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A Universal Account of Relative-Clause Processing in Typologically Diverse Languages

Chien-Jer Charles Lin Thomas G. Bever

The University of Arizona

clin@u.arizona.edu

1. Introduction

This article investigates whether there is a universal processing preference for relative-clause constructions across languages and the basis of such a universal preference if it exists. We attempt to answer the following two questions:

- Is there a universal processing preference for relative-clause constructions across languages?
- If there is a universal processing preference for relative clauses, what is the basis for such universality?

In the sentence processing literature, a predominant comprehension advantage for subject-extracted relative clauses (SRCs) has been reported in various languages. In this article, we provide a typological review of previous processing data based on self-paced reading tasks, and discuss the source of such a processing preference. Our goal is to show that there exists a universal parsing preference for subject-extracted relative clauses. We argue that this kind of processing preference results from universal “parsing” mechanisms, based on a parsing theory called the incremental minimalist parser.

In the following, we first discuss the issues of grammar, parser, and processor in Section 2. In Section 3, we further review processing preferences of relative clauses across various languages in terms of three typological properties. Section 4 considers various processing theories, including a parser-based account for the processing preferences observed. Section 5 concludes the paper.

2. Grammar, the Parser, and the Processor

Three aspects need to be discussed separately when we talk about the universality and diversity of sentence processing: grammar, the parser, and the processor. Grammar refers to the syntactic knowledge that derives the formal structure of the sentence being processed. The parser constructs syntactic structures incrementally from left to right in a computationally idealized situation. The processor puts the parser in real time and space, parsing sentences within the constraints of human capacity (such as working memory, resulting in locality, recency, and frequency effects). Processing involves knowledge about grammatical structures, the parser, and the human cognitive capacity. As illustrated by (1), the processor level encloses the parser, which requires the knowledge of grammar as its basis.

(1)



In the following sections, we discuss the grammatical basis of relative clauses across languages from a typological perspective. A review of the processing preferences of relative clauses in different languages suggests that across languages, subject-extracted relative clauses receive a universal processing advantage in sentence comprehension. We further examine whether such a preference is best accounted for by a theory based on parsing mechanisms or by a theory based on the cognitive requirement of the processor.

3. Processing and the Typology of Relative Clauses

Relative-clause constructions are common across languages. The structures of relative clauses may, however, be rather divergent across languages. For example, Aoun and Li (2003) review various analyses of relative clauses in English, Mandarin Chinese, Japanese, and Arabic, and proposed non-uniform formal structures and derivations for relative clauses in different languages (e.g. adjunction vs. complementation, head raising vs. operator movement, etc.). In this section, we consider the structures of relative clauses and relevant processing data in the psycholinguistic literature. Three typological factors regarding the structure of relative clauses are discussed separately: (a) head position (head-initial vs. head-final), (b) basic word orders and case-marking (SVO vs. SOV), and (c) whether relative clauses are overtly marked by relativizers.

3.1. Head Positions

The most distinguished typological feature of relative clauses is the position of the head noun in relation to the relative clause. Languages with head-initial relative clauses have the head noun appearing before the relative clauses. Languages with head-final relative clauses have the head noun following the relative clause. The position of the head noun in relation to the relative clause is important in sentence processing because it implies different filler-gap relations. Since the gap is contained in the relative clause, when the head precedes the relative clause, the filler (i.e. the head noun) precedes the gap. When the head follows the relative clause, the gap precedes the filler. Filler-gap relations may potentially involve different processing strategies. A filler that precedes the gap it fills searches for the gap as the sentence continues, thus involving the so-called Active-Filler Strategy (Frazier & d'Arcais, 1989):

(2) Active Filler Strategy: Assign an identified filler as soon as possible; i.e., rank the option of a gap above the option of a lexical noun phrase within the domain of an identified filler.

