THE COMPLEXITY OF NESTED STRUCTURES IN JAPANESE

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This article presents two questionnaire experiments that investigate the processing complexity of a variety of nested constructions in Japanese. The first experiment demonstrated that embedded structures containing a direct object NP in the most embedded clause were more complex than comparable nested structures that lacked an object NP in the most embedded clause. The second experiment demonstrated that a construction consisting of a relative clause embedded within a sentential complement is less complex than the reverse embedding, consisting of sentential complement embedded within a relative clause. These results are discussed in terms of the syntactic prediction locality theory (Gibson 1998).*

1. SYNTACTIC COMPLEXITY. It has long been observed that structures with nested syntactic dependencies are difficult to process (Chomsky 1957, 1965, Yngve 1960, Chomsky & Miller 1963, Miller & Chomsky 1963, Miller & Isard 1964).[1] For example, the English sentences in 1 are associated with increasing processing complexity.

(1) a. The pictures were damaged by the child.
b. The pictures [$_{S'}$ which [$_{S}$ the photographer took]] were damaged by the child.
c. #The pictures [$_{S'}$ which [$_{S}$ the photographer [$_{S'}$ who [$_{S}$ John met yesterday]] took]] were damaged by the child.

In 1b, the relative clause S′ *which the photographer took* is nested within the matrix sentence subject-verb dependency *the pictures . . . were damaged*.[2] A sentence like 1c is said to be doubly nested/center-embedded, because a second S′ (*who John met yesterday*) interrupts the subject-verb dependency in the first S′ (*the photographer took*). Ex. 1a, which includes no nested dependencies, is the easiest to process. A structure like 1b, which contains one nested structure, is more complex (Hakes et al. 1976, Wanner & Maratsos 1978, Holmes & O'Regan 1981, Ford 1983, King & Just 1991). Finally, the

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[1] A category *A* is said to be nested (or center-embedded) within another category *B* if *A* is contained within *B* and there is lexical material on either side of *A* within *B*. Sentences that cause extreme processing difficulty are prefixed with the # symbol.

[2] Following Gibson 1998, we will assume a theoretically neutral phrase structure grammar including expansions of the form S→ NP VP and S′ → Comp S. No complexity results hinge on this assumption. In particular, the assumption of the categories Infl and Comp (Chomsky 1986) is consistent with the theory described here as are more recent proposals involving additional functional categories like Agr, Tense and Aspect, as are phrase structure assumptions from other current syntactic frameworks (e.g. head-driven phrase structure grammar, Pollard & Sag 1994).

doubly nested structure in 1c is so difficult to process that people often cannot process it correctly, despite the fact that it contains the same kinds of structures as 1b does, only greater in number.

The processing difficulty associated with 1c is not related to ambiguity confusions (e.g. a GARDEN-PATH effect), because there is no local ambiguity within the sentence. Furthermore, it is not just the length of the sentence and complexity of the thematic relationships in 1c that make this structure difficult to understand. Sentence 2 includes the same words and phrases in the same thematic relationships to one another as 1c, but is much easier to understand, because it does not contain any nested structures.

(2) [$_S$ Yesterday John met the photographer [$_{S'}$ who [$_S$ took the pictures [$_{S'}$ which [$_S$ were damaged by the child]]]]].

The difficulty in understanding nested structures appears to be a crosslinguistic universal: the set of Japanese sentences in 3 differ in perceived complexity in an analogous fashion to the sentences in 1.

(3) a. Ani -ga imooto -o ijimeta
older-brother NOM younger-sister ACC bullied
'My older brother bullied my younger sister.'

b. Bebiisittaa -ga [ani -ga imooto -o ijimeta to]
babysitter NOM [older-brother NOM younger-sister ACC bullied that
itta
said
'The babysitter said that my older brother bullied my younger sister.'

c. #Obasan -ga [bebiisittaa -ga [ani -ga imooto -o
aunt NOM [babysitter NOM [older-brother NOM younger-sister ACC
ijimeta to] itta to] omotteiru
bullied that] said that] thinks
'My aunt thinks that the babysitter said that my older brother bullied my younger sister.'

Like 1c, 3c contains a doubly nested structure: an S embedded within a subject-verb dependency which forms a second S, all of which is embedded within another subject-verb dependency. This doubly nested structure is very difficult to process.

Many theories have been proposed to account for the complexity of sentence structures like 1c and 3c. Almost all of these theories account for the processing difficulty in terms of working memory limitations (Chomsky & Miller 1963, Miller & Chomsky 1963, Miller & Isard 1964, Bever 1970, Kimball 1973, Cowper 1976, Kaplan 1974, Wanner & Maratsos 1978, Hakuta 1981, MacWhinney 1987, Gibson 1991, 1998, Abney & Johnson 1991, Pickering & Barry 1991, Lewis 1993, 1996, Stabler 1994, Babyonyshev & Gibson 1995, Gibson & Thomas 1996). Gibson's (1998) locality-based theory, the SYNTACTIC PREDICTION LOCALITY THEORY (SPLT), accounts for nesting complexity effects across a wide variety of structures. According to Gibson, difficulty in understanding nested structures arises because processing a nested structure necessitates passing through a parse state where there are many incomplete head-dependency relationships, some of which have been incomplete across the processing of much intervening material.

We evaluate the SPLT as applied to a variety of nested structures in Japanese, a head-final language. Looking at the processing complexity of unambiguous structures across typologically different languages is interesting for two reasons. First, languages with different grammars generate different constructions and make it possible to test

the predictions of theories of processing complexity on a fuller set of data than any single language would allow (Hawkins 1990, 1994, 1999). Second, only by testing the current processing theories crosslinguistically can we answer one of the most basic questions facing the field of language processing: Are the mechanisms involved in language processing universal? The results reported here support the SPLT, in a formulation unchanged from the original proposal. The results therefore lend support to the hypothesis that both the human sentence processing mechanism and the computational resources available for sentence processing are universal.

2. THE SYNTACTIC PREDICTION LOCALITY THEORY. There are two components to the SPLT: an integration-cost component, and a memory-cost component. Both of these components are locality based (cf. other locality-based complexity theories such as Wanner & Maratsos 1978, Joshi 1990, Rambow & Joshi 1994, Hawkins 1990, 1994, 1999). According to the integration-cost component of the theory, the resources needed to integrate a new head into the structure(s) built thus far are dependent on the distance between the new head and the head to which it connects in the current structure, as quantified by the number of new discourse referents separating the two heads. The integration-cost component of the SPLT accounts for reading time effects in unambiguous constructions, such as singly embedded RCs (Gibson 1998, Gibson & Ko 1998, King & Just 1991). These experiments show that longer distance integrations take longer to perform.

According to the memory-cost component of the SPLT, each syntactic head that is required to complete the current input string as a grammatical sentence except for the head of the top-level predicate is associated with a memory cost. The memory cost for each predicted syntactic head h increases as linguistic material not matching h is processed. Thus syntactic predictions that were made earlier in the sentence are more costly to maintain. The total memory cost at a word in a partially processed input sentence is obtained by summing together the costs for all the required syntactic heads at that point. This theory requires a hypothesis about the set of syntactic heads comprising sentences. We assume a syntactic theory with a minimal number of functional categories, such as HEAD-DRIVEN PHRASE STRUCTURE GRAMMAR (Pollard & Sag 1994) or LEXICAL FUNCTIONAL GRAMMAR (Bresnan 1982). Under these syntactic theories, the minimal number of syntactic head categories in a sentence is two: a noun for the subject, and a verb for the predicate. If additional words necessitate other syntactic heads to form a grammatical sentence, then these heads are also predicted, and additional memory load is incurred. SPLT's memory cost for each required head is given in 4.

(4) Syntactic prediction memory cost
   a. The prediction of the top-level predicate, V_0, is associated with no memory cost.
   b. For each required syntactic head C_i other than V_0, associate a memory cost of $M(n)$ memory units (MUs), where $M(n)$ is a monotone increasing function and n is the number of new discourse referents that have been processed since C_i was initially predicted. For simplicity, it is assumed that $\mathrm{M(n)} = \mathrm{n}$.

