually did display the grammatical illusion like English native speakers. Gillion Dowens et al. (2011) found that L1 Chinese learners of Spanish could show a P600 component for Spanish syntactic agreement that is not present in the L1.

The second claim suggests that if L1 and L2 share similar morphosyntactic features, L2 learners are able to acquire these features in L2 learning (e.g., Franceschina, 2001; Hawkins & Franceschina, 2004; Kotz et al., 2008; MacWhinney, 2015; Osterhout et al., 2006). This claim has been systematically concluded by the Unified Competition Model (UCM). The UCM suggests that when we are parsing a sentence, we are parsing a number of linguistic "cues'. It was reported that English native speakers could rely on multiple cues during sentence processing, including but not limited to alphabetic orthographic consistency, form-meaning mappings, syntactic structural cues, non-structural cues such as gender and context. (Lee, 2018; Patil et al., 2016; Rau et al., 2016; Van Assche, Duyck, & Hartsuiker, 2016; Van Dyke & Johns, 2012) Such cues enable native speakers to untangle complex sentence structures and to comprehend without making efforts. According to the UCM, when using or processing their second language, adult L2 learners tend to be influenced by their L1 language system (e.g., [morpho]syntax, phonology, etc.), which has already become deeply entrenched in their brains (Tolentino & Tokowicz, 2011). What differs between L1 and L2 learning is the way in which these processes are configured (MacWhinney, 2011). Several studies did find positive evidence to support this model that the successful acquisition lies in language similarity. For example, Alemán Bañón et al. (2014) examined how English-Spanish speakers processed number agreement. The results indicated that similar to Spanish native speakers, English-Spanish learners showed P600 for violations. Since English and Spanish both contain number agreement, the L2 Spanish learners could generate native-like agreement processing. Morales (2014) also found that the young English-speaking participants who was learning Spanish had a Spanish verbal agreement like native speakers. By contrasting subject-verb agreement within German and English that share the feature, Eubank (1994) and Tanner et al. (2013) pointed out that English-German speakers had a P600 effect regardless of their L2 proficiency, resembling German native speakers who had a P600 component for violations.

The third claim coincided with the Shallow Structure Hypothesis (SSH; Clahsen & Felser, 2006; Heredia et al., 2016). On the premise of the assumption that L1 and L2 speakers have basically the same processing capacity, including physical structures and mental mechanisms, the SSH claims that L2 speakers cannot perform an equally effortless sentence processing as native speakers. Even highly proficient L2 speakers would encounter difficulties when processing abstract syntactic representations in real time. Furthermore, L2 speakers tend to be influenced more strongly than native speakers by semantic, pragmatic, probabilistic, or surface-level information (Clahsen & Felser, 2018). It is difficult to distinguish L2 speakers of high proficiency from native speakers on the surface level. However, the SSH suggests that L2 speakers more or less will have difficulty putting their grammatical knowledge into use during real-time processing. Even those who demonstrate nativelike grammatical knowledge are sometimes found to show non-nativelike processing patterns (Clahsen & Felser, 2018). For instance, Felser and Roberts (2007) found that in comprehending *wh*-dependencies, Greek-English speaking learners had shallow structures more frequently than native speakers to lessen the burden of L2 processing. Neurological evidence has also confirmed the differences. By conducting fMRI study, Suh et al. (2007) suggested that the left inferior frontal gyrus (IFG) was both activated when Korean-English speakers and English native speakers were processing center-embedded and conjoined sentences, but the degree of left IFG activation was different for L1 and L2. For native speakers, the activation was smaller for conjoined sentences than that for embedded sentences, whereas there was no activation difference between the two types of sentences for Korean-English speakers.

The existing discrepant theories concerning L2 processing drives the exploration into the field. This study is interested in finding which above model/theory lies behind the processing of subject-verb agreement for Chinese-English speakers.

1.2 Subject-verb agreement processing for Chinese-English L2 learners

L1 Chinese learners of English have been reported to have difficulty integrating the number of the subject with the verb form during processing. Jia (2003) indicated that Chinese-English learners, even with advanced proficiency, still had problems identifying violations after at least five years of exposure to English. Chen et al. (2007) did an ERP experiment to discuss the syntactic processing obstacles for Chinese leaners of L2 English. The results showed that although the participants managed to detect the violations, their brain responses indicated different patterns from native speakers' pattern. While natives yielded a typical biphasic LAN-P600 effect, the Chinese participants showed a negative pattern from 500ms to 700ms. Jackson et al. (2018) compared agreement between Chinese and Swedish L2 English speakers. It turned out that both groups of participants exhibited major attraction effects. In Ma and Zou (2018)'s study, the Chinese learners of English did make subject-verb errors, especially when the local noun is plural and the head noun is singular. Noticeably, Jackson et al. (2018)'s and Ma and Zou (2018)'s studies invariably pointed out that L2 proficiency might modulate the performance. The latter found more agreement errors among learners with intermediate proficiency than advanced learners.

Lacking agreement in Chinese might be attributed to the above processing gap. A singular subject takes a singular verb in English to show agreement, and the verb is inflected with *-s* to specify its plurality. Chinese does not have this subject-verb agreement (Hsieh, 2009; Lardiere, 1998a, 1998b). Thus, the *-s* morphological variation of a verb is not required in Chinese, which basically has a smaller morphological complexity than English (Li, 1999; Li & Thompson, 1989).

(1)

a. They <u>play</u> basketball.
他们 <u>打</u> 篮球
tamen <u>da</u> lanqiu

b. She <u>plays</u> basketball.
她 <u>打</u> 篮球
ta <u>da</u> lanqiu

In example (1), *play* has different variations depending on the subject. When the subject *(she)* is the third person singular, the verb *(plays)* has to be singular. However, in Chinese the verb (*da)* remains the same form when the subject is either plural or singular.