(Frazier & d'Arcais, 1989)

As for head-final relative clauses, even though a gap preceding its filler may also search for its filler as the sentence continues, the fact that gaps are usually not overtly marked makes a corresponding Active-Gap Strategy less likely to be in effect. Nevertheless, one may as well consider these two accounts as competing hypotheses for the processing of filler-gap relations in head-final relative clauses: the Active-Gap Hypothesis predicts that the parser tries to fill a gap with each incoming word and that a SRC should be harder than an ORC since the gap in the former lingers for a longer time; the universal Active-Filler Hypothesis predicts that the lack of gap-markers delays the gap-filling process until the filler is reached, and that once the filler is reached, a similar gap-searching process like the Active Filler Strategy applies. In the following, we consider relative clauses in English (head-initial) and relative clauses in Mandarin Chinese (head-final) to examine these predictions.

Processing Head-Initial Relative Clauses: English

English relative clauses are preceded by the head nouns that they modify. Examples of relative clauses involving subject and object extractions are provided in (3):

(3) a. Subject-Extracted Relative Clause (SRC):

[The girl]_{FILLER} that [GAP] invited John majored in physics.

b. Object-Extracted Relative Clause (ORC):

[The girl]_{FILLER} that John invited [GAP] majored in physics.

A preference for SRCs over ORCs has been consistently found in English. Ford (1983) designed a “Continuous Lexical Decision Task,” in which the participants made lexical decisions (i.e. whether a stimulus is a word or not) on each word of a sentence. She demonstrated that this task was sensitive to both the internal syntactic structure of a sentence and the whole sentence as a processing unit. Ford’s results showed that the difficulty with ORCs started at the gap location and continued till two words after the gap. King and Just (1991) conducted a self-paced reading study of English relative clauses by comparing the performance of participants with high and low working memory spans. They asked the participants to read sentences at their own pace, to memorize the last words of the sentences they read, and to answer comprehension questions regarding the target sentences. Their results confirmed that ORCs were harder to understand, as participants with low memory span spent longer time reading ORCs, while producing higher rates of comprehension errors. Participants with high memory span also made more errors with ORCs than SRCs when the demand for working memory increased. The difference between reading SRCs and ORCs was also observed in follow-up ERP studies (King & Kutas, 1995), eye-movement-monitoring experiments (Traxler, Morris, & Seely, 2002), and self-paced reading tasks (Gibson, Desmet, Grodner, Watson, & Ko, 2005). The results across these studies confirmed the active-filler

strategy—once a filler is identified, the parser starts looking for a gap. An object gap is located farther away from the filler than a subject gap, and is therefore more costly to process.

Processing Head-Final Relative Clauses: Mandarin Chinese

In Mandarin Chinese, the head noun is preceded by the relative clauses, which are marked by the relativizer *de*. Examples of Mandarin relative clauses involving subject and object extractions are provided in (4):

(4) a. Subject-Extracted Relative Clause (SRC):

[GAP] gouyin yuanzhang de [shaonyu]_{FILLER} zhuangdao le yiyuan
seduce dean REL young_lady bump_into ASP congressman
'The young lady that seduced the dean bumped into the congressman.'

b. Object-Extracted Relative Clause (ORC):

yuanzhang gouyin [GAP] de [shaonyu]_{FILLER} zhuangdao le yiyuan
dean seduce REL young_lady bump_into ASP congressman
'The young lady that the dean seduced bumped into the congressman.'

Lin (2006) conducted self-paced reading tasks showing that in Mandarin Chinese, even though the gap precedes the filler, the construction of a filler-gap relationship does not start until the filler is reached. SRCs were read more quickly than ORCs at the relativizer and the head-noun regions, which suggested that the parser starts to look for a gap for the filler when the relativizer and the head noun are reached.¹ Processing data suggest that the filler searches for a gap in the preceding relative clause in a similar fashion as those in head-initial relative clauses. A gap that is located at a higher structural position (such as the subject position) is reached earlier than a gap located at a lower position (such as the object position). As a result, Mandarin relative clauses with subject extractions are processed with higher efficiency than those with object extractions. These results suggest that crosslinguistically, whether the filler precedes or follows the gap, as long as the gap is not overtly marked, the parser starts gap-searching only when the filler is reached. Consequently, a gap that is located higher in structure gets filled earlier than a gap located further down in structure.