We hypothesize that a large factor in the intuitive judgment of a sentence's complexity is the maximal memory cost incurred at any point during its processing.[3] A sentence

[3] Alternatively, the intuitive complexity of a sentence may be determined by the maximal ratio of integration cost to memory space available. This hypothesis is explored briefly in Gibson 1998 and in more depth in Gibson & Ko 1998. Like the memory-based intuitive complexity theory, this hypothesis accounts for the English contrasts to be described here as well as the Japanese results to be presented later.

that requires a minimum of X MUs to be processed will be rated as less difficult to process than a sentence that requires a minimum of X + Y MUs, Y > 0, as long as other factors (such as ambiguity) are equivalent.

The conceptual motivation for the claim that there is no memory cost associated with predicting the top-level predicate is that most utterances are headed by a predicate, with the consequence that the processor usually expects a predicate. This prediction may therefore be built into the processor. Empirical evidence for this aspect of the SPLT memory cost hypothesis is provided in Gibson 1998.[4] The literature on short-term memory supplies motivation for the claim that syntactic memory cost increases with distance. It is harder to retain items (e.g. unrelated words or digits) in short-term memory as more interfering items are processed (Waugh & Norman 1965; see Lewis 1996 for a recent summary of relevant results). According to the memory-cost hypothesis in 4, intervening elements that cause substantial cost increments are words introducing new discourse referents: NPs (object referents) and the main verbs of VPs (event referents). The motivation for this hypothesis is that much computational effort is involved in building a structure for a new discourse referent (Haviland & Clark 1974, Halliday & Hasan 1976, Garrod & Sanford 1977, 1994). To assume that the memory-cost function is linear (M(n) = n) is an oversimplification, but one that suffices for most examples, except those in which predicted head distances are greatly lengthened. Such examples suggest that the cost function is not linear in its limiting behavior, but rather heads asymptotically towards a maximal complexity.

The SPLT memory-cost theory accounts for the difficulty in processing nested structures in a variety of constructions crosslinguistically. For example, the large complexity difference between singly nested RC structures, as in 1b (*The pictures which the photographer took were damaged by the child*), and doubly nested RC structures, as in 1c (*#The pictures which the photographer who John met yesterday took were damaged by the child*), is accounted for straightforwardly.

The point of maximal memory complexity in processing 1b occurs at the point of processing the noun *photographer*. At this point, there are three heads that are required to complete the partial sentence grammatically: (1) the top-level verb, (2) a verb to head the RC, and (3) an NP empty-category to be coindexed with the RC pronoun *which*. The

[4] For single-clause sentences, the hypothesis that the prediction of the topmost predicate is cost-free means that the prediction of the matrix clause is cost-free. However, when the first predicted predicate is encountered in a multiclause sentence, this clausal head may be shunted out of working memory. There is a large body of evidence for a clause-based closure principle like (i) (from Gibson 1998; cf. Caplan 1972, Jarvella 1971, 1979; Marslen-Wilson et al. 1978, Frazier & Fodor 1978, Bever & Townsend 1979, Milsark 1983, Gibson et al. 1996, and Roberts et al. 1997).

(i) Clause-based closure: The initiation of a new clause causes closure of an earlier clause whose obligatory requirements have been satisfied.

When such shunting occurs, a new prediction becomes the topmost predicted predicate, associated with no memory cost. Apply the closure principle to the Japanese left-branching sentence in (ii).

(ii) inu -ga kanda hito -ga soojo -o mita
dog NOM bite man NOM girl ACC saw
'The man who the dog bit saw the girl.'

As soon as the sentence begins, a predicate is predicted. This prediction is satisfied when the verb *kanda* 'bite' is encountered. When the next word *hito-ga* 'man-NOM' is processed, the initial clause is attached as a relative clause modifying this noun, and a new predicate is predicted. The prediction of the new predicate is then cost-free, because this is the topmost predicted predicate at the point where it is predicted. When this prediction is satisfied, this predicate could turn out to be the matrix predicate (as in ii) or it might be another clausal dependent of a further predicate yet to occur.

prediction of the matrix verb is assumed to be cost-free. The other two predictions were made at the point of processing the RC pronoun *which*, and one new discourse referent, the NP *the photographer*, has been processed since each of these predictions were made, resulting in a total cost of 2M(1) MUs = 2 MUs at this point. The point of maximal complexity in processing the doubly nested structure in 1c occurs at the point of processing the name *John*. Five heads are required to complete the partial sentence grammatically at this point: (1) the top-level verb (zero cost); (2) a verb to head the first RC (M(2) MUs, corresponding to two new discourse referents processed since the prediction was first made: *the photographer* and *John*); (3) an NP empty category to be coindexed with the first RC pronoun (also M(2) MUs); (4) a verb to head the second RC (M(1) MUs, corresponding to one new discourse referent processed since the prediction was first made: *John*); and (5) an NP empty category to be coindexed with the second RC pronoun (also M(1) MUs). Thus the total SPLT memory cost at this point is 2M(2) + 2M(1) = 6 MUs (under the assumption that M(n) = n), which is much greater than the maximal memory cost in processing the singly embedded structure, and the contrast is accounted for.

Empirical evidence for the discourse-based distance metric is provided by Gibson and Warren (1997) (also reported in Gibson 1998) who used a complexity rating questionnaire to show that doubly nested RC structures are easier to process when a first- or second-person pronoun is in the subject position of the most embedded RC, as in 5, as compared with a similar structure in which an NP introducing a new object into the discourse is in the subject position of the most embedded clause, as in 1c (cf. Bever 1970, Kac 1981).

(5) The pictures which the photographer who I met yesterday took were damaged by the child.

This can be accounted for in the SPLT framework if the memory increment for a predicted category is larger for new discourse referents than for referents that are already part of the current discourse, such as first- or second-person pronouns. (It is assumed that the current discourse always includes a speaker/writer and a hearer/reader.) The maximal memory cost needed to process 1c is 2M(2) + 2M(1) = 6 MUs, which occurs at the most embedded subject *John*. If there is no memory-cost increment for referents that are already part of the current discourse (such as *I* and *you*), then the memory cost at the point of processing *I* in 5 is only 2M(1) + 2M(0) = 2 MUs, corresponding to one fewer new discourse referent processed for each predicted head than at the corresponding point in 1c. The memory cost at all other parse states in 5 is also lower than the 6 MUs needed to process 1c. As a result, the maximal memory cost required to process a doubly nested RC structure with a new referent in its most embedded subject position is greater than that required to process a similar structure with an old referent in its most embedded subject position.

One nesting complexity contrast to be explored in Japanese is the one between a construction consisting of a noun with a sentential complement (SC) whose subject is modified by a relative clause (RC) and the reverse embedding, consisting of a noun with an RC modifier, whose subject has an SC (Cowper 1976, Gibson 1991, Gibson & Thomas 1996, 1997).

(6) a. Sentential complement, then relative clause (SC/RC)
The fact [that the employee [who the manager hired] stole office supplies] worried the executive.

b. Relative clause, then sentential complement (RC/SC)
#The executive [who the fact [that the employee stole office supplies] worried] hired the manager.

The structure in which the SC contains the RC (SC/RC for short) is easier to comprehend than the reverse embedding, the RC/SC structure. The locality basis of the SPLT accounts for this contrast. In particular, the difference between the two constructions is accounted for by the fact that in the SC/RC construction there is only one long incomplete category prediction—the SC verb—whereas in the RC/SC construction there are two long incomplete category predictions—the RC verb and the RC empty category position. The maximal memory complexity of the SC/RC construction occurs upon processing the word *manager*, at which point the memory cost is M(2) + 2M(1) = 4 MUs corresponding to:

1. 0 MUs for the prediction of the matrix verb;
2. M(2) MUs for the prediction of the verb in sentential complement of *the fact that* . . . ;
3. M(1) MUs for the prediction of the verb in the relative clause, which was predicted after processing *the employee who* . . . ;
4. M(1) MUs for the prediction of a position coindexed with the WH-pronoun *who* in the relative clause.

