IMPACT OF CONSTITUENT LENGTH ON SYNTACTIC AMBIGUITY RESOLUTION IN CHINESE SILENT READING

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Abstract Three experiments were conducted to address the issue of prosody-driven syntactic parsing, by examining how constituent length would affect the comprehension of Chinese ambiguous sentences, which is a critical factor of prosodic structure. A syntactically ambiguous word "和 (*he*, tone2)" was embedded between two nouns that are Chinese translations of foreign names, resulting in two possible interpretations of the sentences. The participants' tendency to adopt late closure interpretation was found to be not sensitive to the length variation of the noun following *he* (Exp. 1 and Exp. 3). The tendency was weakened when the noun preceding *he* was a long name compared to a short name (Exp. 2 and Exp. 3). Moreover, the results show that length difference of one standard foot (i. e., two syllables/characters) is sufficient to trigger the change of interpretation (Exp. 3). Our findings thus suggest that syntactic parsing of written sentences could be affected by the length of the constituents at some particular position (but not all), presumably because such positions are fatal to the placement of implicit prosodic phrasal boundaries.

Key words Implicit prosody, Syntactic ambiguity, Constituent length, Silent reading.

1. INTRODUCTION

A comprehender has to overcome various sources of ambiguities before achieving a unified representation of a sentence to accomplish comprehension. Among those, syntactic ambiguities are common and pervasive, since single words or even grouping words may have their lexical forms in common but greatly differ in terms of their syntactic categories, i. e., syntactic roles they could play in the specific position in the current sentence, particularly when the given context imposes little constraints on subsequent parsing. Instead of marking the ambiguous constituents as "underspecified" and postponing the analysis until more clues [1], listeners are known to rely heavily on prosody for a more instant parsing decision during speech comprehension ([2, 3, 4] among others). The term prosody denotes the supra-segmental information conveyed in language. Prosodic properties are usually recognized in terms of acoustic variations such as pitch, intensity, and duration, and these properties hierarchically constitute a prosodic structure, which relates to the surface syntactic structure of a sentence [5, 6]. For instance, when one heard "The reporter interviewed the policeman and …", he may not be confused about whether the "and" is to connect another object of the verb "interviewed", or to connect a cleft with another predicate structure. The reason is that he has sound cues. The sound cues that the word "policeman" is lengthened and followed by a relatively long pause could be rapidly decoded as signaling an intonational phrase boundary at "policeman", and therefore suggest the listener to predict another predicate structure in the following despite the alternative options. As noted, prosodic cues are able to alter the

reading preference that is fostered due to other types of information such as semantic plausibility and frequency [7, 8, 9].

Over the recent decade, there is growing evidence across languages showing that such prosody-driven syntactic analysis not only functions in speech comprehension but also affects silent reading (see [10, 11] for a review). Much emphasis is placed on constituent length, an important manifestation of prosodic structure. Take English relative clauses (RCs) for an example:

(1) Someone shot the servant of the actress who was on the balcony.

When preceded by a genitive nominal phrase in which two nouns are connected with "of", the relative clause "who was on the balcony" could be interpreted, syntactically, as being attached to either the servant or the actress. Results of offline comprehension tests revealed that 60% native English speakers prefer a local attachment, i. e., RC attaching "the actress" after silently reading this sentence [11], consistent with the syntactic parsing strategies such as Late Closure and Minimal Attachment [12]. However, such a preference could be significantly reduced given a longer relative clause such as "who cried all through the night". Studies in a variety of languages also confirm that short RCs are more likely to attach to the lower noun head than long RCs (see [13] for a summary), reflecting the need for a short RC to be grouped prosodically into a larger phrase with adjacent words [10]. These findings are further considered to be in line with Optimal Length Constraints [14], which proposes the maximal and minimal size of an intermediate phrase (major phrase, phonological phrase) on the syntax-prosody interface.