3.2. Canonical Word Orders and Case Marking

Variation of word orders across languages may also affect the access of the relativized gaps depending on at which structural position a gap is located. We consider relative clauses in French (with the semi-flexible SVO/SOV order), German (with the SOV order for subordinate clauses), Mandarin (with the dominant SVO order) and Japanese (with the

¹ An earlier study by Hsiao and Gibson (2003) also investigated relative-clause processing in Mandarin. The result of Hsiao and Gibson (2003) indicated a processing preference for ORCs. However, Lin and Bever (2006) pointed out a critical confound in Hsiao and Gibson's study: the ORCs used in Hsiao and Gibson's study involved serial dependencies while the SRCs involved nested dependencies. Hsiao and Gibson's study, therefore, does not provide solid information regarding the processing of subject versus object relative clauses.

dominant SOV order) in this section. These four languages provide a nice typological comparison in terms of head positions, canonical word orders, and the existence of case-markers (see Table 1).

Table 1. Typological Features of Relative Clauses in French, German and Japanese.

Language	Head Position	Canonical Word Order	Case Marking
French	Head-initial	SVO/OVS	Yes
German	Head-initial	SOV	Yes
Mandarin	Head-final	SVO	No
Japanese	Head-final	SOV	Yes

Processing Relative Clauses with SVO/OVS Orders: French

Relative clauses in French are postnominal and indicated by case-marked relativizers such as *qui* (for SRCs) and *que* (for ORCs). The relatively flexible word order in French results in cases where SRCs and ORCs can only be distinguished by the relativizer, as in (5).

(5) RCs in French (a & b are cited from Frauenfelder, Segui, & Mehler, 1980: 330)

a. SRC:

[Le savant]_{FILLER} qui [GAP] connaît le docteur travaille dans une université moderne.

‘The scientist who knows the doctor works in a modern university.’

b. ORC (transposed):

[Le savant]_{FILLER} que [GAP] connaît le docteur travaille dans une université moderne.

‘The scientist who the doctor knows works in a modern university.’

c. ORC (typical):

[Le savant]_{FILLER} que le docteur connaît [GAP] travaille dans une université moderne.

‘The scientist who the doctor knows works in a modern university.’

(5b) is usually adopted to avoid the occurrence of two consecutive verbs as a stylistic variation of a normal ORC like (5c).

Frauenfelder, Segui, and Mehler (1980) conducted a phoneme-monitoring task, in which the participants were asked to respond when they hear a target phoneme (e.g. /t/ or /d/) in a sentence. They contrasted between (5a) and (5b), and found that when the target phoneme appears right after the RC boundary at the beginning of the main verb, participants took significantly longer time to respond to ORCs than to SRCs. No difference was found when the target phoneme was located within the RC on the embedded noun. Similar results were obtained from more recent click-monitoring experiments (Cohen & Mehler, 1996). Even though their results showed a processing preference for SRCs, they did not conclude that SRCs were intrinsically easier than ORCs. In their study, the word order of ORCs was OVS, not the dominant word order in French (i.e. SVO). This peculiar word order may be the factor that caused longer reading times for ORCs. Nevertheless, the results suggested that a gap is not merely accessed at its surface position. More complicated semantic computation takes

place regarding the canonical word orders in the languages and the recovery of the base-generated positions.