In contrast, the maximal memory complexity of the RC/SC construction is 2M(4) = 8 MUs, which occurs upon processing the word *supplies*. At this point, the following unresolved predictions are present in the structure for the input:

1. 0 MUs for the prediction of the matrix verb;
2. M(4) MUs for the prediction of the verb in the relative clause, which was predicted after processing *the executive who* . . . ;
3. M(4) MUs for the prediction of a position coindexed with the WH-pronoun *who* in the relative clause.

Because $2M(4) > M(2) + 2M(1)$ for many monotonically increasing functions M(n), including M(n) = n, the SPLT correctly predicts a memory complexity difference between the two constructions, as desired. Note that complexity theories such as those proposed by Chomsky & Miller 1963, Bever 1970, Kimball 1973, Abney & Johnson 1991, Gibson 1991, Lewis 1993, 1996 and Stabler 1994, all of which lack a distance-basis, do not account for the observed contrast.

2.1. APPLYING THE SPLT TO JAPANESE. Several properties of Japanese grammar (the fact that it allows empty pronominals, is head-final, and lacks overt relative pronouns) conspire to make this language highly locally ambiguous. As a result, assumptions about ambiguity resolution play a central role within any theory of sentence processing that attempts to account for Japanese data. There are three main issues relevant to ambiguity resolution: (1) what constraints affect the initial interpretation of an ambiguous input; (2) how many representations can be followed initially: one (the serial hypothesis) or more than one (the parallel hypothesis); and (3) how reanalysis takes place. With respect to the first issue, we assume that multiple constraints interact to determine the preferred reading(s) at points of ambiguity, as argued for in Tyler & Marslen-Wilson 1977, Marslen-Wilson & Tyler 1987, Crain & Steedman 1985, Altmann & Steedman 1988, Gibson 1991, Trueswell et al. 1993, Trueswell et al. 1994 and MacDonald et al. 1994, among others. The interacting constraints that we assume include lexical frequency (Trueswell et al. 1993, MacDonald et al. 1994, Garnsey et al. 1997), plausibility (Trueswell et al. 1994, Garnsey et al. 1997), and syntactic complexity as determined by the SPLT (Gibson 1998; Gibson et al. 1997).

For serialism/parallelism and reanalysis our assumptions are as follows. First we

assume that the parser can retain multiple representations in parallel as long as they are evaluated to have similar heuristic value, up to memory limitations (Gibson 1991, Trueswell et al. 1994, MacDonald et al. 1994, among others). Analyses that receive little support will no longer be worked on, and their activation in the competition set will decrease (Stevenson 1994, Spivey-Knowlton & Tanenhaus 1996, Tabor et al. 1997). Although they are not being actively worked on, these representations remain in the representation space with a low activation, so that a later incoming element may reactivate one of them, if there is no other alternative. Reanalysis in this framework consists of (1) the parser reactivating a representation whose activation has dropped below threshold previously, (2) returning to the point in the structure where the activation had dropped below threshold, and then (3) parsing left-to-right from this point in the same way as in first analysis, if necessary reparsing material that was processed and misattached earlier. In this way, error cues drive the parser to the appropriate earlier representation (Fodor & Inoue 1994, Fodor & Ferreira 1998), and then the intervening segment is reprocessed (more quickly than initially, because representations for these words have been recently activated). Thus, in this parallel framework, structure-building in reanalysis is identical to structure-building in first analysis (Gibson et al. 1998).

Consider the Japanese input string in 7a in light of these assumptions. After processing the two NPs marked with nominative case, the input string is consistent with either an SC structure, where the SC is of a verb to follow, as in 7b, or an RC structure, as in 7c.

(7) a. Bebiisittaa -ga ani -ga
babysitter NOM older-brother NOM

b. Bebiisittaa -ga [ani -ga naita to] itta
babysitter NOM [older-brother NOM cried that] said
'The babysitter said that my older brother cried.'

c. Bebiisittaa -ga [ani -ga e_i ijimeta] kodomo$_i$ -ni
babysitter NOM [older-brother NOM e_i teased] child$_i$ DAT
situmonsita.
questioned
'The babysitter asked a question of the child whom my older brother teased.'

Within the SPLT framework, an RC structure requires more memory resources than an SC structure in a head-final language like Japanese, because an RC structure involves more predicted heads: both require an embedded verb and a complementizer (possibly nonlexical), but the RC also requires a head noun for the RC to modify. Suppose that the difference in the quantity of memory resources required by the two structures is sufficiently large for the RC structure in 7c to be discarded by the parser, so that only the SC structure in 7b is retained at *ani-ga* 'older-brother-NOM'. Reanalysis will therefore be necessary in 7c when the head of the RC (*kodomo-ni* 'child-DAT') is encountered. At this point, the parser returns to the point of ambiguity, where the RC interpretation was discarded, and proceeds to parse the structure again, this time pursuing the RC analysis.[5]

[5] The example above is somewhat simplified, because only two structures for the ambiguous input are considered. The input string in 7a is actually compatible with at least one other structural analysis, consisting of a nominative matrix subject followed by a nominative matrix direct object, because Japanese stative verbs may assign nominative case to their objects. This structure is illustrated in (i).

(i) Bebiisittaa -ga ani -ga hihan dekira
babysitter NOM older brother NOM criticize can
'The babysitter can criticize my older brother.'

In the remainder of this article, we will compare the overall processability of two (or more) structures. Because differences in reanalysis may affect the acceptability of a structure, it is necessary to ensure that the parser engages in the same amount of reanalysis to arrive at each of the structures being compared. If the reanalysis is the same in each, then we can disregard the temporary ambiguities, and compare the memory requirements of processing the target structures. The target structure that requires the smaller quantity of resources throughout all of its parse states will be the less complex structure. We constructed the examples in the experiments such that there are minimal reanalysis differences between the structures being compared. Thus, we will present only the analysis of the target structure, ignoring ambiguity. Although in many cases the parser adopts the target analysis only after trying one (or more) other interpretations, the target structure is built in the same manner it would be built if it were the only structure adopted by the parser.

3. EXPERIMENT 1: EMBEDDED OBJECTS AND PROCESSING COMPLEXITY. Experiment 1 tests a prediction of the SPLT that has not yet been tested in any language: the number of NPs indicating new discourse referents that intervene between the point at which a category is predicted and the point at which the category is realized affects processing complexity. In particular, a sentence with an embedded clause containing two arguments, such as 8a, should be more complex than a sentence with an embedded clause containing only one argument, such as 8b.

(8) a. Bebiisittaa -ga [ani -ga imooto -o ijimeta to]
babysitter NOM [older-brother NOM younger-sister ACC bullied that]
itta
said
'The babysitter said that my older brother bullied my younger sister.'

b. Bebiisittaa -ga [ani -ga naita to] itta
babysitter NOM [older-brother NOM cried that] said
'The babysitter said that my older brother cried.'

According to the SPLT, the maximal memory load associated with processing 8a is $2M(1) = 2$ MUs, which occurs upon processing the NP *imooto-o* 'younger-sister-ACC'. In contrast, the maximal memory load associated with processing 8b is only $M(1) = 1$ MU, at the point of processing the verb *naita* 'cried'. Thus the SPLT predicts that 8a is more complex than 8b. The complexity difference should be even larger in doubly nested structures, because of the larger number of unresolved predicted categories. Thus 9a, which contains a transitive verb in its most embedded clause, should be harder to process than 9b, which contains an intransitive verb in its most embedded clause.

(9) a. Obasan -ga [bebiisittaa -ga [ani -ga imooto -o
aunt NOM [babysitter NOM [older-brother NOM younger-sister ACC
ijimeta to] itta to] omotteiru
bullied that] said that] thinks
'My aunt thinks that the babysitter said that my older brother bullied my younger sister.'

There is not yet empirical evidence relevant to whether the Japanese parser's preferred interpretation of 7a is 7b or (i). The main clause analysis (i) is syntactically simpler, and requires fewer memory resources within the SPLT framework (as well as a number of other frameworks), but lexical and morphological frequences strongly bias the initial interpretation towards the two-clause, sentential complement hypothesis 7b, because the nominative marker *-ga* is much more frequent as a subject marker than as an object marker.

b. Obasan -ga [bebiisittaa -ga [ani -ga naita to]
aunt NOM [babysitter NOM [older-brother NOM cried that]
itta to] omotteiru
said that] thinks
'My aunt thinks that the babysitter said that my older brother cried.'