1.3 The strength of cues in L2 processing

According to the UCM, parsing multiple cues during sentence processing enables us to determine how to interpret a particular sentence structure and how to comprehend the sentence. Specifically, if L1 and L2 are similar enough or the same linguistic cues apply to both the languages, it is said that these cues will benefit from positive transfer and reduce the competition between L1 and L2. And if the same linguistic cues apply differently in L1 and L2, positive transfer will not appear and competition emerges. Finally, if such cues are unique to either of the languages, neither positive transfer nor competition appears (Tuninetti, Warren &Tokowicz, 2015).

Some researches have highlighted this cue strength in comprehension. For example, Tuninetti, Warren and Tokowicz (2015) studied how the cue influences L2 English comprehension for native Arabic and native Mandarin learners by eye movements and grammaticality judgments, and found the cue strength in word order. They also suggested that sensitivity to violations depended on the number and the strength of cues. However, it was also mentioned in this study that their results were not consistent with the L1 transfer theory of the UCM, so there still leaves much space for discussion.

It has also been found in other researches that ambiguous or misleading cues can cause error-prone mistakes of agreement (e.g., Tanner, Nicol, & Brehm, 2014; Wagers, Lau, & Phillips, 2009).

1.4 The role of quantificational cues in subject-verb agreement processing for Chinese-English L2 Learners

At the very beginning of English noun phrase usually appears determiners, including articles, quantifiers, numerals and so on. Typically, numerals are different from quantifiers. But according to Mei and Yang (2002), quantifiers can also be divided into definite quantifiers and indefinite quantifiers. Definite quantifiers include cardinal numbers (e.g., one, two, three) and ordinal numbers (e.g., first, second), while indefinite quantifiers include universal quantifiers (e.g., all, every) and existential quantifiers (e.g., some, few).

In both English and Chinese, a quantifier can act as the determiner of a noun phrase (quantificational cues). For example, quantifiers such as *xuduo (many) and yixie (some)* can appear before a noun to mark plurality (Li & Thompson, 1989). Additionally, the suffix *-men* serves similar function in Chinese. Example (2) below demonstrates the situation.

(2)

a. xuduo laoshi
许多 老师
many teachers

b. yixie laoshi
一些 老师
some teachers

c. laoshi laoshi-men
老师 老师们
teacher teachers

Quantifiers, also quantificational cues, are important terms as they have the role of organizing or pointing out the structure of following sentences and indicating the coming further information (W. Duch et al, 2005). Its role in Chinese-English L2 learners' subject-verb agreement has recently been discussed. Armstrong, Bulkes and Tanner (2018) creatively investigated the role of quantification in subject-verb agreement among L1 Chinese learners of English. The ERP results suggested that the Chinese-English subjects only elicited P600, the result similar to Tanner and Bulkes (2015)'s finding that natives had a P600 effect. As for the effect of quantification, they suggested that quantifying the subject with *many* or *most* reduced the P600 amplitude for the Chinese speakers, which differed from the increase of the P600 amplitude for the native speakers Tanner and Bulkes (2015) reported.

It has to be pointed out that in their study that the native speakers' ERP results used to compare with the Chinese learners' results came from Tanner and Bulkes (2015)'s study where agreement production was employed, whereas the L2 Chinese learns completed agreement comprehension tasks. Therefore, it might be imprecise to draw the conclusion when two different paradigms were involved. Nevertheless, they did find that the presence of quantifier *many* or *most* could change Chinese-English speakers' ERP responses to agreement violations. This indicates that quantification may play a role in subject-verb agreement processing. Eberhard (2005) stated that when one of the singular *one*, *every* or *each* quantifies an unmarked singular subject, one should be able to find a singular verb based on this explicit number information. Likewise, when a subject noun is preceded by one of the plural quantifiers, the verb-agreement mechanism may access the corresponding verb form in a different way on the basis of this extra number information. Apparently, as views regarding the mechanism underlying subject-verb agreement processing among L2 learners has not reached consensus and the probe into Chinese L2 English speakers' subject-verb processing is not sufficient, a further investigation among L1 Chinese learners of English is needed.

1.5 The present study

We assume that the difference between Chinese and English might be a prominent part of the cause to the fact that native Chinese speakers and native English speakers acquire different ways of understanding and comprehending the same quantificational cues. Quantifiers exist in both English and Chinese, which might influence the processing of subject-verb agreement. It is easy to admit that Chinese and English have some quantifiers that share the same syntactic and semantic features. For example, quantifiers such as *two* (二), *three* (三), *many*, etc. These all have the same numerical interpretation in both languages and all signify plurality. And there are also some existential quantifiers that only share the same semantic meanings, such as *most*/*some*, because they can be followed not only by count nouns but also by mass nouns, which leads to different subject-verb agreement conditions. However, subject-verb agreement does not exist in Chinese. Since the quantificational cue *some* and *many* can be followed by both countable and uncountable nouns, whether it can increase the sensitivity to violations of the subjects in Armstrong, Bulkes and Tanner (2018)'s subject-verb agreement experiment or not, whether they will be influenced so as to prefer semantic understanding, or how it can affect native Chinese speakers, all these questions remain suspicious. Armstrong, Bulkes and Tanner (2018)'s preliminary study is inspirational but has certain limitations. The different understanding or comprehension of the quantifier *most*/*some* by Chinese native speakers in L1 might affect their results when processing L2. Thus, studies on this topic could contribute to the discussion. Admittedly, a new perspective to examine L2 subject-verb agreement processing has been provided by Armstrong, Bulkes and Tanner (2018)'s research, which the present study is motivated by and based on.

By recruiting Chinese college students to comprehend English sentence with and without quantificational cues, this present study used ERP to track the participants' simultaneous brain responses. The study intends to explore (1) the role of quantificational cues in subject-verb agreement processing among Chinese-English L2 learners, and (2) if definite and indefinite quantifiers cause different processing patterns.