Holmes and O'Regan (1981) conducted an experiment monitoring the eye movements of participants reading the three RC types in (5). Note again that the SRCs and transposed ORCs have identical superficial word orders (i.e. N V N Rel V N ...) but different underlying thematic relations, while transposed and typical ORCs have identical underlying representations but different surface orders. They analyzed both the initial fixations and regressions, and found that initial fixations were sensitive to the surface orders, while regression patterns were determined by the underlying deep structures. Based on initial fixation data, SRCs and transposed ORCs show a similar pattern, which is distinct from typical ORCs. The regression data showed that participants spent less time on SRCs than on both types of ORCs. The error rates of comprehension questions after reading each sentence also confirmed that SRCs were better understood than ORCs. Typical ORCs were better understood than transposed ORCs. In sum, Holmes and O'Regan supported a two-stage model (like that of Townsend & Bever, 2001), in which the NVN pattern is initially mapped onto the input sentence, followed by a deeper syntactic analysis. The overall preference for SRCs was found, suggesting that with certain flexibility in word orders, a subject gap is still preferred.

Processing Relative Clauses with Subordinate SOV Orders: German

German relative clauses, like those in French, can be ambiguous between subject and object extractions. Though the dominant word order in German is SVO, the word order of the embedded clause is SOV. Thus, the gap always occurs before the verb in relative clauses, and can be taken either as a subject gap or an object gap. One way this can be disambiguated is through subject-verb agreement. If the verb in the RC agrees with the head noun, then the head noun should be associated with the subject gap in the RC. If the embedded verb agrees with the embedded NP, not the head noun, then the head noun should be associated with an object gap in the RC. However, if the head noun and the embedded NP have the same number and gender properties, then the RC cannot be disambiguated.² Examples of SRCs and ORCs in German, cited from Schriefers, Friederici, and Kuhn (1995: 502), are provided below:

(6) RCs in German (cited from Schriefers, Friederici, & Kuhn, 1995: 502)

- a. SRC: Das ist [die Managerin]_{FILLER}, die [GAP] Arbeiterinnen gesehen hat.
 this is the manager who the workers seen has
 'This is the manager who has seen the workers.'

² The relativizer in German is case and gender marked, but the relativizer *die* is ambiguous between marking feminine nominative and marking feminine accusative (singular as well as plural).

- b. ORC: Das sind [die Arbeiterinnen]**FILLER**, die Managerin [**GAP**] gesehen hat.
 these are the workers who the manager seen has
 ‘These are the workers who the manager has seen.’

Schriefers et al. (1995) conducted self-paced reading tasks regarding extraction types (SRC vs. ORC) and semantic biases (i.e. whether the semantics of the nouns and verbs biases towards a subject reading or an object reading). They found that the parser tends to take the head noun to be the subject rather than the object of the relative clause. This preference exists even when there is a semantic bias for an ORC interpretation. Similar distinctions between SRCs and ORCs were found in ERP studies by Mecklinger, Schriefers, Steinhauer, and Friederici (1995). The German data suggest that when no ambiguity is involved, a subject gap is preferred even when both the subject and the object gaps precede the embedded verbs.

Processing Relative Clauses with Dominant SOV Orders plus Case Marking: Japanese

The word order of Japanese is SOV in both the matrix and embedded clauses. The cases of the nominal arguments are overtly marked. Relative clauses are, however, not indicated by an overt relativizer. The head nouns directly follow the relative clauses. Examples of Japanese RCs are provided in (7).

- (7) a. Japanese SRC (cited from Miyamoto & Nakamura, 2003: 343)

[**GAP**] tosiyorino obaasan-o basutei-made miokutta [onnanoko]**FILLER**
 elderly woman-Acc bus stop-to accompanied girl
 ‘the girl that accompanied the elderly woman to the bus stop’

- b. Japanese ORC (cited from Miyamoto & Nakamura, 2003: 343)

tosiyorino obaasan-ga [**GAP**] basutei-made miokutta [onnanoko]**FILLER**
 elderly woman-Nom bus stop-to accompanied girl
 ‘the girl that the elderly woman accompanied to the bus stop’