However, there is also evidence arguing against a universal preference of low attachment ([15] with Italian; [16] with French; [17] with Brazilian Portugese). As reported in those studies, native readers prefer the strings to be parsed into units with the same length no matter whether they are all long or short. For instance, Pynte [16] examined the native French speakers' tendency to interpret a frame comprising a determiner, a noun and a Prepositional Phrase (PP) preceded or surrounded by two context prosodic units whose length was varied. Models of Prosodic uniformity constraint successfully predicted the primary result. When the phrasing is short (one prosodic word per syntactic constituent), the PP was favored to be attached at the matrix verb level, forming the reading 'Ce matin || il enlève-Verb || cette-Det chaîne-Obj || du vélo-Prep' (This morning he removes this chain from the bicycle); When the phrasing is long (two prosodic words per syntactic constituent), in contrast, the native speakers prefer a low attachment for the PP, forming the alternative reading 'Le lendemain matin || il avait enlevé-Verb || cette-Det chaîne-Obj de vélo-Prep' (The next morning he had removed this chain of the bicycle). Interestingly, the relative length of the critical and context prosodic units also showed impact on parsing in listening, as short context phrases following a long prosodic unit of the NP-PP (i. e., without an internal prosodic break in between) remarkably increased the low attachment interpretation 'Ce matin || il enlève-Verb || cette-Det chaîne-Obj de/du vélo-Prep'. The authors thus suggest that phrasing effects may occur in a retroactive way along with the utterance gradually unfolds.

However, these findings are convergent from the perspective of Implicit prosody hypothesis (IPH), which is proposed by Fodor [11]. It claims that readers may project the default prosodic contour onto the sentence during silent reading and the parser favors the syntactic phrasing that goes well with the most natural prosody. For the case of English RC, a prosodic phrasal boundary is more likely to be silently inserted before a long RC for bene-

fits of articulation simulation, as a result, attenuating the close connection between the RC and the adjacent head, both semantically and syntactically. Similarly, a phonological phrasal boundary right preceding the prepositional phrase in the French example is critical for breaking the tendency of attaching the PP to the neighboring object. But note that IPH does not indicate how the default prosody is formed and why it differs between languages.

The current study aims to investigate whether prosodic length contribute to the parsing of syntactically ambiguous sentences in Chinese. The merits are two folds. First, to our knowledge, few empirical study of Chinese sentence processing has been reported to target the resolution of attachment ambiguity. So it is critical to add Chinese data before reaching any conclusion regarding language-universal or typological constraints. Second, it would help improve our understanding of the relation between rhythm and prosodic phrasing. Linguistic rhythm is usually defined as the regular alternations of stronger and weaker elements at different levels of prosodic hierarchical structure [18]. Chinese is a language with a unique rhythm system. At the segmental level, Chinese shows a pattern of the duration of consonants and vowels intervals similar to syllable-timed languages like French and Italian, but not to stress-timed languages like English [19, 20]. At the level of metrical feet, there is no consensus on whether Chinese consistently has a heavier element in a basic rhythmic unit [21, 22, 23, 24], which is an equivalent structure of foot with two-to-three syllables. But such a rhythmic unit tends to be isochronally distributed, just like stress-timed languages where one stressed and one unstressed syllable defines a foot. At the phonological phrasal level where rhythm may signal word order by assignmnig prominence within phonological phrases, Chinese is again ambiguous: unlike languages generally favoring either head initial (e.g., English, French, Italian) or head final position (e.g., Japanese, Latin), Chinese entertains both orders, depending on the syntactic structure. The prominence pattern within phonological phrases, therefore, might be ambiguous as compared to the other languages. Provided that the typological difference of rhythm may result in the division of prosodic phrasing strategies, to compare the dominant phrasing strategy for Chinese native speakers with other languages' may hint at what level prosodic phrasing operates.