The memory complexity profiles for 9a and 9b are provided in Tables 1 and 2 respectively.

SYNTACTIC PREDICTION	INPUT WORD [NP_1 aunt-NOM]	[NP_2 babysitter-NOM]	[NP_3 brother-NOM]	[NP_4 sister-ACC]
Matrix $verb_1$	0	0	0	0
$Verb_2$	–	M(0)	M(1)	M(2)
$Comp_1$	–	M(0)	M(1)	M(2)
$Verb_3$	–	–	M(0)	M(1)
$Comp_2$	–	–	M(0)	M(1)
Total cost (MUs)	0	0	2	6

	[V_3 bullied]	[$Comp_2$ that]	[V_2 said]	[$Comp_1$ that]	[V_1 thinks]
Matrix $verb_1$	0	0	0	0	0
$Verb_2$	M(3)	M(3)	*	–	–
$Comp_1$	M(3)	M(3)	M(4)	*	–
$Verb_3$	*	–	–	–	–
$Comp_2$	M(2)	*	–	–	–
Total cost (MUs)	8	6	4	0	0

TABLE 1. SPLT memory-cost profile for the Japanese sentence *Obasan-ga bebiisittaa-ga ani-ga imooto-o ijimeta to itta to omotteiru* 'My aunt thinks that the babysitter said that my older brother bullied my younger sister'.

* = position at which prediction is satisfied
– = prediction not active at this position

SYNTACTIC PREDICTION	INPUT WORD [NP_1 aunt-NOM]	[NP_2 babysitter-NOM]	[NP_3 brother-NOM]
Matrix $verb_1$	0	0	0
$Verb_2$	–	M(0)	M(1)
$Comp_1$	–	M(0)	M(1)
$Verb_3$	–	–	M(0)
$Comp_2$	–	–	M(0)
Total cost (MUs)	0	0	2

	[V_3 cried]	[$Comp_2$ that]	[V_2 said]	[$Comp_1$ that]	[V_1 thinks]
Matrix $verb_1$	0	0	0	0	0
$Verb_2$	M(2)	M(2)	*	–	–
$Comp_1$	M(2)	M(2)	M(3)	*	–
$Verb_3$	*	–	–	–	–
$Comp_2$	M(1)	*	–	–	–
Total cost (MUs)	5	4	3	0	0

TABLE 2. SPLT memory-cost profile for the Japanese sentence *Obasan-ga bebiisittaa-ga ani-ga naita to itta to omotteiru* 'My aunt thinks that the babysitter said that my older brother cried'.

* = position at which prediction is satisfied
– = prediction not active at this position

The lefthand column in each memory-complexity profile contains all the syntactic predictions required in the parse of the sentence. The words in the sentence are given at the top of each of the other columns. An entry in the table consists of the memory

load of the prediction (the row) at the word position (the column). For expository reasons, the English glosses are used in the complexity tables.

The maximal memory cost incurred in processing a doubly nested transitive structure like 9a is 2M(3) + M(2) = 8 MUs, which occurs at the point of processing the most embedded verb *ijimeta* 'bullied'. At this point, there are four syntactic predictions with the following corresponding costs: (1) the matrix verb (no cost), (2) the first embedded verb (M(3) MUs), (3) the outer complementizer (M(3) MUs), and (4) the most embedded complementizer (M(2) MUs). In contrast, the maximal memory load needed for processing a doubly nested intransitive structure like 9b is only 2M(2) + M(1) = 5 MUs, which occurs at the point of processing the most embedded verb *naita* 'cried'.

3.1. TRANSITIVITY. Experiment 1 tests the prediction that embedded transitive structures are more complex than embedded intransitive structures using an acceptability judgment task on doubly nested items like 9a and 9b. Doubly nested structures were used because of the greater complexity difference predicted on such structures as compared with singly nested structures. The experiment has a 2x2 design, crossing transitivity of the most embedded clause (transitive, intransitive) with a factor indicating whether the first subject NP is topicalized (topic, no topic). Because Japanese sentences usually have topics, the lack of a topic may cause part of the processing difficulty of example sentences like 9a and 9b. Alternatively, there may be increased complexity due to morphological case interference among the initial NPs in the nontopicalized examples, because there are three initial NPs marked with nominative case in these examples (Babyonyshev 1996, Uehara 1996). The conditions that were tested in this experiment do not distinguish these hypotheses, so they will not be discussed further.

Where the SPLT predicts that the transitive structures should be more complex than the intransitive structures, some earlier complexity theories predict no difference in this comparison. According to Lewis's (1993, 1996) theory, for example, memory cost is associated with having multiple incomplete X-bar relationships of the same kind. Under Stabler's (1994) proposal, memory cost is associated with multiple incomplete case-assignment relationships of the same type. Thus, sentences with three initial subjects that occur before their verbs are highly complex because of interference among the incomplete relations: incomplete spec-IP (subject of S) X-bar relationships for Lewis's theory; and incomplete nominative-case assignment relationships for Stabler's. These theories predict no transitivity difference because they assume that memory complexity is quantified by the largest set of incomplete syntactic relations of the same kind, with no interference from other kinds of incomplete relationships. Thus the additional incomplete X-bar (case-assignment) relationship required for the accusative NP in the transitive condition does not affect the complexity of the nested structures, because this relationship does not interfere with the incomplete spec-IP (nominative case assignment) relationships.

3.2. THE EFFECT OF STRUCTURAL AND INHERENT CASE ON PROCESSING COMPLEXITY. Gibson's (1991) complexity theory predicts a transitivity effect, associating memory cost with incomplete semantic role (or θ-role) assignment relationships. According to this theory, the maximal memory complexity of processing 9a occurs at the point of processing the embedded object *imooto-o* 'younger-sister-ACC', at which point there are four NPs that need θ-roles: the three nominative NPs and the accusative NP. In contrast, there are only three initial NPs locally lacking θ-roles in the processing of 9b, so a transitivity complexity contrast is predicted. However, as Babyonyshev and Gibson

observed (1995), Gibson's theory fails to explain the fact that singly nested examples like 10 (from Lewis 1993) are easier to comprehend than doubly nested examples like those in 9.

(10) Taroo -ga Hajime -ni [Akira -ga Hanako -ni Sigeru -o
Taroo NOM Hajime DAT [Akira NOM Hanako DAT Shigeru ACC
syookai sita to] itta
introduced that] said
'Taroo said to Hajime that Akira introduced Shigeru to Hanako.'

There are five NPs that initially do not receive θ-roles in 10, so according to the θ-role theory, this structure should be harder to process than 9a or 9b. But, the reverse is true: 9a and 9b are harder to process than 10.

Because of this problem with the θ-role theory, Babyonyshev and Gibson (1995) hypothesized that not all nominals preceding their role-assigning verbs are associated with the same memory cost. In particular, they proposed that inherently cased nominals lacking a role-assigning predicate, such as the dative marked NPs in 10, are not associated with memory cost in the same way that structurally cased nominals, like the nominative and accusative NPs in 10, are. Motivation for this idea comes from the claim that there is a tight connection between inherent case assignment and θ-role assignment, but not between structural case assignment and θ-role assignment (e.g. Chomsky 1981; see Miyagawa 1989 and Sadakane & Koizumi 1995 for discussion of grammatical tests distinguishing structurally and inherently cased nominals in Japanese). Under this proposal, the maximal memory complexity of processing 10 is only three local thematic violations; this is less than the maximal complexity of processing the doubly nested transitive 9a and equal to that of processing the doubly nested intransitive 9b.

Although there are conceptual problems with this hypothesis, it can still be tested empirically for examples like 9a by varying the case on the most embedded NP.[6] The object NP in 9a is a structural accusative object. Four conditions in experiment 1 vary the case of this object in two ways, crossing the type of case assignment (structural, inherent) with the morphological case marker (accusative, dative).