Miyamoto and Nakamura (2003) conducted self-paced reading tasks comparing the comprehension of SRCs and ORCs in Japanese. Their results showed that RTs were not different at the RC section. At the head-noun region, ORCs took longer to read than SRCs. No significant difference was found on all other regions. The same results were obtained when case-marking on the head noun (e.g. topic, nominative, & accusative) was controlled for. A similar preference for subject gaps was found when the RCs contained both subject and object gaps (see Nakamura, 2003). Miyamoto and Nakamura concluded that the results were better accounted for by a structure-based theory (e.g. Hawkins, 1999; O’Grady, 1997) than by a theory that is based on linear distance between the filler and the gap (Warren & Gibson, 2002). The Japanese data showed that when the gaps preceded the embedded verbs (like German relative clauses), a gap at the subject position is still preferred in processing. Crucially, these Japanese data suggested that in a strictly head-final language, a gap preceding the filler is

processed similarly as in a head-initial language.

Together with the Mandarin data that we discussed in the last section, we see that despite variations in head positions and basic word orders, a universal preference for subject positions was still obtained. These crosslinguistic results suggest that a filler-initiated gap-searching mechanism is universal in both head-initial and head-final relative clauses, and that the different word orders do not affect the effect of subject extractions being easier to process than object extractions.

3.3. Relative-Clause Markers

The last typological aspect we consider is the existence of a relative-clause marker (i.e. a relativizer). A relative-clause marker indicates a certain part of a sentence as a relative clause. In languages with head initial relative clauses, the relativizer, in the form of a relative pronoun, follows the head noun immediately and precedes the relative clause.³ These relative pronouns can be case-marked, therefore specifying the kind of extraction in the upcoming clause. In languages with head-final relative clauses, a relativizer does not always exist, and is usually not case-marked. In the following, we consider Korean, in which relative clauses are overtly marked, in comparison with Japanese, where no overt marking exists at the boundary of relative clauses.

Processing Relative Clauses with Relativizers: Korean

The structural properties of RCs in Korean are similar to those in Japanese. They are prenominal; the basic word order is SOV; nominal arguments are morphologically case-marked. However, the verbs in Korean RCs are marked by an inflectional suffix *-n*, which indicates that the previous clause is an embedded relative clause. Examples of Korean RCs are provided in (8).

(8) a. Korean SRC (Kwon, p.c.)

[GAP] naitun pwuin-ul bes cenkecang-kkaci tonghayngha-n [sonye]FILLER
elderly lady-acc bus_stop-to accompany-rel girl
'the girl that accompanied the elderly woman to the bus stop'

b. Korean ORC (Kwon, p.c.)

naitun pwuin-i [GAP] bes cenkecang-kkaci tonghayngha-n [sonye]FILLER
elderly lady-nom bus stop-to accompany-rel girl
'the girl that the elderly woman accompanied to the bus stop'

Kwon, Polinsky, and Kluender. (2006) conducted self-paced reading tasks and found SRCs to be read faster than ORCs. They found RT differences not at the embedded verb or the relativizer, but at the head noun. These results are similar to those of Japanese (where a

³ In English, the relativizer of an ORC can be omitted as in *The girl John invited majored in physics*.

relativizer does not exist), suggesting that the existence of a relativizer suffix does not immediately induce RT differences between SRCs and ORCs. The difference became significant at the head noun, suggesting again that filler-gap integration takes place at the head noun.

In Mandarin, however, Lin (2006) observed shorter RTs for SRCs than ORCs starting at the relativizer *de*. The difference, nevertheless, gets larger at the head-noun region. This suggests that the parser already initiates a gap-identifying process as soon as the relativizer is reached. A subject gap takes more time to identify than an object gap. It is, however, at the head-noun region that the parser is more intensively engaged in constructing filler-gap relations; therefore, larger RT differences were observed.

Table 2 summarizes the typological differences across languages and the processing preferences regarding subject and object extractions.