2. METHOD

2.1 Participants

27 Chinese-English learners participated in the experiment(19 females, 8 males, ages range from 22 to 25 years old.). Participants were recruited from the graduate and undergraduate student at East China Normal University according to their scores of College English Test for University Students (CET-6) in China (no lower than 439 points and no higher than 591 points). In addition, all participants self-rated their English proficiency and their master of grammar, listening, speaking, reading and writing as well as Chinese proficiency with seven-point Likert (1=pretty low, 7= highly proficient)(see **TABLE 2**). All were strongly right-handed by self-report (Oldfield, 1971) and had normal or corrected-to-normal vision; none reported any history of head injuries or neurological impairment, and none reported taking psychoactive medication. Equipment failure prevented two participants from completing the experiment, 6 participants were removed for excessive EEG artifact. This left a total of 19 L2 participants with acceptable data for analysis. All participants provided informed consent and received a small amount of cash for taking part. See **TABLE 1** for background information about participants.

TABLE 1. Background of the participants

	Mean	SD	Range
Age of participants	23.11	1.02	22-25
Years of English learning	9.95	2.11	0-18
Scores of CET-6	496.94	42.47	439-591

Table 1. Among the participants who finally participated in the experiment, most of them began to learn English from the age of 7-14, most of them have studied English for more than 12 years (10 people), some have studied English for 8-12 years (8 people), and one has studied English for 4-7 years. In the table, we take the median value of the data containing the

time period to calculate the average and standard deviation.

TABLE 2. Self-rating Scores of Participants

	Mean	SD	Range
Overall English Level	4.63	0.74	3~6
Grammar	4.58	1.14	3~7
Listening	3.53	1.23	2~6
Speaking	3.21	1	1~5
Reading	5.21	1.06	3~7
Writing	4.21	1	2~6
Overall Chinese Level	5.89	0.55	5~7
Listening	5.95	0.89	4~7
Speaking	6	0.73	4~7
Reading	6.05	0.69	5~7
Writing	5.16	0.99	3~7

Table 2. According to the Self-rating of the participants of their English and Chinese abilities, we can find that most of them scored higher in Chinese than in English, with a difference of about 1-2 points. Among scores in English, the lowest is speaking (Mean=3.21, SD=1), the highest is reading (Mean=5.21, SD=1.06), which can generally represent the characteristics of Chinese students. In the Chinese part, the lowest score is in writing (Mean=5.16, SD=0.99), and the highest score is still reading (Mean=6.05, SD=0.69).

2.2 Materials

We designed four sets of sentences to present to our subjects. The subjects in three sets of sentences were respectively modified by the definite quantifier *three*, the indefinite quantifier *many*, and article *the* that does not belong to quantifiers. The last set was filler. All sentences had both grammatical and ungrammatical forms of subject-verb agreement. In addition, we took the English proficiency level of our participants into consideration. As a result, our test materials for this study were revised from those used by Tanner and Bulkes (2018) by changing difficult words and shortening the sentence length to make sure that participants were familiar with the materials.

Grammaticality (grammatical, ungrammatical) and quantification (quantified/many, quantified/three, unquantified) were crossed in a 2*3 design (see **Table 3**). The quantified sentences were divided into two groups, one group beginning with *many* and another with *three*, while sentences in the unquantified condition always started with *the*. The subject noun was always marked with a plural -s morpheme and grammaticality was determined by using either a singular or plural marked verb. Each condition has 30 sentences, and there were totally 180 sentences for the study. Additional 180 filler sentences were also included.

TABLE 3. Example Materials

Quantification	**Grammaticality**	**Example sentences**
Definitely quantified */many*	Grammatical	Many sharks hide deep in the sea.
	Ungrammatical	Many sharks *hides* deep in the sea.
Indefinitely quantified */three*	Grammatical	Three sharks hide deep in the sea.
	Ungrammatical	Three sharks *hides* deep in the sea.
Unquantified */the*	Grammatical	The sharks hide deep in the sea.
	Ungrammatical	The sharks *hides* deep in the sea.

2.3 Procedure

Participants were asked to fill in informed consent and language background information before the experiment. All sentences were presented word by word at the center of the computer screen during the presentation. A fixation cross appeared for 500 ms. After a 300 ms blank screen, the words of each trial were presented in the center of the screen one at a time for 350 ms with a 300 ms interstimulus interval. Sentences were followed by a 1000 ms blank screen, after which an acceptability judgment with the words Good and Bad appeared. The presentation of words were terminated by a button pressing, after which a blank screen for 1000 ms was followed. The trials participants did not respond within 2000ms were excluded as errors. The instructions before the formal experiment explained that “correct” sentences would be both grammatically and semantically acceptable. “incorrect” sentences would either be ungrammatical or have an implausible meaning. A rest break was provided between blocks and there were 6 blocks in formal experiment. A practice block with 10 trials was used before the formal experiment in order to familiarize participants with the procedure. Before the task, participants were told to minimize movements and refrain from blinking during sentence presentation.

Electroencephalogram (EEG) was recorded continuously using an electrode cap outfitted with 64 sintered Ag/AgCI electrodes mounted according to the extended international 10–20 system. The signals were re-referenced offline to the average of the left and right mastoids. Electrooculogram (EOG) was recorded via two pairs of additional electrodes, with one placed above and below the left eye and the other placed to the external canthi of both eyes. The EEG and EOG were amplified and digitized by a Neuroscan SynAmps2 Amplifier with a band pass of 0.05–100 Hz and a sampling rate of 500 Hz. Electrode impedance was maintained below 5 kΩ throughout the experiment. The EOG artifacts were corrected using a correlation method proposed by Semlitsch et al. (1986). The EEG was segmented into 1, 200-ms epochs beginning 200 ms prior to stimulus onset. Epochs in the correct trials were selected, but those contaminated with artifacts exceeding ±80 μV were rejected before averaging. The averaged ERP waveforms were digitally filtered with a low pass filter of 20 Hz (24 dB/Octave).