In this study, ambiguous Chinese sentences structured as "NP1 + VP1 + Noun2 + *he* + Noun3 + VP2 + ... " were used (Table 1), for they allow for two possible syntactic interpretations due to the ambiguity of *he*. Given no prosodic clues, native speakers may read it as a structure with VP1 taking two patient objects Noun2 and Noun3 (i.e., late closure interpretation). In such a case, *he* serves as a conjunction, analogous to English "and". It can also serve as a preposition analogous to English "with", linking Noun3 with Noun1, such that both of them serve as the agents of VP2 (i.e., early closure interpretation). Explicit prosody, i.e., prosody in speech, can easily direct the parser to either interpretation by providing a prosodic boundary cue at the position between Noun2 and *he* (hence called early prosodic boundary) or between Noun3 and VP2 (hence called late prosodic boundary).

The primary manipulation here is the length of Noun2 and Noun3. Our predictions are as follows: a) A short Noun3 would enhance late closure interpretation; b) A balance of Noun2's and Noun3's length would enhance late closure interpretation.

2. EXPERIMENT 1

To investigate the impact of constituent length on silently reading ambiguous sentences, we firstly manipulated the length of

Noun3 by using a long or a short name. The ambiguous *he* and its following part is placed after the main SVO, a position which is comparable to the canonical example of English ambiguous RC in terms of linear word order (see (1)). If low attachment is preferred by Chinese native speakers, *he* should be more likely to be interpreted as a conjunction locally attached to the object, and Noun3 thereby serves as the other object of VP1, forming a late closure interpretation rather than am early closure interpretation. Furthermore, we predicted that a long Noun3 may attenuate such a tendency if it successfully leads the readers to place before *he* a phrasal boundary in implicit prosodic structure.

2.1 Participants

Twenty-four volunteers (12 females, 18-26 years old) who were students of Peking University attended this experiment. They were all native speakers of Mandarin.

2.2 Design and materials

Fourty pairs of sentences were created, each framed as "NP1 + VP1 + Noun2 + he + Noun 3 + VP2". NP1 is a pronoun or the translation of a foreign name with 1 to 4 characters and Noun2 is a name translation with 2 to 3 characters. The two sentences in one pair varied only in the length of Noun3. Noun3 is a name translation with 2 to 3 characters in SHORT condition while with 7 to 8 characters in LONG condition. In total there were 80 critical sentences.

These sentences were assigned to two lists, such that each list had 20 sentences of SHORT condition and 20 of LONG condition. Besides, each list had identical fillers, which were 38 sentences with a similar ambiguous structure. But they were disambiguous in terms of meaning by introducing an adverbial phrase or a context with strong semantic hints. In a list, sentences were then arranged in a pseudo-random order such that there were no more than three consecutive trials from the same conditions.

The experiment was conducted in a sound-proof lab with computers to collect data. Participants were randomly assigned to read either list, and judged for each sentence which interpretation, the late closure or the early closure interpretation, was consistent to their intuition. Please see Table 1 for examples.

Table 1 An example of critical sentences and the forced-choice task

Condition	Example
SHORT Noun3	老师丢下库恩科和亚历到野人出没的地方去了.
LONG Noun3	老师丢下库恩科和库奥托冯哈布斯堡到野人出没的地方去了.
Fillers	工厂老板扔下所有设备和全厂工人全款潜逃了.
Option	**Example**
Late closure	老师丢下亚历./老师丢下库奥托冯哈布斯堡.
Early closure	老师和亚历一起去了./老师和库奥托冯哈布斯堡一起去了.

Table 2 Results of judgment in Exp. 1

Judgment	SHORT	LONG
Late closure	293(63.7%)	279(60.7%)
Early closure	167(36.3%)	181(39.3%)

2.3 Results

Data of one participant was excluded because he made wrong judgments on more than 10% of the unambiguous filler sentences. Thus there were 460 trials for both SHORT and LONG condition (20 trials/participant * 23 particilants) entering further analysis.

In general, participants favored the late closure over the early closure interpretation,

showing a local-attachment preference (shown in Table 2): In SHORT condition, 63.7% trials were judged as double-patient-structured and 36.3% as double-agent-structured; in Long condition, similarly, 60.7% were judged as double-patient-structured and 39.3% as double-agent-structured. Statistical analysis confirmed that both patterns were significantly different from chance level, $\chi 2 = 17.03$, $p < .001$ for SHORT and $\chi 2 = 10.13$, $p = .001$ for LONG condition, respectively. But no remarkable difference was found between these two conditions, $\chi 2 = 0.10$, $p = 0.75$.

