

Similarity Interference and Scrambling in Japanese

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Abstract

Lewis and Nakayama (1999) claim that the difficulty of comprehending sentences is a function, in part, of similarity-based interference, a limitation on working memory. By examining Japanese sentences, they found that the syntactic category, the syntactic position, and the consecutive occurrence of the same category all contribute to the difficulty of sentences. The present study examines the similarity interference hypothesis in Japanese scrambling sentences. According to the hypothesis, the scrambled sentences that reduce similarity interference would be considered easier than the unscrambled sentences. This prediction was borne out. However, the experimental results also showed that sentences with scrambled embedded objects were more difficult than unscrambled sentences. We argue that there are independently-motivated explanations for the difficulty of these sentences. Therefore, the results still support the similarity interference hypothesis, and indeed similarity interference plays a significant role in the difficulty of comprehending sentences.

1. Introduction

The difficulty of comprehending center-embedded sentences like (1) is traditionally thought to be deeply related to working memory limitations (Miller, 1962; Miller and Chomsky, 1963).

- (1) The salmon that the man that the dog chased smoked fell off the grill.

The problem faced by the parser in a center-embedding is that it must temporarily set aside the partial products of working on the initial part of a constituent while it parses another embedded constituent, then retrieve those earlier partial products to finish the parsing. The original insights of Miller and Chomsky (1963) concerning center-embedding led to a rich line of work on resource-limited parsing, but it has been surprisingly difficult to produce models and metrics that are empirically adequate, particularly when considered against a broad range of cross-linguistic embeddings. Furthermore, there has been little independent psychological motivation for the proposed memory structures (e.g., stacks, lookahead buffers) and their associated limitations. See Lewis (1996) for a review.

A metric based purely on the amount of center-embedding does not account for many difficulty contrasts in English and other languages. As an example of the kind of empirical hurdle faced by any theory of syntactic working memory, consider (2).

- (2) What the woman that John married likes is smoked salmon. (Cowper, 1976; Gibson, 1991)

Though this construction involves two levels of center-embedding of sentential structures, it does not cause the comprehension difficulty associated with the classic structure in (1). Although increasing center-embedding certainly increases difficulty, another important observation is that increasing the similarity of the embedded constituents increases difficulty, and making constituents more distinct or dissimilar in some way helps processing (e.g., Bever, 1970; Miller and Chomsky, 1963; Kuno, 1974).

Why is this observation significant? Similarity-based interference is a principle that holds of working memory in general. Lewis (1996) reviews evidence for a range of working memory types subject to selective, type-specific interference, including verbal, spatial, odor, kinesthetic, and sign language. The robust result across domains is that when to-be-remembered items are followed by stimuli that are similar along some dimensions, the original items are more quickly forgotten. Building on these results, and the work cited earlier by Cowper (1976) and Gibson (1991), Lewis (1993, 1996) hypothesized that similarity-based interference is a general principle that applies to syntactic working memory as well. Lewis described a computational model that embodies retroactive, type-specific syntactic interference, and accounts for a range of cross-linguistic data on difficult center-embeddings. The model posited a simple buffer that could maintain no more than two constituents of a particular syntactic type.

The type specificity of the limitation is crucial to the empirical success of the model. To see why, consider the comprehensible Japanese construction in (3) below (Lewis, 1993):

- (3) Taro-wa Hanako-ni Ziro-ga Mari-ni Yoshiko-o syookaisita to itta.
-Top -Dat -Nom -Dat -Acc introduced that said
"Taro said to Hanako that Ziro introduced Yoshiko to Mari".

Sentences such as (3) do not cause the difficulty associated with (1), despite the stacking up of five Noun Phrases (NPs), Taro-wa, Hanako-ni, Ziro-ga, Mari-ni, and Yoshiko-o. A crucial difference is that (3) requires buffering of no more than two NPs of any particular syntactic function: at most two subjects (Taro-wa and Ziro-ga), two indirect objects (Hanako-ni and Mari-ni), and a direct object (Yoshiko-o). What this theory amounts to is adding "syntactic" to the list of immediate memory types that exhibit type-specific interference and decreased performance with increased similarity. Just as there is the well-known phonological similarity effect, there is also a "syntactic similarity effect", and one way this effect manifests itself is difficulty with center-embedding. Lewis (1998) extends this theory to combine both retroactive and proactive interference into a measure of working memory load. The new theory increases the empirical coverage considerably, and directly yields moment-by-moment predictions of processing load.