Table 2. Typology of Preferences for RC Processing

Language	Head position	RC Word Order	Case Marking	Relativizer	Preference
English	Head-Initial	SVO	Partially	Yes	SRC
French	Head-Initial	SVO/OVS	Yes	Yes	SRC
German	Head-Initial	SOV	Yes	Yes	SRC
Japanese	Head-Final	SOV	Yes	No	SRC
Korean	Head-Final	SOV	Yes	Yes	SRC
Mandarin	Head-Final	SVO	No	Yes	SRC

4. A Universal Parsing Account for Relative-Clause Processing

In section 3, various typological aspects of relative clauses were reviewed; nevertheless, relative clauses across languages observed a predominant processing preference for subject extractions. The question arises as to why there is this universal processing preference across languages. In this section, we consider the accountability of four theories of sentence comprehension, and show that a structure-based theory can best account for the universality of processing across languages.

4.1. Frazier's (1987) Garden-Path Theory

Based on the assumptions that processing resources are limited and that syntactic categories are the only information used in parsing, Frazier's (1987) Garden-Path Theory (GPT) allows the parser to only construct *one* structure for an ambiguous sentence being parsed. When this structure is proven wrong, the parser has to revise the parse. The time it takes to do this revision is known as the garden-path effect. Three parsing principles have been discussed in predicting what kind of parses are preferred—Minimal Attachment, Late Closure, and Minimal Chain Principle (Frazier & Clifton, 1996: 9):

- (9) Minimal Attachment: Do not postulate any potentially unnecessary nodes.
- (10) Late Closure: If grammatically permissible, attach new items into the clause or phrase currently being processed (i.e., the clause or phrase postulated most recently)
- (11) Minimal Chain Principle: Postulate required chain members at the earliest point grammatically possible, but postulate no potentially unnecessary chain members (De Vincenzi, 1991).

These three principles can be seen as surface phenomena that result from a more general principle: the parser builds syntactic structures *locally*. New structures are attached locally to the ones being operated upon, and reanalysis should involve as little revision as possible.

The Minimal Chain Principle is of particular relevance to the construction of filler-gap dependencies because the Active Filler Strategy, which we discussed in (2), is proposed based on it (Frazier, 1978, 1987; De Vincenzi, 1991). According to the Active Filler Strategy, as soon as a filler (i.e. the head noun) is recognized, the parser creates a minimal chain between the filler and a potential position for the gap. In languages like English, the potential gap that minimizes the filler-gap distance (thus creating a minimal chain) in relative clauses is at the subject position. Therefore, the parser prefers subject RCs. The Active Filler Strategy predicts an immediate increase of reading times at the post relativizer region of an ORC, where a gap is expected for a short filler-gap dependency.

The Active Filler Strategy does not make specific predictions about head-final relative clauses. As discussed in Section 3, a relative clause is not identified until the parser reaches the relativizer in sentences with head-final relative clauses. An active filler still searches for its gap even though the gap precedes the filler in terms of linear relation. If the filler searches structurally from top down, then the subject gap will be found first, thus generating a preference for SRCs. If the filler probes linearly backwards, then an object gap should be reached first; thus an ORC receives an advantage in processing. The typological review in Section 3 suggests that the structure-based gap searching process is more accurate.

4.2. Incremental Minimalist Parser (Lin, 2006)

Lin (2006) proposes the Incremental Minimalist Parser (IMP), which builds syntactic structure incrementally from left to right, with operators searching to bind their variables downstairs in a syntactic tree. When parsing English relative clauses, IMP constructs a chain between the relativizer and the subject position within the relative clause as soon as the relativizer is reached (based on the Minimal Link Condition). A subject gap is, therefore, preferred to an object gap because the closest base-generated position for the *wh*-operator is a subject gap, not an object gap.

For the processing of head-final RCs in Mandarin, IMP also predicts that a subject gap should be preferred. The relativizer *de* carries with it a two-place feature ([IDENT(X, Y)]) that must be valued by matching with an embedded trace and the upcoming head noun. The

head noun is adjoined to the relative-clause CP, and identifies with the embedded trace by checking the [IDENT] feature of the relativizer. In comparison with SRCs, the dependency between the head noun and the trace is harder to establish in ORCs because the structural distance between the relativizer and the object gap is longer than that between the relativizer and the subject gap. In summary, the filler-gap/probe-goal relationship should make ORCs harder to process than SRCs crosslinguistically. This effect should be most obvious at the relativizer and head-noun regions for head-final relative clauses. Therefore, IMP predicts universal processing preferences for subject extractions since subject positions are higher than object positions universally.