ERPs time-locked to the onset of the critical verb in each of the experimental sentences were averaged relative to a 200 ms prestimulus baseline. Mean amplitudes were computed for each participant in the 500–800 ms time window, as this corresponds to the traditional time window for the P600 component. We additionally analyzed the 300–500 ms time window to assess whether an N400 effect or LAN was present, as some prior work has shown that both L1 and L2 populations can display N400 effects in morphosyntactic contexts (Grey, Tanner, & Van Hell, 2017; Osterhout, McLaughlin, Pitka nen, Frenck-Mestre, & Molinaro, 2006; Tanner & Van Hell, 2014; Tanner et al., 2013)and LAN was considered as a way to check whether L2 learners can process the sentence native-like. A repeated-measures analysis of variance (ANOVA) was conducted separately for the LAN latency and amplitude, with *Grammaticality*(grammatical, ungrammatical), *Quatification* (quantified/many, quantified/three, unquantified), *Site* (F3/Fz/F4, FC3/FCz/FC4, and C3/Cz/C4), and *Hemisphere* (left, midline, and right) as within-subjects factors. Due to the fact that there was always no discernable peak of N400 and P600 across participants, the mean amplitude of the N400 (330–430ms) and P600 (650–850ms) were measured respectively. Analyses of the N400 and P600 data were performed in two phases. The primary analyses focused on the five midline electrodes (Fz, FCz, Cz, CPz, and Pz). For the N400 and P600 component, a 2(grammaticality) × 3(*quantification*) × 5(*Site*) repeated-measures ANOVA was conducted separately. The secondary analyses examined hemisphere effects. A 2(grammaticality) × 3(*quantification*) × 8(*Site:*F3/F4, F7/F8, FT7/FT8, FC3/FC4, C3/C4, CP3/CP4, P3/P4, and TP7/TP8) × 2(*Hemisphere*) ANOVA was conducted separately. In addition, we analyzed the data in a way as Tanner and Bulkes (2018) did. We respectively analyzed anteriority (electrodes Fz, Cz, and Pz) and Lateral electrodes grouped into four regions of interest(left frontal (F7, F3, FC5, FC1), right frontal (F4, F8, FC2, FC6), left posterior (CP5, CP1, P7, P3), and right posterior (CP2, CP6, P4, P8)). The Greenhouse-Geisser epsilon correction was applied for all repeated measures with more than 1 degree of freedom; Post hoc comparisons were made by used a Bonferroni procedure.

3. RESULTS

3.1 Behavioral Data

Mean behavioral performance for the end-of-sentence judgments are reported in TABLE 4. No significant differences in accuracy were displayed between grammaticality and ungrammaticality in all the three conditions of quantification. The participants achieved a little bit higher accuracy in grammatical sentences in general as expected. There were no reliable differences in the accuracy of sentences with definite quantification *(Three)* and indefinite quantification *(Many)*, whether they were grammatical or ungrammatical. Yet the results showed that within sentences with the definite quantification "three" the accuracy of grammatical sentences was lower than that of ungrammatical sentences, while in the other two kinds of sentences grammatical ones always triggered a slightly higher accuracy than ungrammatical ones.

On the other hand, the accuracies of ungrammatical sentences decreased monotonically from definitely quantified sentences (91.75%), indefinitely quantified sentences (90.17%) to unquantified sentences (88.77%).

In TABLE 5, we generalized the quantification types into two categories: quantified and unquantified, thus their difference in grammaticality is clearly showed.

TABLE 4. Acceptability judgment Task Results (1)

Quantification	**Grammaticality**	**Accuracy**
Many	/	91.17%
The	/	90.61%
Three	/	90.61%
/	Grammatical	91.36%
/	Ungrammatical	90.23%
Definite quantification (*Three*)	Grammatical	89.47%
	Ungrammatical	91.75%
Indefinite quantification (*Many*)	Grammatical	92.16%
	Ungrammatical	90.17%
Unquantified (*The*)	Grammatical	92.46%
	Ungrammatical	88.77%

TABLE 5 Acceptability judgment Task Results (2)

Quantification	**Grammaticality**	**Accuracy**
Quantified	Grammatical	90.82%
	Ungrammatical	90.96%
Unquantified	Grammatical	92.46%
	Ungrammatical	88.77%

3.2 ERP Results

For clarity, we marked our materials with numbers. The indefinite-quantified sentences are marked as type 12, the definite-quantified sentences are marked as type 34, and the unquantified sentences are marked as type 56. And the odd numbers(1,3,5) refer to grammatical sentences while the even numbers(2,4,6) refer to ungrammatical sentences. Totally, we had six types of material sentences.

3.2.1 Definite-quantified sentences(type 34) and Unquantified sentences(tpye 56)

ANOVA results for the mean amplitude measured along the midline electrodes during 500-800ms time window showed salient interactions between grammaticality and anteriority in type 3456(F（2, 15）=7.908， p=0.005， η_p^2=0.513). Also, we found significant interactions between grammaticality and quantification(F（1, 16）=4.717, p=0.045, η_p^2=0.228), showing that for grammatical sentences, unquantified sentences elicited more positive brain responses than definite quantified sentences. It also showed a main effect of quantification over midline electrodes in which brain responses were more positive in type 34 than in type 56(F（1, 16）=8.167, p=0.011, η_p^2=0.338).