2.4 Discussion

In this experiment, we observed that native Madarin speakers incline to adopt local attachment when encountering ambiguous *he* structure. However, to our surprise, the manipulation of phrasal length did not yield remarkable change of parsing. One possible explanation is that the prosodic influence is position-specific. In regard of speech production, if a speaker is about to produce such a sentence, he has to make a decision about what structure to use in advance (to some extent), and accordingly determine whether there should be a phrasal boundary to close down a clause at Noun2. From this point of view, it is reasonable to expect that the constituent which precedes the potential phrasal boundary would impose prosodic influence on syntactic parsing rather than the constituent following the boundary. Experiment 2 was set up to test this hypothesis.

We noted that a considerable portion of previous studies did not have semantic load well controlled when manipulating the prosodic structure. For instance, Fernandez, Bradley and Fodor [25] lengthened the RCs by inserting adverbial phrases, which increased not only the number of syllables but also lexical meanings to be retrieved and integrated. Here we used translations of foreign names, that are possible to be long or short in common sense, as the critical constituent. During a simple interpretation task (rather than a memory task), a long name may function as one unit in working memory system despite of more characters and syllables [26, 27], therefore causing little extra efforts in terms of semantic and syntactic processing. Our findings thus suggest that the confounding of semantic/syntactic load should be taken into account and carefully ruled out in examining the effect of phrasal length in sentence interpretation.

3. EXPERIMENT 2

In this experiment, Noun2 instead of Noun3 was controlled for the length. A shift of parsing decision is predicted for the change of word length.

3.1 Participants

Twenty-three students from Peking University (12 females, 18-26 years old) were recruited for the experiement. All were native speakers of Mandarin.

3.2 Design and materials

The experiment design was almost identical to that of Exp. 1 in a way that it also had two critical conditions, SHORT and LONG, and that all sentences were framed as "NP1 + VP1 + Noun2 + *he* + Noun 3 + VP2". But here the critical constituent that was prosodically manipulated was Noun2, which was to the left of the ambiguous *he*, instead of Noun3. Noun2 is a name translation with 2 to 3 characters in SHORT condition while with 6 to 8 characters in LONG condition. In total 40 pairs of sentences were created. Thus each participant would read 40 sentences of SHORT condition and 40 of LONG condition. After each sentence, a forced-choice task regarding interpretation was given. Please see Table 3 for examples.

Table 3 An example of critical sentences in Exp. 2

Condition	Example
SHORT Noun2	老师丢下亚历和恩科到野人出没的地方去了.
LONG Noun2	老师丢下库奥托冯哈布斯堡和恩科到野人出没的地方去了.

Table 4 Results of judgment in Exp. 2

Judgment	SHORT	LONG
Late closure	309(67.2%)	258(56.1%)
Early closure	151(32.8%)	202(43.9%)

3.3 Results and discussion

As shown in Table 4, participants generally preferred the late closure to the early closure interpretation, generally replicating the result of Exp. 1.

More importantly, the results showed a clear difference between sentences of SHORT and LONG condition, $\chi 2 = 12.0$, $p < 0.005$, as the latter induced a weaker local attachment preference than the latter. In other words, the attachment of the syntactically ambiguous constituent was influenced by the length of the preceding noun, rather than itself. Despite hesitation, readers tend to locally link *he* to Noun2 such that *he* is assigned to serve as a conjunction, connecting Noun2 and Noun3 to form a coordinating structure. However, a long Noun2 seemed to intensify uncertainty about parsing probably because the readers were more likely to generate a "break" after a long name. As predicted by Implicit Prosody Hypothesis[11], this break might have increased the distance between accessing Noun2 and accessing the following constituent, and correspondingly increased the structural distance between them. As a result, readers made less local attachment judgment on sentences with a long Noun2.