IMP also provides structural/grammatical basis for the somewhat ad hoc typological generalization of Keenan and Comrie (1977, 1979), usually referred to as the Keenan-Comrie Accessibility Hierarchy:

(12) Accessibility Hierarchy: Subject > Object > Indirect Object / Oblique Case > Genitive
(revised version, cited from Hawkins, 2004: 177)

Their original proposal was that across languages, NPs of different syntactic functions show a universal pattern regarding how easily it can be relativized/extracted. NPs at the subject positions are generally easier to extract in all languages. NPs that are lower in the hierarchy are harder to relativize. Like other structure-based theories such as O'Grady (1997) and Hawkins (2004), IMP provides such universal tendencies with structural substance. The accessibility hierarchy actually reflects the syntactic positions of the NPs. Those that are higher in the hierarchy are also higher in the syntactic structure and are therefore easier to get at than those at lower syntactic positions.⁴

4.3. Gibson's (1998) Syntactic Prediction Locality Theory

Gibson (1998) proposes the Syntactic Prediction Locality Theory (SPLT), which takes into consideration both sentence processing mechanisms and computational resources that are required for processing. SPLT assumes the existence of syntactic structures in sentence processing. However, it focuses more on the computational resources needed to construct and maintain these syntactic structures than the nature of the structure itself. The two major components of computational resources are the structure integration cost and the structure storage cost, defined in (13).

(13) a. An integration cost component dictates what quantity of computational resources needed to be spent on integrating new words into the structures built so far.

⁴ Hawkins (1999, 2004) offers a structural account for the Keenan-Comrie Hierarchy by measuring the "Filler-Gap Domain" involved in processing. A Filler-Gap Domain is defined as "the smallest set of terminal and nonterminal nodes dominated by the mother of a filler and on a connected path that must be accessed for gap identification and processing (Hawkins, 1999: 248)." However, the structure that he assumes for the different syntactic positions is different from that of IMP, and the counting of nodes in the structure is also different from the feature theory, on which IMP is based.

- b. A memory cost component dictates what quantity of computational resources [is] required to store a partial input sentence. (Gibson, 1998: 8)

Gibson's SPLT can be taken as a memory/resource-based theory. The human processor is assumed to possess limited computational resources at each temporal point of processing. When a sentence is more complex in structure and/or when it involves dependencies that are less local (e.g. involving units that should be kept in the working memory longer before it can be integrated), this sentence requires more computational resources and is thus more costly to process. Locality is a central theme in SPLT. The constructed syntactic units that are "held in memory over longer distances are more expensive, ..., and longer-distance head-dependent integrations are more expensive (Gibson, 1998: 8)." It should be noted that SPLT places special emphasis on the role of discourse referents in calculating integration costs. A new discourse referent (such as pronouns, tenses, etc.) is believed to increment the integration cost substantially.

SPLT takes the subject/object asymmetry in RC processing as one important piece of evidence for the distance-based integration cost. The theory predicts that ORCs in English should be more difficult at the point of the embedded verb because it has to integrate two new discourse referents (i.e. the embedded verb itself—as an event referent which assigns a theta role to the embedded subject, and the embedded empty category—the object). The embedded verb of an SRC only has to integrate one new discourse referent (i.e. the verb itself as an event referent), thus making SRCs less difficult.

For head-final relative clauses, however, the linear distance between a subject gap and the head noun is longer than that between an object gap and the head noun. Based on the locality theory of integration cost, an ORC in Mandarin Chinese, Japanese, and Korean should be easier than an SRC. This prediction was, however, not supported by the experimental evidence in all three languages reviewed in Section 3.