Over lateral sites, simple effect analysis found that for grammatical sentences, brain responses showed anteriority bias（F（1, 16）=5.983, p=0.026, η_p^2=0.272）. There were significant interactions between hemisphere and grammaticality(（F（1，16）=6.055，p=0.026，η_p^2=0.275）, indicating that for grammatical sentences, brain responses showed right hemisphere bias. And in right hemisphere, grammatical sentences elicited more positive brain responses than ungrammatical sentences did（F（1，16）=5.866，*p*=0.028，η_p^2=0.268）.

The significant interaction was also found among grammaticality, quantification and anteriority (F（1，16）=9.655，*p*=0.007，η_p^2=0.376). In the right frontal sites, definite quantified sentences elicited less positive brain responses than unquantified sentences（F（1，16）=4.506，p=0.050，η_p^2=0.220）, and for unquantified sentences, grammatical sentences elicited more positive brain responses than ungrammatical sentences did（F（1，16）=12.778，p=0.003，η_p^2=0.444）.

3.2.2 Indefinite-quantified sentences(type 12) and Unquantified sentence(type 56)

ANOVA results for the mean amplitude measured along the midline electrodes during 500-800 ms time window showed salient interactions between grammaticality and anteriority(Fz, Pz and Cz) in type 1256 (F(2，15)=8.055，p=0.004，η_p^2=0.518). This indicated P600 effects. At Fz, we found larger p600 in ungrammatical sentences than in grammatical sentences(F(1，16)=15.730，p=0.001，η_p^2=0.496). Meanwhile, for grammatical sentences, brain responses were more significant at Pz than at Fz (p=0.016) in both type 12 and type 56. Under Type12, at Pz greater brain responses were elicited than at Fz（p=0.044）, and in Type 56 the brain responses were still more positive at Pzthan at Fz（p=0.014）.

Over lateral sites, a significant main effect was detected at anterior and posterior regions (F（1, 16）=5.575，p=0.031，η_p^2=0.258) with an anteriority bias（M=0.417，SE =0.079）. According to simple effect analysis, brain responses showed respectively left hemisphere bias（F(1, 16)=5.832，p=0.028，η_p^2=0.267）and anteriority bias（F(1，16)=7.881，p=0.013，η_p^2=0.330）for grammatical sentences. And significant interactions between anteriority and quantification(F(1，16)=7.266，p=0.016，η_p^2=0.312) were also found, displaying stronger brain responses in Type56 than in Type12 in the anterior brain region（F(1, 16)=5.803，p=0.028，η_p^2=0.266）.

There were also significant interactions among hemisphere, quantification, and grammaticality(F（1，16）=24.500，p=0.000，η_p^2=0.605), and among anteriority, quantification, and grammaticality(F（1，16）=9.581，p=0.007，η_p^2=0.375). In the left hemisphere, grammaticality elicited more positive brain responses than ungrammaticality under Type12 (F (1, 16) =8.652, p=0.010, η_p^2=0.351) , while under Type56, greater brain responses were produced by ungrammaticality（F（1，16）=0.000，p=0.984，η_p^2=0.000）. However, the results in the anteriority are the opposite: under Type12 grammaticality failed to elicit more significant brain responses（F（1，16）=1.816，p=0.197，η_p^2=0.102）, which in Type56 are elicited more by grammaticality (F（1，16）=9.291，p=0.008，η_p^2=0.367）.

3.2.3 Indefinite-quantified sentences(type 12) and Definite quantified sentences(type 34)

ANOVA results for the mean amplitude measured along the midline electrodes during 500-800 ms time window showed a main effect of quantification in which brain responses were more positive in type 34 than in type 12(F（1，16）=8.946，p=0.009，η_p^2=0.359）. The interactions among anteriority, quantification, and grammaticality were also salient(F（2，15）=13.634，p=0.000，η_p^2=0.645).

Over lateral sites, the main effect of grammaticality is salient (F（1，16）=7.013，p=0.018，η_p^2=0.305).there were significant interactions between hemisphere and grammaticality (F (1, 16) =16.914，p=0.001，η_p^2=0.514）, indicating that the positivity was larger over left hemisphere electrodes in type 12. The same results were also found in type 34. The interactions between anteriority and grammaticality is significant (F（1，16）=8.915，p=0.009，η_p^2=0.358). Also, there are significant interactions between hemisphere and quantification (F（1，16）=7.969，p=0.012，η_p^2=0.332), in left hemisphere type 12 were more positive than type 34; while in right hemisphere, the result reversed. When we see the result of anteriority, hemisphere and quantification, we could find that the interactions are salient (F (1, 16) =6.828，p=0.019，η_p^2=0.299). Like the results found in midline electrodes, The interactions among hemisphere, quantification, and grammaticality were also salient(F（1，16）=12.260，p=0.003，η_p^2=0.434).

3.2.4 An overall result analysis

To conclude, along the midline electrodes, the grand mean ERPs showed that agreement violations basically caused a late posterior positivity, compared to grammatical sentences. Over lateral sites, through simple effect analysis we also found that for unquantified sentences, the main effects of grammaticality and interactions with anteriority showed that brain responses to ungrammatical verbs were more positive-going than to grammatical verbs in posterior areas（$F(1, 16)=7.561$, $p=0.014$, $\eta_p^2=0.321$）, and this indicates signs similar to significant P600 effects (see **FIGURE 1**; In **FIGURE 1**, Grand mean ERP waveforms in the unquantified condition are showned.).However, for quantified sentences, we didn't see any significant sign of P600. But ANOVA results for the mean amplitude also showed a significant main effect of quantification over midline electrodes ($F(2, 15)=5.652$, $p=0.015$, $\eta_p^2=0.430$). Brain responses were more positive to unquantified sentences than to quantified sentences during the 500-800ms time window. What's more, we also found that definite quantificational cues elicited a slightly larger positivity than indefinite quantificational cues did ($F(1, 16)=8.946$, $p=0.009$, $\eta_p^2=0.359$).