4. EXPERIMENT 3

Exp. 2 provided some supporting evidence of the impact of phrasal length on the comprehension of syntactically ambiguous sentences. We performed Experiment 3 in attempt to replicate these findings with the phonological length variation controlled at foot level, which is the basic level depicting syllable chunking. A Chinese standard foot is usually a rhythmic unit with two full syllables. So a practical question to be answered is whether a standard foot is sufficient to drive the parser. Moreover, instead of focusing on only one constituent in one study, we manipulated the length of both Noun2 and Noun3 in Exp. 3 to study whether the prosodic attributes of these two constituents interactively affect the syntactic parsing.

4.1 Participants

Thirty-nine students from Peking University (25 females, 17-25 years old) were recruited for the experiement. All were native speakers of Mandarin.

4.2 Design and materials

As we did in the previous experiments, we employed sentences with ambiguous *he* structure. Noun2 and Noun3 were both Japanese names, manipulated to be either SHORT, i.e., 2 characters/syllables (such as "Du Bian 渡边"), or LONG, i.e., 4 characters/syllables (such as "Jing Shang Yang Jie 井上洋介"). These two factors were crossed in a 2 * 2 design. Eighty sentences were then created on the basis of twenty parental sentence frames, and assigned to four lists in latin-square design. Fifty unambiguous fillers sentences were also added to each list. Other procedures were the same as the previous experiments. Please see Table 5 for an example.

Table 5 An example of critical sentences in Exp. 3

Condition	Example
SHORT Noun2/ SHORT Noun3	村山航甩开渡边和中野抄小路先往终点赶了.
LONG Noun2/ SHORT Noun3	村山航甩开山口一郎和中野抄小路先往终点赶了.
SHORT Noun2/ LONG Noun3	村山航甩开渡边和井上洋介抄小路先往终点赶了.
LONG Noun2/ LONG Noun3	村山航甩开山口一郎和井上洋介抄小路先往终点赶了.

Table 6 Results of judgment in Exp. 3

Judgment	Late closure	Early closure
SHORT Noun2/ SHORT Noun3	393(54.7%)	325(45.3%)
LONG Noun2/ SHORT Noun3	327(45.6%)	390(54.4%)
SHORT Noun2/ LONG Noun3	394(54.7%)	326(45.3%)
LONG Noun2/ LONG Noun3	357(49.7%)	362(50.3%)

4.3 Results and discussion

Data of three participants were trimmed due to their low accuracy for fillers (below 95%). Missing values were also excluded from the data analysis. Estimates are from a generalized linear mixed model for participants' judgment, with Noun2 (SHORT/LONG) and Noun3 (SHORT/LONG) as the fixed factors. Participants and stimulus items were treated as crossed random factors.

Results are shown in Table 6. The main effect of Noun2 was significant as revealed by statistical analysis, $b = 0.393$, $SE = 0.088$, $z = 4.48$, $p < 0.001$, suggesting that a long name at this position decreased the possibility of interpreting "Noun2 *he* Noun3" as a coordinating structure. Neither the main effect of Noun3 nor the interaction between Noun2 and Noun3 was significant.

These findings of constituent length effect were in general the resemblance of what we found in the previous experiments. Only the length of Noun2, which is to the left of the ambiguous constituent for attaching, matters to the final attachment decision. Noun3 as a part of the ambiguity, by contrast, does not have such influence by itself nor interactively affect Noun2's function. In other words, whether *he* should serve as a conjunction or a preposition is a decision to make on the grounds of the preceding elements; once decided, the syntactic assignment seems to close down, leaving no room for the subsequent input to operate.

However, we are aware of the preference of local/nonlocal attachment differing from the the results of Exp. 1. Chi-square analysis revealed that none of the four conditions reached significance when we compared the judgment pattern with chance-level, ps > 0.08, indicating that the participants did not have clear local/non-local attachment preference for these ambiguous sentences. In fact the early closure reading was even numerically superior to the late closure reading on sentences with 4-syllable Noun2.