(14) a. SRC in Mandarin: $[\underbrace{[GAP] V N}] \text{ de } N_{\text{head}}$

b. ORC in Mandarin: $[N V \underbrace{[GAP]}] \text{ de } N_{\text{head}}$

4.4. Word-Order and Template-Based Theories

A different line of theories takes a top-down approach to sentence processing. Bever (1970) argues that linguistic structure and behavior are "the joint product of both linguistic and psychological structures (282)." By proposing perceptual strategies underlying language behavior, such as (15) and (16), Bever makes predictions on interpretations that are preferred and dispreferred in sentence comprehension.

(15) The first N ... V ... (N) ... clause is the main clause, unless the verb is marked as subordinate. (Strategy B, cited from Bever, 1970: 294)

(16) Any *Noun-Verb-Noun* (NVN) sequence within a potential internal unit in the surface structure corresponds to “*actor-action-object*.” (Strategy D, cited from Bever, 1970: 298, italics original)

These two strategies are top-down mechanisms that underlie the syntactic and semantic expectations during sentence processing. The human processor adopts a simple template-based strategy to assign syntactic and semantic roles. Any sentence-initial NVN sequence is perceived as the matrix element of a clause. The most dominant semantic template is mapped onto this NVN sequence. Thus the first noun is taken as an actor, the second noun as the object (i.e. patient). These strategies do not guarantee correct parsing, and may lead to garden-path effects in sentences such as *the horse raced past the barn fell* (Bever, 1970: 316).

In recent years, a model called the Late Assignment of Syntax Theory (LAST) has been advanced by Townsend and Bever (2001). LAST is a two-stage model for sentence comprehension. The first stage is called “pseudosyntax,” during which the parser uses the canonical word order in a language as a template to map the default grammatical and thematic relations onto the input sentences. In English, as discussed earlier, this template is NVN or Agent-Action-Patient. The second stage is “real syntax” where more complicated reanalysis and phrase structures are constructed. Based on LAST and the canonical-template hypothesis of Bever (1970), SRCs in English should be easier than ORCs since English SRCs follow the canonical order, SVO. The order in ORCs, which is OSV, does not conform to the template, and is more costly to understand.⁵

(17) **The guy** who __SUBJ **invited me** caught a trout.
S (S) V O

(18) **The guy** who **I invited** __OBJ caught a trout.
O S V (O)

In Mandarin Chinese, the dominant word order is SVO as in English. However, RCs are prenominal in Mandarin, thus making an ORC easier since its word order matches the canonical order.

⁵ Essentially, a word-order based theory has the same predictions as a theory that is based on the direction of thematic assignment (e.g. “trace-deletion theory” for Aphasic RC processing, Grodzinsky, 1986, 1995). A theory based on the assignment of theta role hypothesizes that the verb assigns the agent role to the left and the patient role to the right when the canonical word order in the language is SVO. When the direction has to be altered (e.g. ORCs in English and SRCs in Chinese) for the head noun to receive the correct theta role, this sentence is predicted to be more difficult to comprehend.

(19) Yaoqin wo de pengyou zhuadao yi zhi zunyu
 invite I DE friend catch one CL trout
 V O S

‘The friend that invited me caught a trout.’

(20) Wo yaoqin de pengyou zhuadao yi zhi zunyu
 I invite DE friend catch one CL trout
 S V O

‘The friend that I invited caught a trout.’

These predictions were not supported by the self-paced reading data discussed in Section 3, either.

5. Concluding Remarks

In this article, we reviewed three typological properties of relative clauses across languages, and showed that despite the typological differences, a universal processing preference for relative clauses involving subject extractions exists nonetheless. These crosslinguistic processing data supported a structure-based parsing theory, such as the Incremental Minimalist Parser, but contradicted the predictions of a template (word order)-based theory, and a locality theory based on linear distance or numbers of interfering discourse referents. We conclude that the crosslinguistic processing preference for relative clauses stems from a parsing advantage for subject positions in terms of filler-gap relations, rather than a processor-based theory that focuses on cognitive resources and locality.

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