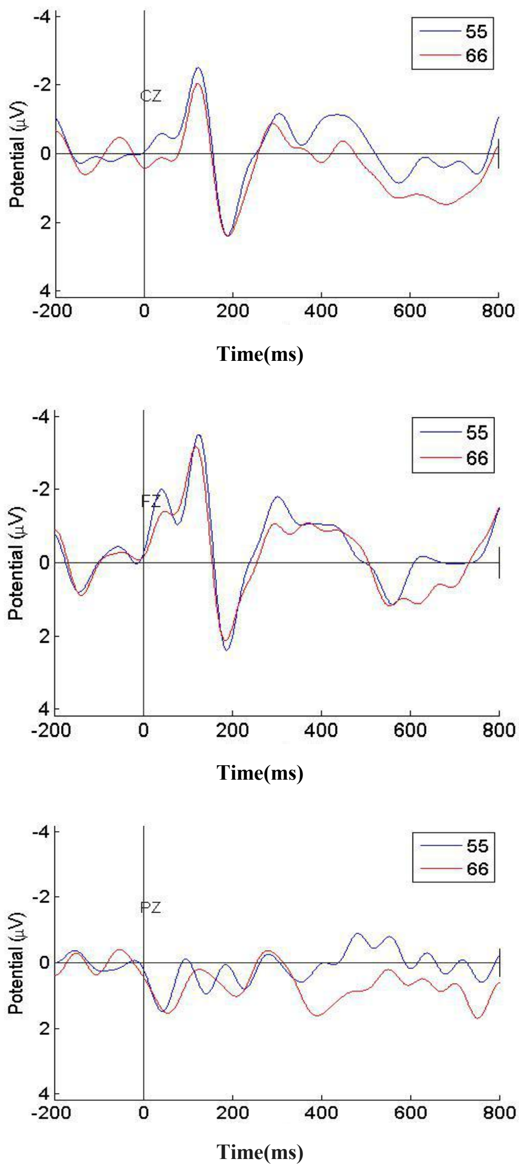

FIGURE 1. Grand mean ERP waveforms for the grammatical (blue line;55) and ungrammatical (red line;66) verbs in the unquantified condition at the midline electrodes (Cz, Fz and Pz).

4. DISCUSSION

Our study provides evidence for one of our hypotheses that quantificational cues have the ability to modulate subject-verb agreement processing among Chinese-English L2 learners and cause a different processing pattern from the native English speakers. Comparing the results of our study with the results from Armstrong, Bulkes and Tanner (2018), we have found similar evidence that in both their study and ours that unquantified cues elicited significant P600 effects. And under the modulation of quantificational cues, the L1- Chinese participants in both studies show a different processing mechanism from native English speakers. What is worth mentioning is that, in Armstrong, Bulkes and Tanner (2018), quantificational cues elicited P600s but reduced the sensitivity of subject-verb agreement violations (p600) for their L1 Chinese participants, while in Tanner and Bulkes (2015), they reported that for the native speakers there was an increase of the P600 amplitude. However, in our study, quantificational cues didn't cause a significant P600 effect. But this can also be seen as a reduction of the sensitivity of morphosyntactic violations.

However, our findings do not support our hypothesis that definite and indefinite quantifiers may cause different agreement processing patterns within Chinese-English L2 learners. This may suggest that the category of quantifiers do not affect English number agreement processing. But they do influence our participants' subject-verb agreement processing in a varying degree. In our study, definitely quantificational cues (like *three)* elicit a slightly larger positivity than indefinitely quantificational cues (like *many*). This could be an interesting finding that we will have a further discusssion later.

The results of our experiment have also raised three major questions for us to segue into further discussions:

① Why did ungrammatical verbs with quantified cues (like *many* and *three*) cause significant P600s in Armstrong, Bulkes and Tanner (2018), but in our study these cues didn't?

One possibility may be that the L2 English proficiency has impact on the subject-verb agreement processing. Second language proficiency has long been considered to influence the second language processing mechanism. For example, in Zhang, Bian and Wang (2017), they found that participants in L2 high proficiency group demonstrated richer ERP effects than those in L2 low proficiency group and only the high proficiency group was detected P600 effects. The same results are found in Jackson et al. (2018)'s and Ma and Zou (2018)'s studies, that L2 proficiency might modulate participants' performance. Also, there have been several researches using longitudinal design to study the relationship between L2 language proficiency and L2 language performance (e.g. Osterhout et al., 2006; White et al., 2012). These studies suggest that in the early stage of second language learning, morphological or syntax violations are generally regarded as inflections or collocations, thus showing no signs of P600. But after a period of intensive training, P600 effects can appear as a sign of detecting morphological or syntax violations and trying to reanalyze and correct such violations. And according to these studies, language similarities seem to have no impact on this situation (more reference: Mclaughlin et al. 2010). The language competence of our L2 participants is clearly not as good as the one of participants in Armstrong, Bulkes and Tanner (2018), since our participants are only graduates and undergraduates living and studying in China, while their participants all live and study in English language environment. Thus, it is reasonable that the participants in our study did not show significant P600 effects.

However, second language proficiency may not affect the results of our experiment. Many studies have confirmed that even with high proficiency, L1 Chinese-L2 English learners can have syntactic processing obstacles(Jia, 2003; Chen et al., 2007). Evidence shows that a same P600 effect can be found in both German native speakers and English-German speakers regardless of their L2 proficiency (Eubank, 1994; Tanner et al., 2013). In Armstrong, Bulkes and Tanner (2018), individual differences are also taken into consideration. But linear mixed effects regression models tell that neither proficiency nor working memory is systematically related to P600 effects or the reduction of P600s. That was also the reason why we didn't consider dividing our participants into different proficiency groups and making a comparison in our study in the first place.