Although the interference theory is quite successful on the extant data, many important questions remain, such as: What precisely are the features that contribute to similarity interference? For example, does semantic similarity count? Is interference alone sufficient to account for all the data, or is there still some role for level of embedding or locality? Lewis and Nakayama (1999) have explored some of these issues, using embedded structures in Japanese. In this paper, we report the results of an experiment with scrambling sentences supporting Lewis and Nakayama's similarity interference hypothesis. The organization of this paper is as follows: The next section presents a summary of Lewis and Nakayama (1999). An experiment will be discussed in Section 3.

2. Lewis and Nakayama (1999)

Lewis and Nakayama (1999) identify more precisely what makes complex syntactic embeddings difficult (or easy) to process. The head-final syntax (e.g., a verb appears right-most in the verb phrase) and overt case-marking (e.g., Nominative -ga and Accusative -o) of Japanese makes it particularly useful for teasing apart some of the factors contributing to processing complexity. See Nakayama (1999) for the overview of Japanese syntactic characteristics and sentence processing. For example, it is possible to keep the level of embedding and amount of stacking constant (STACK), while increasing the

number of syntactically similar NP arguments (SIM). The following four sentence types shows the same level of embedding, i.e., one complement clause, while they contain three and four different NPs.

- (4) a. Type DI (STACK3, SIM0) [NP-ga NP-ni [NP-ga V-to] V]
 Ani-ga sensei-ni onna-no-ko-ga asondeiru-to renrakushita.
 elder brother-Nom teacher-Dat girl-Nom playing that notified
 'My older brother notified the teacher that a girl was playing.'
- b. Type TT (STACK3, SIM2) [NP-ga [NP-ga NP-o V-to] V]
 Haisha-ga daitooryoo-ga tsuuyaku-o yonda-to oboeteirta.
 dentist-Nom president-Nom interpreter-Acc called that remembered
 'The dentist remembered that the President called the interpreter.'
- c. Type DT (STACK4, SIM0) [NP-ga NP-ni [NP-ga NP-o V-to] V]
 Anaunsaa-ga juumin-ni keikan-ga daigakusei-o shirabeta-to
 announcer-Nom citizens-Dat policeman-Nom college student-Acc investigate that
 hoosooshita.
 broadcasted
 'The announcer broadcasted to the citizens that the policeman investigated the college student.'
- d. Type TD (STACK4, SIM2) [NP-ga [NP-ga NP-ni NP-o V-to] V]
 Otoko-no-ko-ga hahaoya-ga isha-ni akachan-o miseta-to omoidashita.
 boy-Nom mother-Nom doctor-Dat baby-Acc showed that remembered
 'The boy remembered that the mother showed her baby to the doctor.'

Sentence types (4a) and (4b) contain three NPs, but the verbs in the main and embedded clauses are different. Sentence type (4a) includes a ditransitive verb in the main clause while it has an intransitive verb in the embedded clause (Type DI). Sentence type (4b) contains transitive verbs in the main clause and in the embedded clause (Type TT). Sentence types (4c) and (4d) have four NPs. Sentence type (4c) includes a ditransitive verb in the main clause while it has a transitive verb in the embedded clause (Type DT). Sentence type (4d) contains a transitive verb in the main clause and a ditransitive verb in the embedded clause (Type TD). Since both DI and TT sentences contain three NPs and both DT and TD sentences contain four NPs, they are labeled as STACK3 and 4, respectively. Furthermore, only TT and TD sentences contain the two consecutive overt NPs with the same case marker -ga (i.e., similarity interference). Thus, they are labeled as SIM2. This experiment tested the effects of positional similarity vs. amount of stacking employing a rating questionnaire study, where 60 native speakers of Japanese were asked to rate the difficulty of a sentence on a seven point scale. It is a 2x2 design with two levels of stacking (3 NP and 4 NP constructions) and two levels of positional similarity (adjacent subject NPs and non-adjacent subject NPs), holding constant level of embedding. Each subject sees four versions of the four experimental types (16 total experimental sentences) interspersed with 34 fillers, for a total of 50 sentences.