(11) [NP-nom [NP-nom [NP-nom NP-(accusative, dative)-(inherent, structural) V] Comp V] Comp V]

The extended θ-role-based theory predicts that the inherent conditions will be rated as more acceptable than the structural conditions. Further, this theory predicts no difference between the inherent conditions and the intransitive (untopicalized) condition. In contrast, the SPLT predicts no difference among the inherent and structural conditions, but predicts that the transitive condition should be more complex than the intransitive condition.

3.3. METHOD: PARTICIPANTS, MATERIALS AND PROCEDURE.

Participants

Thirty-seven native speakers of Japanese from the Boston area, primarily members

[6] One problem with the extended θ-role-based hypothesis is that it predicts that 10, which contains three initial structurally cased NPs and two initial inherently cased NPs should be at least as complex as 9b, which contains three initial structurally cased NPs with no initial inherently cased NPs. But the reverse is true: 9b is more complex than 10. A second problem with the extended θ-role-based hypothesis is that, at the point of processing an inherently cased NP, there is no way for the parser to know whether the NP is inherently or structurally cased, because this distinction depends on the following verb, not the NP or the case marker.

of the MIT community and their spouses, participated in the study. The participants ranged in age from 17 to 50. They were paid $6.00 each for taking part in the study.

Materials

Four septuples of items were constructed, in two 2x2 designs as described above. One of the conditions, the structural accusative transitive condition, made up one of the cells in each of the 2x2 designs, so that the total number of conditions was seven, and not eight. All of the nominal arguments in the experimental sentences were overt. Phonologically empty pronouns were avoided in order to reduce the ambiguity of the sentences: a null pronominal (*pro*) may correspond to any syntactic element in a sentence, not necessarily a subject. In addition, when a clause begins with *pro*, the hearer/reader is not given an unambiguous cue that a new clause has been started. Note that the absence of *pro*s makes the experimental sentences somewhat unusual, because most Japanese sentences contain empty pronouns. Sentence structures containing empty pronouns also seem to be easier to process than sentences with full lexical NPs. Within the SPLT, this phenomenon is explained by noting that when used felicitously, a *pro* refers to an element whose reference is present in the discourse, so that the memory cost of a sentence does not increase when the *pro* is processed.[7] (See §2 for a summary of evidence from English supporting this hypothesis.)

The first 2x2 set of items crossed transitivity with topicalization. A sample quadruple of items is given in 12.

(12) a. Intransitive, no topic
Wakai kyooju -ga [TA -ga [gakusei -ga
young professor NOM [teaching assistant NOM [students NOM
konransita to] sengensita to] utagatta
panicked that] announced that] doubted
'The young professor doubted that the teaching assistant announced that the students panicked.'

b. Transitive, no topic
Kankyaku -ga [rajioanaunsaa -ga [yuumeina sukeetosensyu -ga
spectator NOM [radio announcer NOM [famous skater NOM
sukeetogutu -o kowasita to] sengensita to] utagatta
skate ACC broke that] announced that] doubted
'The spectator doubted that the radio announcer announced that the famous skater broke a skate.'

c. Intransitive, topic
Eegakantoku -wa [purodyusaa -ga [kireina joyuu -ga koronda to]
film director TOP [producer NOM [pretty actress NOM fell that]
itta to] omotteiru
said that] thinks
'As for the film director, he thinks that the producer said that the pretty actress fell.'

[7] For example, the doubly nested example in (i) is easier to understand than the doubly nested example in 9a:

(i) Obasan -ga [bebiisittaa -ga [*pro* gohan -o tabeta to] itta to] omotteiru.
aunt NOM [babysitter NOM [*pro* meal ACC ate that] said that] thinks
'My aunt thinks that the babysitter said that she ate (a meal).'

The maximal memory cost in processing (i) is 3M(2) = 6 MUs at the point of processing *tabeta* 'ate', which is less than that for 9a, because of the fewer new discourse referents introduced at points of high complexity in (i).

d. Transitive, topic
Ounaa -wa [sihainin -ga [kyaku -ga wazato ueitaa -o
owner TOP [manager NOM [guest NOM deliberately waiter ACC
osita to] itta to] omotteiru
pushed that] said that] thinks
'As for the owner, he thinks that the manager said that a customer deliberately pushed the waiter.'

The second 2x2 set of items varied the case of the most embedded NP on two dimensions: (accusative, dative) x (structural, dative). A sample is given in 13. Note that 13a is the same as 12b above.

(13) a. Structural accusative
Kankyaku -ga [rajioanaunsaa -ga [yuumeina sukeetosensyu -ga
spectator NOM [radio announcer NOM [famous skater NOM
sukeetogutu -o kowasita to] sengensita to] utagatta
skate ACC broke that] announced that] doubted
'The spectator doubted that the radio announcer announced that the famous skater broke a skate.'

b. Inherent accusative
Manukena hannin -ga [kisya -ga [keisatukan -ga
foolish criminal NOM journalist NOM policeman NOM
siryooteikyoosya -o atenisita to] sengensita to] utagatta
informant ACC counted on that] announced that] doubted
'The foolish criminal doubted that the journalist announced that the policeman counted on the informant.'

c. Structural (quirky) dative
Syutujoosya -ga [hyooronka -ga [zuuzuusii kontestokuiin -ga
runner-up NOM [announcer NOM [impudent contest winner NOM
sinsain -ni kisusita to] sengensita to] utagatta
judge DAT kissed that] announced that] doubted
'The runner-up doubted that the commentator announced that the impudent contest winner kissed the judge.'

d. Inherent dative
Hyooronka -ga [supookusuman -ga [syoodootekina
commentator NOM [spokesman NOM [impulsive
senkyokoohosya -ga kyoosooaite -ni denwasita to]
candidate NOM opponent DAT called that]
sengensita to] utagatta
announced that] doubted
'The commentator doubted that the spokesman announced that the impulsive candidate phoned his opponent.'

Each septuple of items among the four sets of items contained the same sentential complement verbs (i.e. the matrix verb and the intermediate embedded verb). The most deeply embedded verb varied across the seven conditions. The nominals used were all count nouns, with a different set of nominals in each condition. The plausibility of the test sentences across the conditions was matched in the judgment of the experimenters. The most deeply embedded verbs in the inherent accusative transitive conditions failed tests for structural case assignment, such as passivization and the ability to host floated quantifiers when separated from them (see Miyagawa 1989 for discussion). The θ-role

of the objects in the inherent dative transitive conditions was goal. The dative case of the goal argument of ditransitive verbs appears to have properties of both structural and inherent case, passing some tests for structural case status and failing others. Within the θ-role theory it is necessary to analyze this case marker as inherent case in order to account for the acceptability of sentence initial ditransitive arguments, as in 10. The θ-role of the objects in the structural (quirky) dative condition varied, but was not goal or experiencer.

The test sentences were combined with 82 filler sentences of similar length and complexity as the targets (including the other experimental items discussed in this paper) to form a single list of 110 sentences. Two different versions of this list of items were constructed by pseudo-randomizing the sentences. Eighteen participants received one list and nineteen received the other. There were ten items on each page of the questionnaire, and the pages were randomized for each subject. See Appendix A for a complete listing of the sentences used in this experiment.

Procedure

The stimuli were presented in the form of a questionnaire, in which the participants were asked to rate the sentences presented based on how easy they were to understand. A five-point scale was used, with 1 being the easiest and 5 being the most difficult. The participants were instructed to read each sentence once at a natural pace, and then to provide a rating. Completing the questionnaire required about thirty minutes for each subject.

3.4. RESULTS. The unacceptability rating means and standard errors for the conditions crossing the transitivity and topic factors are presented in Table 3. The rating means

	TRANSITIVITY		
TOPICALIZATION	Intransitive	Transitive	Mean
No topic	3.51 (0.16)	3.72 (0.16)	3.61 (0.11)
Topicalized	2.70 (0.14)	3.03 (0.15)	2.86 (0.11)
Mean	3.10 (0.12)	3.38 (0.12)	

TABLE 3. Complexity ratings of the conditions in experiment 1: Crossing topicalization with the transitivity of the most embedded clause.

Higher ratings reflect higher complexity.
Standard errors are in parentheses.

and standard errors for the conditions crossing the two case factors for the embedded object are presented in Table 4. Note that the transitive, no-topic condition in Table 3 is the same as the structural accusative condition in Table 4.