Another possibility comes from VanPatten's theory of Processing Instruction (PI), which has also been discussed in Armstrong, Bulkes and Tanner (2018). According to VanPatten (2005，2007), second language learners tend to focus on the meaning of the input first rather than on the form (The Primacy of Meaning Principle). And when the lexical information and the grammatical form of the input both point to the same semantic information, L2 learners prefer information that is carried lexically (The Lexical Preference Principle). Thus, in our case, our L2 participants possibly prefer processing the meaning of our quantificational determiner rather than its inflection-based grammatical information, and thus, show no significant signs of P600 by the subject-verb agreement violations tested. As we have discussed in our introduction part, there are three popular claims regarding to L2 learners' syntax processing. One is that novel L2 features can be acquired. The second claim suggests that if L1 and L2 share similar morphosyntactic features, L2 learners are able to acquire these features in L2 learning (UCM). The third claim coincided with the Shallow Structure Hypothesis (SSH), which holds that L2 speakers can never perform an equally effortless sentence processing as native speakers. If L2 proficiency is not related to the absence of the P600 effect, then our results can also be seen as evidence for the third claim. Our findings can support that L2 learners is more likely to be influenced than native speakers by semantic or surface-level information. However, we actually didn't not detect any robust or reliable sign of N400/LAN in our study. That's why we jump over this part in our data analysis. Nevertheless, to be clear, we didn't find any sign of specific semantic processing when we were testing subject-verb agreement. Thus this may require further investigation on quantifier comprehension and syntactic-semantic association skills.

The third explanation is based on the possible impact of the explicit environment on the language acquisition. The environment for second language acquisition can be generally divided into two types: Implicit Learning and Explicit Learning. The former learning type refers to the situation where learners are completely immersed into a language without receiving specific and explicit hints of grammatical rules or instructions. It is normally how the first language is acquired (Morgan-Short et al., 2007). Different from the first language spontaneously acquired without explicit teaching, however, a second language is assumed to be learned under explicit and systematic instruction. This puts L2 learners, and obviously our participants, into an explicit environment for language acquisition. In an ERP study, researchers used artificial language paradigm and tested the implicit learning group and the explicit learning group respectively. This study testified that only when learners are immersed in an implicit environment can they acquire a L1-like processing pattern (Morgan-Short et al., 2010). Other behavior studies have also showed huge influences of the explicit classroom learning and the immersive implicit learning on the development of L2 (Collentine ＆ Freed，2004) and their impact on the processing mode of L2 (Morgan-Short et al., 2010; Morgan-Short et al., 2012, Morgan-Short ＆ Steinhauer, 2012).

We assume that lack of P600s among L2 learners in our experiment may also be attributed to the overgeneralization of grammatic rules under explicit learning environment which reinforce the meaning of the quantification. Some scholars, such as White (1987), have put forward that negative evidence like "error correction" or explicit teaching could be an effective source of input during the second language acquisition. This means that such explicit exposure to L2 is a necessary input for L2 learners to improve their "monitoring abilities" ---- abilities to judge a sentence. Thus, under such environment, the function of quantifications like *many* or *three* as a cue to pluralism is further reinforced. For L2-learners, the function of quantified quantification is simply generalized as a hint of pluralism. According to White (1992), L2 learners tend to make mistakes on overgeneralization based on their first language. The hint of plurality is so strong that L2 participants would ignore the grammatical agreement between subject and verb. They simply assume there must be a plural verb after the beginning *many/three*. Thus, they would be attracted by the meaning of the number suggested in "many/three/…", yet fail to distinguish the ungrammaticality lying behind the quantification. This may explain why significant P600 of our L2 participants didn't show up in this study.

② When processing ungrammatical verbs with quantified cues (like *many* and *three*) in subject-verb agreement, why L1 Chinese-L2 English learners in our study and in Armstrong, Bulkes and Tanner (2018) both show a reduction of sensitivity?

The sign of P600 has long been considered as the sign of subject-verb agreement processing for native speakers (Friederici, 2002; Kim and Osterhout, 2005; Neiuwland andVan Berkum, 2006; Schacht, 2014). We can now somehow be sure that when encountering quantificational cues, L1 Chinese-L2 English learners use a different subject-verb agreement processing pattern from native speakers. This piece of evidence also highly coincides with the Shallow Structure Hypothesis as we discussed above. There are several possible perspectives of explanations proposed in Armstrong, Bulkes and Tanner (2018) that we also want to put emphasis on.

The first one is that they considered it as a form of anticipation or prediction. Recent psycholinguistic work has been paying more and more attention to the mechanisms and the roles of anticipation and prediction regarding to language comprehension. Some studies have found that anticipation has a facilitative effect on lexico-semantic processing (Altmann, Kamide, 1999; Arnon & Snider, 2010; Staub, 2015; Demberg, Keller, & Koller, 2013; Smith & Levy, 2013). In Freunberger, D. and Roehm, D. (2017), researchers measured ERPs to predictable target words and their preceding adverbs. They used linear mixed-effects analyses and found that prediction has a facilitative effect on semantic processing. Although psycholinguistic researches in such aspects often detect the change of the N400 amplitude, which is used to reflect the retrieval lexical-semantic information from our long-term memory, and to identify the predictive effect in language processing (DeLong, Urbach and Kutas, 2005; Kutas et al., 2011; Van Berkum et al. 2005; Brothers et al., 2015), in Cheng and Almor (2017), there is evidence indicating that predictability comes from not only semantic but also syntactic factors. It is found that we may be able to acquire a referent predictability to improve our reading ability and L2 language learners have significantly lower syntactic-semantic association skills than native speakers, which means a weaker anticipation ability. Thus, it is reasonable that the interference of anticipation of the subsequent linguistic expressions may overshadow the upcoming inflectional information that does not exist in L1 language (in our case, Chinese). However, what needs to be mentioned is that whether anticipation or prediction can efficiently affect morphosyntactic comprehension still lack sufficient evidence and supports.