5. GENERAL DISCUSSION

This study aimed to explore how Mandarin native speakers cope with syntactic attachment problems in Chinese. Firstly, evidence of constituent length affecting sysntactic parser during silent reading is convergent: the constituent length at the specific position causes significant impact on the resolution of syntactic ambiguity. By employing "*he*" structure, we showed that the ambiguous constituent, i.e., *he* and the following noun, is sensitive NOT to the length of itself, but to the length of the preceding element. This observation is in line with the general claim that syntax is

not immune to prosody; rather, prosodic factors are processed in parallel with syntactic processing and may even alter the build-up of syntactic structure.

Our finding of the position effect could not be be explained by theories that address the matchup between prosodic length and syntactic heaviness. In her influential paper [10], Fodor proposed "same-size-sister constraint", which refers to the language-universal preference of a prosodically balance phrasing for the parser. A constituent simply likes to have a sister of its own size. Larger consititents in terms of prosody/syllable counts deserve to be dominated by higher nods in a syntactic tree. If it holds true, we should expect incrased preference of local attachment (late closure interpretation) for a short Noun3 or length-balanced Noun2 and Noun3. But it is not the case.

To account for the position effect of constituent length, we consider Implicit Prosody Hypothesis [11] as an option. As we indicated above, readers place prosodic boundaries to the text during silent reading just like they vocally realize the prosodic boundaries when reading aloud the materials. Since prosodic boundaries indicate how to group the words and phrasing in nature, the placement of boundaries could be critical to the resolution of syntactic ambiguity if other semantic or pragmatic cues are absent [28].

But the question remains at what position the prosodic boundaries are more likely to be placed by the readers. To answer this question, we would like to draw on models of Prosodic uniformity constraint [16], which opens the possibility that the precedent partially determines the consequent chunk at length. However, our interpretation is not simply a stronger tendendy for a 4-character Noun3 locally attached to a 4-character preceding Noun2; in fact, our observation is the opposite. What we argue here is that in Chinese reading, a foot, i.e., 2-syllable, is the length of prosodic uniformity constraint regardless of the prior sentence context. With regard to the sentence frame in this study, a 2-syllable Noun2 would be considered the most natural length for an object noun, which is more likely to give rise to a prosodic word boundary that follows before proceeding to the subsequent syntactic role "*he*". When this noun becomes longer, e.g., 7-8 characters in Exp. 2 or just 4 characters in Exp. 3, the prosodic boundary may change as well to become a phrasal boundary. As a result, readers are more inclined to wrap up the clause SVO at this position and adopt the early closure interpretation.

This account also explains why Noun2 but not Noun3 makes the difference in the parsing decision. Given the prior context, "*he* + Noun3" is either divided from the matrix SVO no matter whether a prosodic word boundary or a phrasal boundary follows. Or "*he* + Noun3" is locally attached to Noun2, thus forming a big chunk of object. In such cases, a prosodic phrasal boundary is highly expected to come along with Noun3 regardless of its length. Further phonetic research on the prosodic boundaries in speech production would help clarify our hypotheses.

Besides, despite an overall preference of late closure reading in Exp. 1 and Exp. 2, such a tendency was much attenuated in Exp. 3. It may reflect that late closure reading is a default way to resolve ambiguity for native Chinese speakers, but it is monitored by a relatively flexible strategy which encourages shifts between different parsing style. On the basis of our results, we thus assume that Chinese native speakers behave closer to speakers of syllable-timed langauges like French than to speakers of stress-timed languages.

To sum up, this study uncovers the impact of constituent length on resolving syntactic ambiguity during Chinese sentence reading. By using the sentence frame with a syntactically ambiguous word "和 (*he*, tone2)", we

found that the adoption of late closure interpretation, in which *he* and its subsequent noun were locally attached to the preceding noun to form a coordinate structure, decreased when the preceding noun was long, i. e., with 4 or more characters. We suggest that this position effect of constituent length impact could be accounted for by assuming 2-syllable as the prosodic uniformity constraint in Chinese silent reading.

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