	Structural	Inherent	Mean
Accusative	3.72 (0.16)	3.84 (0.13)	3.78 (0.10)
Dative	3.85 (0.14)	4.00 (0.14)	3.93 (0.10)
Mean	3.79 (0.11)	3.92 (0.10)	

TABLE 4: Complexity ratings of the conditions in experiment 1: Varying the case of the object of the most embedded clause.

Higher ratings reflect higher complexity.
Standard errors are in parentheses.

The topicalized conditions were significantly easier than the nontopicalized ones ($F1(1,36) = 51.1$, $p < 0.001$; $F2(1,3) = 75.0$; $p < .01$). Furthermore, the intransitive conditions were judged to be significantly easier to process than the transitive ones according to the participants' analysis ($F1(1,36) = 15.4$, $p < .001$), although the items' analysis did not reach significance ($F2(1,3) = 3.06$; $p = .18$), probably because of

the small number of items. If the eight items in each of the transitive and intransitive conditions are analyzed as eight independent items (not four, as in the analysis reported above), then the items' effect is greatly improved ($F2(1,7) = 4.2$; $p = .08$). This is a reasonable analysis, since the only overlap between the items that are being collapsed over in the previous analysis consists of two of the verbs in the items. All other material, including all of the nominals and the most embedded verb, is different. There was no interaction between these factors ($Fs < 1$).

The conditions containing inherently cased nominals were judged to be slightly more difficult to process than conditions containing structurally cased nominals according to the participants' analysis ($F1(1,36) = 6.07$, $p < .05$), but this effect was not close to significant in the items' analysis ($F2(1,3) < 1$), suggesting that this is not a real difference. There was no significant difference between the conditions containing nominals with accusative case-marking and those containing nominals with dative case marking ($F1(1,36) = 2.66$, $p > 0.1$; $F2(1,3) < 1$), and there was no interaction between the two case factors ($Fs < 1$). Finally, the intransitive (untopicalized) condition from the previous quadruple was significantly easier to process than either 1) the inherent transitive conditions ($F1(1,36) = 13.88$; $p < .001$; $F2(1,3) = 9.47$, $p = 0.05$) or 2) the four transitive untopicalized conditions, grouped together ($F1(1,36) = 20.55$; $p < .001$; $F2(1,3) = 9.38$, $p = 0.06$).

3.5. DISCUSSION. Taken together, these findings support the SPLT. The SPLT predicts that Japanese sentence structures containing an embedded transitive structure should be more complex than comparable sentence structures containing an embedded intransitive structure. This prediction was confirmed.

Although the SPLT accounts for the finding that embedded intransitives are easier to process than embedded transitives, this finding is also compatible with a complexity rating theory that associates longer sentences with worse ratings. That is, it is possible that the observed complexity difference is due simply to the length of the items: longer sentences get higher ratings. If this alternative explanation is correct, then there should also be a positive correlation between the length of a sentence and its rating in the filler sentences in the experiment. The filler sentences in this experiment were constructed in three separate groups: acceptable and grammatical; borderline acceptable and grammatical; and clearly unacceptable or ungrammatical. There were 18 items in each group for a total of 54 items that were not conditions in any experiment. Analyses revealed no correlations between length and rating scores in either the acceptable or unacceptable filler groups ($ps > 0.4$), and a significant negative correlation in the intermediate acceptability filler group ($r^2 = 0.59$, $p < .001$). When all three groups were combined, the negative correlation between length and difficulty remained ($r^2 = 0.35$, $p < 0.001$). Similar analyses of the fillers from the English questionnaire results of Gibson & Thomas 1997 revealed the same lack of a positive correlation. Nonstructurally defined length is probably not the cause of the observed difference between transitive and intransitive conditions.

Like the SPLT, the θ-role-based theory predicts a transitivity complexity difference, but it also predicts that embedded clauses containing structurally cased NPs should be more complex than comparable embedded clauses containing inherently cased NPs and that embedded transitive clauses containing inherently cased NPs should be equally complex as embedded intransitive clauses. Both of these predictions were disconfirmed. There was no observed difference between embedded transitive clauses depending on the inherent/structural case, as was predicted by the θ-role-based theory. More importantly, the transitive inherent conditions were more complex than the intransitive condi-

tion, contrary to the prediction of the θ-role-based theory. In contrast, both of these results are as predicted by the SPLT.

Related evidence in support of the SPLT over the θ-role-based theory is provided by intuitions about examples like 14.

(14) #John -ga Mary -ni [$_{S'}$[$_{S}$ e_j Sally -ni [$_{S'}$[$_{S}$ e_i Ann -ni denwa
John NOM Mary DAT [$_{S'}$[$_{S}$ e_j Sally DAT [$_{S'}$[$_{S}$ e_i Ann DAT telephone
-siteita]] Sam$_i$ -o syookaisita]] Harry$_j$ -o syookaisita
do-PROG-PAST]] Sam$_i$ ACC introduced]] Harry$_j$ ACC introduced
'John introduced to Mary, Harry, who introduced to Sally, Sam, who was telephoning Ann.'

Sentence 14 is unacceptable, although at its worst point, immediately before the first verb is encountered, it contains only three structurally cased NPs lacking a θ-assigner, which should not be enough to cause severe processing difficulty under the θ-role-based theory. In contrast, the unacceptability of this sentence is accounted for by the SPLT, because inherently cased NPs contribute to processing complexity, just as structurally cased NPs do.[8]

Finally, the results provide evidence of the importance of topichood in Japanese sentence processing. The topichood difference is consistent with a number of hypotheses, including the hypothesis that Japanese sentences with topics are easier to process simply because most Japanese sentences contain topics, or the hypothesis that the nontopicalized sentences are more complex because of case interference among the nominative NPs.

4. EXPERIMENT 2: SENTENTIAL COMPLEMENTS AND RELATIVE CLAUSES. An English complexity contrast that is accounted for by the SPLT and not by most other complexity theories is the relative acceptability of the SC/RC construction (a relative clause embedded within a sentential complement) as compared to the RC/SC construction (a sentential complement embedded within a relative clause). (Ex. 6 is repeated here for convenience; see §2 for the SPLT account of this contrast.)

(6) a. Sentential complement, then relative clause (SC/RC)
The fact [that the employee [who the manager hired] stole office supplies] worried the executive.

b. Relative clause, then sentential complement (RC/SC)
#The executive [who the fact [that the employee stole office supplies] worried] hired the manager.

Experiment 2 investigates the same complexity comparison in Japanese, as exemplified in 15.[9]

(15) a. SC/RC
Dooryoo -ga [kowai joosi -ga [[raikyaku -ga *pro* musisita]
coworker NOM strict boss NOM [[visitor NOM *pro* ignored]
hisyo -o] hihansita to] itta
secretary ACC] criticized that] said
'The coworker said that the strict boss criticized the secretary whom the visitor ignored.'

[8] We thank an anonymous referee for making this observation.

[9] There is debate among syntacticians over whether Japanese RCs include an operator in the specifier position of S′ (CP), so that the relativized position contains a trace of movement to the operator position (as in English), or whether there is no operator, only a nonlexical pronominal *pro* in the relativized position (Saito, 1985; Murasugi, 1991). None of our results depend on one analysis over the other. For simplicity, we assume the *pro* analysis in our discussions of these structures.

b. RC/SC
Kootyoo -ga [[sensei -ga [syoojo -ga *pro* tunetta to]
principal NOM [[teacher NOM [girl NOM *pro* pinched that]
itta] otonasii syoonen -o] semeta
said] well-behaved boy ACC] blamed
'The principal blamed the well-behaved boy whom the teacher said that the girl pinched.'