The second possible reason is the influence of the L1 on L2 processing. In Chinese, the quantificational cue *many* has a parallel "许多" (xuduo) and *three* also has the number equivalent called "三" (san) or the Arabic number "3". But the exact corresponding concept of the definite article *the* in English is absent in Chinese. In our study, it is reasonable to suggest that after realizing the meaning of the quantifier and using this information to predict the number feature of the coming subject, the participants tend to process the verb in a way that is influenced by their L1 Chinese processing mechanism, where the subject-verb agreement does not exist. When the determiner *the* is placed before the subject noun phrase in the sentences, L2 learners are able to acquire L2 processing patterns like English native speakers without the influence of their L1. But this finding of cross-language competition in our study is inconsistent with the hypothesis of UCM, where it is suggested that if the same linguistic cues apply to both the languages, these cues will benefit from positive transfer and reduce the competition between L1 and L2. Also, this explanation can not answer our third question why *three* could elicit larger positivity than *many*, although their difference is very slight or insignificant in our study.

③ Consequently, this leads to our discussion about the third question: as what was found in our study, quantificational cues both caused a different pattern of L2 subject-verb agreement computation from L1. Why definitely quantificational cues (like *three*) could elicit larger positivity than indefinitely quantificational cues (like *many*)?

Although the difference in the numerical value is slight, there are still some possible explanations we would like to shed some light on. As Eberhard (2005) pointed out, if a subject noun is quantified by numbers or similar modifiers (like *each* and *every*), one should be able to expect its corresponding singular/plural verb based on this explicit number information. In our case, the definite quantificational cue "three" may also have such kind of influences. Definite quantifiers generally bear more explicit number information, thus making our participants slightly more sensitive to subject-verb agreement violations. However, this is only a guess because there is only a small gap between the two kinds of quantifiers, although its difference is significant ($p=0.009$).

However, we have to admit that it is also possible that definite quantifiers modulate L2 subject-verb agreement processing in the same way that indefinite quantifiers do. According to our end-of-sentence judgment task results, there is also no significant difference of the accuracy between definitely quantified sentences and indefinitely quantified sentences, and between grammatical sentences and ungrammatical sentences in the quantified condition. However, in the unquantified condition, there is a sharp drop of accuracy from grammatical sentences to ungrammatical sentences. There have been few studies regarding to this finding, neither. And considering the corresponding meanings that *many* and *three* have in Chinese, it may be better to expect further researches using another quantifier criteria like positive and negative quantifiers (for example, few and a few).

What also needs to be noted is that our behavioral data indicated that our participants showed no discrimination of grammatical and ungrammatical sentences in quantified conditions. They achieved similar accuracy in both grammatical and ungrammatical sentences that were quantified. Whereas, when the sentences were unquantified, there was a significant difference in accuracy (92.46% in grammatical sentences and 88.77% in ungrammatical sentences). What's more, the accuracy of ungrammatical sentences decreased monotonically from definitely quantified sentences (91.75%), indefinitely quantified sentences (90.17%) to unquantified sentences (88.77%). This might result from the plurality marked by different quantificational cues.

Based on our results and our discussion, we expect that the possible impact of the implicit and explicit learning environment could be furthered studied through experiments with the participants under these two environments of language learning. Also, to better investigate the impact of quantificational cues on L2 subject-verb agreement processing, we also expect further quantification-related subject-verb researches such as researches that use positive and negative quantifiers. What's more, during the experiment we have found that second language proficiency or English level should be taken into consideration. Besides, we want to point out that the sample size we took from our participants may be a little bit smaller than we expected due to the sudden interruption by the 2020 covid-19 pandemic, which could be avoided in the further studies as much as possible. But we firmly believe that our research and result are still authentic, meaningful and inspiring.

5. Conclusion

The present study showed that L1 Chinese-L2 English learners produced a reliable P600 only to subject-verb agreement violations with unquantified sentences in English. This is a different finding from the result of Armstrong, Bulkes and Tanner (2018) where P600 was observed in both quantified and unquantified sentences. Thus, our study can not prove a novel processing similarity between native and nonnative speakers for this structure. Our finding that quantificational cues can not elicit significant P600 effects in L2 subject-verb agreement processing also suggests that L1 English speakers were more sensitive to agreement violations when the subject NP has a quantifier determiner, whereas the Mandarin-English bilingual speakers showed a reduction of sensitivity to ungrammatical sentences. Thus, our results can be seen as positive evidence for the SSH hypothesis and negative evidence for the UCM hypothesis although we think that second language proficiency and cross-language transfer are likely to play a role in this interaction. We also want to attribute the absence of the P600 effect (or the reduction of syntactic violation sensitivity) of our L2 participants to the VanPatten's PI theory and the impact of semantic anticipation although we didn’t focus on the left central or anterior negativity (N400 or LAN) in our ERP analysis. This requires or can hopefully inspire further investigations and experiments on the interaction and relationship between semantic and syntactic online processing. What's more, in our study, we find that there is no systematic or significant difference between definite quantificational cues and indefinite quantificational cues regarding to the L2 subject-verb agreement processing. However, this can not prove that different quantifier has the same modulation ability. We expect more studies on this subject.

6. References

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7. 致谢

本论文得以顺利完成，首先感激我们的导师常欣教授，在本论文的写作过程中，常老师为我们倾注了极大的心血。从选题到结题论文，从实验到写作，常老师都一遍遍指出每稿中的具体问题、严格把关、循循善诱，并且在其鼓励与指导下，我们学习到许多科研和实验技能。同时，还要感激一同协助我们进行研究的研究生学姐汤雯婷，在我们进行文献阅读、汇报和选题中均为我们分享了较多经验，也教会我们如何使用 E-Prime 编程，在论文写作中，也帮助我们进行了具体的修改。最后，要感谢本课题组所有成员，是大家的共同努力，才能让项目顺利完成。