Table 1 is a summary of the average ratings of the four sentence types. The results show that the STACK3 sentences (DI and TT) were significantly easier to understand than the STACK 4 sentences (DT and TD) and the SIM0 sentences (DI and DT) were easier than the SIM2 sentences (TT and TD).

Table 1: Average Ratings of the Four Sentence Types

STACK\SIM		0	2	
3	DI	3.02	TT	5.07
4	DT	4.2	TD	5.14

The degree of positional and syntactic similarity of the NP arguments appears to be the most significant factor in the perceived complexity of these single embeddings. This position is similar to Uehara's (1999), who independently came to the conclusion that it is repetitive nominativeness that causes the difficulty in parsing. Stacking also has an effect, but its effect is smaller and can also be explained as a reduced interference effect among syntactically distinct NPs.

Since all of the NP arguments were humans in the above experiment, i.e., the arguments were semantically indiscriminable, their second experiment tested the effects of semantic similarity in the DT and TD sentences (STACK4, but SIM0 and SIM2, respectively) including inanimate NPs. Consider (5).

- (5) a. Type DT (STACK4, SIM0, ANI4) [NP-ga NP-ni [NP-ga NP-o V-to] V]
 Anaunsaa-ga juumin-ni keikan-ga daigakusei-o shirabeta-to
 announcer-Nom residents-dat policeman-Nom col. student-Acc investigated that
 hoosooshita.
 broadcasted
 'The announcer broadcasted to the residents that a policeman investigated the college student.'
- b. Type DT1 (STACK 4, SIM0, ANI3)
 Ani-ga sensei-ni onna-no-ko-ga basu-o untensuru-to renrakushita.
 elder brother-Nom teacher-Dat girl-Nom bus-Acc drive that informed
 'The elder brother informed the teacher that a girl is going to drive a bus.'
- c. Type DT2 (STACK4, SIM0, ANI2)
 Kachoo-ga kaisha-ni hitobito-ga hoteru-o yoyakushita to hookokushita.
 section chief-Nom company-Dat people-Nom hoteru-Acc reserved that reported
 'The section chief reported to the company that people made their own reservations at the hotel.'
- d. Type TD (STACK4, SIM0, ANI4) [NP-ga [NP-ga NP-ni NP-o V-to] V]
 Otoko-no-ko-ga hahaoya-ga isha-ni akachan-o miseta-to omoidashita.
 boy-Nom mother-Nom doctor-Dat baby-Acc showed that remembered
 'The boy remembered that the mother showed a baby to the doctor.'
- e. Type TD1 (STACK4, SIM0, ANI3)
 Haisha-ga tsuuyaku-ga daitoryo-ni nihongo-o oshieru-to oboeteita.
 dentist-Nom interpreter-Nom president-Dat Japanese-Acc teach that remembered
 'The dentist remembered that the interpreter would teach Japanese to President.'
- f. Type TD2 (STACK4, SIM0, ANI2)
 Bengoshi-ga shain-ga apaato-ni shinbun-o kubaru-to kimeta.
 lawyer-Nom employees-Nom apartment-Dat newspaper-Acc deliver that decided.
 'The lawyer decided that the employees will deliver the newspaper to the apartment.'

Sentence types (5a)-(5c) are all DT sentences (i.e., a ditransitive matrix verb and a transitive embedded verb), but they are different in that (5b) contains one inanimate noun in the complement clause while (5c) has two inanimate nouns, each one in the matrix and complement clauses. Similarly, sentence types (5d)-(5f) are all TD sentences (i.e., a transitive matrix verb and a ditransitive embedded verb), but they are different in that (5e) contains one inanimate noun in the complement clause while (5f) has two inanimate nouns in the complement clause. Sentence types (5b) and (5e) contain one inanimate noun while (5c) and (5f) have two inanimate nouns. These six types of sentences (DT (0 inanimate NP=ANI 4), DT1 (1 inanimate NP=ANI 3), DT2 (2 inanimate NPs=ANI 2), (TD (0 inanimate NP=ANI 4), TD1 (1 inanimate NP=ANI 3), TD2 (2 inanimate NPs=ANI 2) with SIM0 vs. 2 and STACK4) were given to 60 native speakers of Japanese (different from those in the above study). They were again asked to rate the difficulty of each of these sentence types on a 7 point scale in the questionnaire. It was a 3x2 design, with three levels of semantic similarity (0 inanimate out of 4, 1 inanimate out of 4, and 2 inanimates out of 4) and two levels of positional similarity (1 pair of adjacent similar NPs vs. 0). Each sentence type had 4 test sentences (i.e., 24 test sentences). There were 56 filler sentences in the questionnaire.