Through the point of processing the three nominative NPs, the preferred interpretation is an embedded sentential complement clause structure like that for the sentences in experiment 1. The presence of the obligatorily transitive verb (rather than an intransitive verb) is a cue to the parser that the initial analysis is incorrect, so that reanalysis is necessary, to an RC whose head noun—coindexed with the object of the transitive verb—has yet to appear.[10] At this point the parser probably continues to scan forward in the input string, looking for clues to what kind of RC structure it should build (Fodor & Inoue 1994). An appropriate head noun is encountered, and the parser goes back to the appropriate point in the input string and reinitiates normal left-to-right structure building, except that it now knows which path to follow at points of local ambiguity. This process involves constructing an RC as the most embedded clause in the SC/RC structure, and constructing an RC as the intermediate clause in the RC/SC structure. Because the reanalysis process is the same in the processing of both constructions, any difference between the perceived complexity of the two constructions is due to complexity independent of ambiguity. The SPLT predicts the same complexity difference here as in English: the SC/RC construction should be easier to comprehend than the RC/SC construction, because of the longer distance that the processor must wait before finding the head noun for the RC in the RC/SC structure. The memory-cost tables for the SC/RC and RC/SC constructions are presented in Tables 5 and 6, respectively, using the English glosses. These tables represent the processing of the target structures, ignoring first-pass processing and reanalysis which is the same in both.

The maximal memory complexity of the SC/RC construction in 15a occurs at the point of processing the embedded object *hisyo-o* 'secretary-ACC', at which point the cost is 2M(3) = 6 MUs. This cost consists of memory load for two predictions that were made at the second subject NP *joosi-ga* 'boss-NOM': the predictions of the second verb, V_2, and its complementizer, $Comp_1$. These predictions have been maintained in memory across the processing of three new discourse referents: the event referent *musisita* 'ignored', the NP *raikyaku-ga* 'visitor-NOM' and the NP *hisyo-o* 'secretary-ACC. In contrast, the maximal complexity of the RC/SC construction in 15b is 3M(2) + M(1) = 7 MUs, which occurs at the verb *tunetta* 'pinched', as depicted in Table 6.[11] At this point, there are three predictions that are associated with M(2) MUs each: the prediction of the second verb, the outer complementizer, and the head noun for the RC. Each of

[10] Japanese allows null pronominals, so with an appropriate context, the missing object could be a null pronominal referring to something in the current discourse. But because these sentences are presented without any context, there is nothing in the current discourse to which the null pronominal could refer, so this is not a viable possibility.

[11] The difference between the maximal memory costs of these two structures is even larger under the assumption that the memory-cost function is not linear in the limit, but approaches a maximal complexity (Gibson 1998). Under the nonlinear assumption, M(3) is only slightly larger than M(2), so that 3M(2) > 2M(3). Thus the maximal complexity of the SC/RC structure, 3M(2) + M(1) MUs, is substantially greater than the maximal complexity of the RC/SC structure, 2M(3) MUs.

SYNTACTIC PREDICTION	INPUT WORD			
	[NP_1 coworker-NOM]	[NP_2 boss-NOM]	[NP_3 visitor-NOM]	[NP_4 *pro*] [V_3 ignored]
Matrix $verb_1$	0	0	0	0
$Verb_2$	–	M(0)	M(1)	M(2)
$Comp_1$	–	M(0)	M(1)	M(2)
$Verb_3$	–	–	M(0)	*
$Comp_2$	–	–	M(0)	*
Head noun of RC	–	–	M(0)	M(1)
Total cost (MUs)	0	0	2	5

	[NP_5 secretary-ACC]	[V_2 criticized]	[$Comp_1$ that]	[V_1 said]
Matrix $verb_1$	0	0	0	0
$Verb_2$	M(3)	*	–	–
$Comp_1$	M(3)	M(4)	*	–
Head noun of RC	*	–	–	–
Total cost (MUs)	6	4	0	0

TABLE 5. SPLT memory-cost profile for the Japanese sentence *Dooryoo-ga kowai joosi-ga raikyaku-ga musisita hisyo-o hihansita to itta* 'The coworker said that the strict boss criticized the secretary whom the visitor ignored'.

* = position at which prediction is satisfied
– = prediction not active at this position

SYNTACTIC PREDICTION	INPUT WORD			
	[NP_1 principal-NOM]	[NP_2 teacher-NOM]	[NP_3 girl-NOM]	[NP_4 *pro*] [V_3 pinched]
Matrix $verb_1$	0	0	0	0
$Verb_2$	–	M(0)	M(1)	M(2)
$Comp_1$	–	M(0)	M(1)	M(2)
Head noun of RC	–	M(0)	M(1)	M(2)
$Verb_3$	–	–	M(0)	*
$Comp_2$	–	–	M(0)	M(1)
Total cost (MUs)	0	0	3	7

	[$Comp_2$ that]	[V_2 said]	[NP_5 boy-ACC]	[V_1 blamed]
Matrix $verb_1$	0	0	0	
$Verb_2$	M(2)	*	–	–
$Comp_1$	M(2)	*	–	–
Head noun of RC	M(2)	M(3)	*	–
$Comp_2$	*	–	–	–
Total cost (MUs)	6	3	0	0

TABLE 6. SPLT memory-cost profile for the Japanese sentence *Kootyoo-ga sensei-ga syoojo-ga tunetta to itta otonasii syoonen-o semeta* 'The principal blamed the well-behaved boy whom the teacher said that the girl pinched'.

* = position at which prediction is satisfied
– = prediction not active at this position

these predictions has been maintained across the processing of two new discourse referents, corresponding to the verb *tunetta* 'pinched' and the NP *syoojo-ga* 'girl-NOM'. A fourth prediction—that of the most embedded complementizer—is associated with an additional M(1) MUs.

The difference in maximal complexities of these sentences occurs for the same reason it occurs in English: at the first element of an S′ complement, two predictions are made

(the embedded verb and the embedded complementizer), but at the first element of an RC, three predictions are made (the verb, the complementizer, and the head noun). As a result, in sentences like 15b, there is an extra prediction being retained in memory over the material of the most deeply embedded clause. Thus, according to the SPLT, the memory cost associated with this extra prediction is responsible for 15b being more difficult to process than 15a. Hence, a sentence that contains an RC embedded inside an SC is predicted to be easier to process than a sentence that contains an SC embedded inside an RC, as in English.

In contrast to the SPLT, other syntactic complexity theories predict no difference between the SC/RC and RC/SC constructions. For example, the θ-role-based theory predicts the two constructions to be equally processable, because there are the same number of initial NPs lacking thematic roles in each (four in each). Similarly, Lewis's X-bar-relation theory and Stabler's case-relation theory also predict no complexity difference. The most complex point in each structure contains three incomplete spec-IP relationships (nominative-case assignment relations) and no difference is predicted.

4.1. METHOD: PARTICIPANTS, MATERIALS AND PROCEDURE.

Participants and procedure

The participants and procedure for this experiment are the same as those in experiment 1.

Materials

Four quadruples of items were constructed, with two of the conditions corresponding to the SC/RC embedding, exemplified in 15a and 16a, and two of the conditions corresponding to the RC/SC embedding, exemplified in 15b and 16b. A second factor was also varied in this experiment: the type of relativization in the condition. Two of the conditions used the accusative case particle *-o* (direct object) relativizations, as in 15, and two of the conditions used dative case particle *-ni* (indirect object and time NP) relativizations, as in 16.

(16) a. SC/RC, dative object-extraction RC
Oji -ga [zuuzuusii musuko -ga [[haha -ga *pro* hanasita]
uncle NOM [impudent son NOM [[mother NOM *pro* talked]
hito -ni] situmonsita to] syutyoosita
person DAT] questioned that] insisted
'My uncle insisted that the impudent son asked a question of the person to whom my mother spoke.'

b. RC/SC, dative object-extraction RC
Gekai -ga [[kangohu -ga *pro* [urusai kanja -ga okita to]
surgeon NOM [[nurse NOM *pro* [noisy patient NOM woke up that]
syutyoosita] masuii -ni] situmonsita
insisted] anesthesiologist DAT] questioned
'The surgeon asked a question of the anesthesiologist to whom the nurse insisted that the noisy patient woke up.'

The sentences were constructed so that the gap in the RC and the head noun of the relative clause had the same case, either accusative or dative. This was done because structures with case mismatches between the head noun and the gap in the RC may cause additional processing difficulty (Sauerland 1996, Sauerland & Gibson 1998).

Within the accusative RC/SC condition, exemplified in 15b, the direct object is relativized from the most deeply embedded clause. This construction is used here be-

cause the position of the direct object of the intermediate verb—*itta* 'say'—is occupied by an S′, so that it cannot be occupied by an empty NP. Thus the empty object NP is in the direct object position of the most deeply embedded verb.