Table 2 shows the summary of the average ratings of the above six test sentence types. The results indicate that there were no animacy effects, but the SIM0 sentences were easier to understand than the SIM2 sentences, the same finding as in the previous experiment.

Table 2. Average Ratings of the Six Sentence Types

ANI\SIM		0	2
4	DT	4.22	TD 5.3
3	DT1	4.28	TD1 5.1
2	DT2	4.87	TD2 5.05

The lack of a significant effect of semantic similarity was rather striking, given that the behavioral measure is off-line, end-of-sentence judgment of processing difficulty. However, the results continued to point to a model of processing complexity in unambiguous embedded structures in which syntactic and positional discrimination were the important factors.

3. Experiment on Scrambling Sentences

The present study investigates the effects of scrambling on the sentences with the matrix and complement transitive verbs. Consider the following sentences.

- (6) a. Type Sso (STACK3, SIM 2)
 Repootaa-ga seito-ga hito-o mitsuketa-to omotta.
 reporter-Nom student-Nom person-Acc found that thought
 'The reporter thought that the student found a person.'
- b. Type soS (STACK2, SIM 0)
 Seito-ga hito-o mitsuketa-to repootaa-ga omotta.
 student-Nom person-Acc found that reportr-Nom thought
- c. Type Sos (STACK3, SIM 0)

- c. Type Sos (STACK3, SIM 0)
 Repootaa-ga hito-o seito-ga mitsuketa-to omotta.
 reportr-Nom person-Accstudent-Nom found that thought

All three sentences in (6) contain the same number of words and the same nouns and verbs, but word orders are different. Sentence (6a) holds the basic word order while both (6b) and (6c) contain scrambled constituents. In (6b), the complement clause is scrambled while in (6c) the object is scrambled in the complement clause. Because of the different word orders, their SIM numbers (similarity interference) are different: only Sso type contains the NP-ga NP-ga sequence (SIM2). These three types of sentences are examined in the experiment. Our hypothesis is that scrambling per se carries no processing cost; the processing cost is determined only by the effects that scrambling has on interference. Thus, it should be possible to scramble NPs and actually reduce working memory costs. Therefore, (6b) and (6c) are predicted to be easier than (6a), and (6b) is easier than (6a) and (6c).

3.1 Design and Procedure

Similar to Lewis and Nakayama's experiments, all test sentences were constructed using nouns and verbs with similar familiarity ratings. Each test sentence was balanced with the ratings of nouns and verbs so that a particular sentence did not contain only less familiar words. Although the familiarity was controlled, the number of mora and letters were not controlled. Appropriate characters (i.e., hiragana, katakana, kanji and romaji) were used in order to avoid reading difficulties. All nouns used in the test sentences were animate (human) common nouns, but those in the filler sentences contained inanimate and proper nouns. The verbs used in the test sentences included both native Japanese and Sino-Japanese verbs (i.e., Verbal Noun+suru). Matrix verbs were all past-tensed while the embedded verbs had the counter-balanced number of present and past tenses (i.e., two non-past and two past tense sentences). For instance, the Sso sentence contained three NPs with a matrix transitive verb and a transitive embedded verb, i.e., two similar consecutive NPs (SIM2) with three stacking (STACK3). These types of sentences were given to 60 native speakers of Japanese, male and female subjects (between 19-23 years old) from Tohoku Gakuin University. They were asked to rate the difficulty of each of these sentence types on a 7 point scale in the questionnaire. In the questionnaire, each sentence type had 4 sentences and 38 filler sentences (total 50 sentences). Three versions were prepared and given to 20 subjects each.

3.2 Results and Discussion

Table 3 shows the summary of the average ratings of the three test sentence types.

Table 3. Average Ratings of the Three Sentence Types

Sso (STACK3, SIM2)	4.53
soS (STACK2, SIM0)	3.5 9
Sos (STACK3, SIM0)	5.2

All three types were significantly different from each other ($F(2, 59)=66.47, p<0.001$; $F(2, 9)=19.42, p<0.001$). As predicted by the similarity interference theory, the soS type sentences like (6b) are the easiest. They are significantly easier than the Sso and the Sos types like (6a) and (6c), respectively, at 0.05 level by Tukey test. Furthermore, the Sso type sentences are significantly easier than the Sos sentences at 0.05 level by Tukey test.

This finding is different from our prediction: because the Sos sentences have SIM0, (6c) should be easier than (6a).

Why, then, are the Sos sentences the most difficult? One possibility is that it is unnatural to have scrambling within the complement clauses. Since the complement clauses were not direct quotes, it is odd to prepose the object within the complement clause. This unnaturalness might have caused the high score in the difficulty rating. If this explanation is correct, it had an independent reason for the difficulty. Another possibility is that there is a kind of garden path effect in (6c) resulting from the initial subject NP and object NP being structured together in the same clause. There is considerable independent evidence that such structuring takes place before the verb in head-final languages (e.g., Bader and Lasser, 1994; Inoue and Fodor, 1995). Thus, the Sos sentences may incur the additional processing cost of reanalyzing the second NP from object of the main clause to object of the embedded clause.

Either of these possibilities provides an independent reason for the difficulty of the Sos structure. Thus, the results of all the studies are consistent with the prediction of the similarity-based interference theory (Lewis, 1996; 1998) that syntactic similarity of NP arguments will be the significant determinant of processing difficulty. We continue to have empirical support for the idea that working memory for syntactic processing is governed by the same processing principles that govern other kinds of working memory, even if the underlying codes used are different.

Endnotes

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References

- Bader, M. and Lasser, I. 1994. German verb-final clauses and sentence processing: Evidence for immediate attachment, in C. Clifton, L. Frazier, and K. Rayner, eds., *Perspectives in Sentence Processing*. Hillsdale, NJ: Erlbaum.
- Bever, Thomas G. 1970. *The Cognitive Basis for Linguistic Structures*, in J. R. Hayes, ed., *Cognition and the Development of Language*. New York: Wiley.
- Cowper, Elizabeth A. 1976. *Constraints on Sentence Complexity: A Model for Syntactic Processing*. Doctoral dissertation, Brown University.
- Gibson, Edward A. 1991. *A Computational Theory of Human Linguistic Processing: Memory Limitations and Processing Breakdown*. Doctoral dissertation, Carnegie Mellon University.
- Hawkins, John A. 1994. *A Performance Theory of Order and Constituency*. Cambridge: Cambridge University Press.
- Inoue, A and Fodor, J. 1995. Information-paced parsing of Japanese, in R. Mazuka and N. Nagai, eds., *Japanese Sentence Processing*, Hillsdale, NJ: Erlbaum.
- Kuno, Susumu. 1974. The position of relative clauses and conjunctions. *Linguistic Inquiry* 5, 117-136.
- Lewis, Richard L. 1993. *An Architecturally-based Theory of Human Sentence Comprehension*. Doctoral dissertation, Carnegie Mellon University.

- Lewis, Richard L. 1996. Interference in Short-Term Memory: The Magical Number Two (or Three) in Sentence Processing. *Journal of Psycholinguistic Research* 25:1.93-115.
- Lewis, Richard L. 1998. Interference in working memory: Retroactive and proactive interference in parsing. ms. The Ohio State University.
- Lewis, Richard L. and Mineharu Nakayama. 1999. Determinants of processing complexity in Japanese embeddings: New theory and data. Paper presented at the International East Asian Psycholinguistics Workshop, The Ohio State University.
- Miller, George A. 1962. Some Psychological Studies of Grammar. *American Psychologist* 17.748-762.
- Miller, George A. and Noam Chomsky. 1963. Finitary Models of Language Users, in D. R. Luce, R. R. Bush and E. Galanter, eds., *Handbook of Mathematical Psychology* Vol.II. New York: John Wiley.
- Nakayama, Mineharu. 1999. Sentence Processing, in N. Tsujimura, ed., *The Handbook of Japanese Linguistics*. Boston: Blackwell.
- Uehara, Keiko. 1999. Center-embedding problem and the contribution of nominative case repetition. ms. City University of New York.