Of the dative particle (*-ni*) conditions, exemplified in 16, half involved an indirect object relativization, in which both the gap and the head noun were indirect objects, and half involved time-denoting NPs, in which both the gap and the head noun were time-denoting NPs. See Appendix B for a complete list of the materials used in this experiment. Because the grammatical function of the gap was not the same as that of the sentential complement, none of the dative particle (*-ni*) examples involved long-distance relativization.

Each of the examples to be compared in a set of four items contained the same sentential complement verb, which acted as the matrix verb in the SC/RC condition and as the intermediate verb in the RC/SC condition. The remaining two verbs varied in all but the indirect-object dative examples, in which one of the remaining two verbs was the same for the two items being compared. The nominals in the items all were count nouns and a different set of nominals appeared in each condition. The plausibility of the test sentences within the different conditions was matched according to the judgment of the experimenters. As in experiment 1, all of the nominal arguments in the experimental items were overt (except for the null pronominals in the RCs) in order to reduce the ambiguity of the sentences.

The test sentences were combined with 94 filler sentences of similar length and complexity as the targets (including the experimental items from experiment 1), so that the total number of sentences appearing on the questionnaire was 110.

4.2. RESULTS AND DISCUSSION. The unacceptability rating means and standard errors for the conditions tested in experiment 2 are given in Table 7. As in English, the

	CLAUSE EMBEDDING TYPE		
CASE OF RELATIVIZED NP	SC/RC	RC/SC	Mean
Dative	3.26 (.13)	3.88 (.15)	3.57 (0.11)
Accusative	3.86 (.16)	4.13 (.11)	4.00 (0.10)
Mean	3.56 (0.11)	4.00 (0.10)	

TABLE 7. Complexity ratings for the structures tested in experiment 2.

Higher ratings reflect higher complexity.
Standard errors are in parentheses.

SC/RC condition was significantly easier to process than the RC/SC conditions ($F1(1,36) = 16.76$, $p < 0.001$; $F2(1,3) = 27.2$, $p = 0.01$). In addition, the accusative object conditions were rated as harder to process than the dative object conditions, but this effect occurred only in the participants' analysis ($F1(1,36) = 29.96$, $p < 0.001$), and did not approach significance in the items' analysis ($F2(1,3) = 1.67$, $p > 0.2$), suggesting that the effect does not reflect a general pattern, but is due to differences in the items. Finally, the participants' analysis revealed an interaction between clause order (SC/RC, RC/SC) and extraction type (direct object, indirect object), but again no such effect appeared in the items' analysis, suggesting that this effect was due to item differences ($F1(1,36) = 7.0$, $p < 0.05$; $F2(1,3) = 1.08$, $p > 0.3$).

This experiment confirms the SPLT's prediction that the SC/RC construction is easier to process than the RC/SC construction in Japanese. The results disconfirm the predictions of the θ-role-based theory and the incomplete X-bar-relation and case-relation theories.

5. CONCLUSIONS. Experiment 1 demonstrated that structures containing an embedded clause with an object NP were harder to process than similar structures containing an embedded clause without an object NP. This result was predicted by the SPLT, because clausal heads and dependents are separated further in the structures containing the additional object NP. Experiment 1 also demonstrated that having a topic in a Japanese structure greatly improves the acceptability of the structure. This result is consistent with a number of possible explanations, including the one that sentences with topics are easier to process because most sentences in Japanese have topics.

Experiment 2 demonstrated that embedding an SC within an RC is more complex than the reverse embedding, mirroring English results (Gibson & Thomas 1997). This complexity observation can be explained straightforwardly within the SPLT, but not under any other current theory. Because processing an RC involves the prediction of more syntactic heads than processing an SC, having to keep a greater number of predicted heads in memory when the RC is the outer structure leads to higher complexity. This explanation has the same general form as the explanation of the similar phenomenon in English, although the relevant structures are quite different in the two languages due to the differences in word order. Taken as a whole, the results of the experiments provide crosslinguistic support for distance-based theories of linguistic complexity such as the SPLT.

APPENDIX A: EXPERIMENTAL ITEMS FOR EXPERIMENT 1

1a. Topic, intransitive
Eegakantoku -wa purodyusaa -ga kireina joyuu -ga koronda to itta to omotteiru
film director TOP producer NOM pretty actress NOM fell that said that thinks
'The film director thinks that the producer said that the pretty actress fell.'

1b. Topic, transitive
Ounaa -wa sihainin -ga kyaku -ga wazato ueitaa -o osita to itta to omotteiru
owner TOP manager NOM guest NOM deliberately waiter ACC pushed that said that thinks
'The owner thinks that the manager said that a customer deliberately pushed the waiter.'

1c. No topic, intransitive
Haha -ga titi -ga hukigenna akatyan -ga naita to itta to omotteiru
mother NOM father NOM fussy baby NOM cried that said that thinks
'My mother thinks that my father said that the fussy baby cried.'

1d. No topic, transitive, structural accusative
Obasan -ga syoojikina bebiisittaa -ga ani -ga imooto -o ijimeta to itta
aunt NOM honest babysitter NOM older brother NOM younger sister ACC teased that said
to omotteiru
that thinks
'My aunt thinks that the honest babysitter said that my older brother teased my younger sister.'

1e. No topic, transitive, inherent accusative
Kisya -ga keisatukan -ga osorosii yoogisya -ga mati -o deta to itta to omotteiru
reporter NOM policeman NOM fearful suspect NOM town ACC left that said that thinks
'The reporter thinks that the policeman said that the fearful suspect left town.'

1f. No topic, transitive, structural dative
Isya -ga kangohu -ga atarasii kanja -ga akkan -ni niteiru to itta to omotteiru
doctor NOM nurse NOM new patient NOM villain DAT resembles that said that thinks
'The doctor thinks that the nurse said that the new patient resembles a villain.'

1g. No topic, transitive, inherent dative
Syuhu -ga yuubinhaitatunin -ga soojihu -ga gyuunyuuyasan -ni yoku syabetta to
housewife NOM mailman NOM cleaning lady NOM milkman DAT long time chatted that
itta to omotteiru
said that thinks
'The housewife thinks that the mailman said that the cleaning lady chatted with the milkman for a long time.'

2a. Topic, intransitive
Sohu -wa sobo -ga genki-na kodomo -ga tobiagatta to sitteiru to syutyoosita
grandfather TOP grandmother NOM energetic baby NOM jumped that knew that insisted
'The grandfather insisted that the grandmother knew that the energetic baby jumped.'
2b. Topic, transitive
Sihainin -wa furontogakari -ga bukiyoo-na berubooi -ga suutukeesu -o otosita to sitteiru
manager TOP front-desk clerk NOM clumsy bell boy NOM suitcase ACC dropped that knew
to syutyoosita
that insisted
'The manager insisted that the front desk clerk knew that the bell boy dropped the suitcase.'
2c. No topic, intransitive
Gankona tenin -ga maneejaa -ga kyaku -ga koronda to sitteiru to syutyoosita
stubborn clerk NOM manager NOM guest NOM fell that knows that insisted
'The stubborn clerk insisted that the manager knows that the guest fell.'
2d. No topic, transitive, structural accusative
Surudoi kaikeisi -ga katyoo -ga juugyooin -ga konpyuutaa -o kowasita to sitteiru
sharp accountant NOM section head NOM employee NOM computer ACC broke that knows
to syutyoosita
that insisted
'The sharp accountant insisted that the section head knows that the employee broke the computer.'
2e. No topic, transitive, inherent accusative
Gaikookan -ga bodiigaado -ga syusyoo -ga kossori taisi -o tazuneta to sitteiru
diplomat NOM bodyguard NOM prime minister NOM secretly ambassador ACC visited that knows
to syutyoosita
that insisted
'The diplomat insisted that the bodyguard knows that the prime minister secretly visited the ambassador.'
2f. No topic, transitive, structural dative
Baatendaa -ga sihainin -ga darasinai saraarainin -ga arukoorutyuudoku -ni mieru to
bartender NOM manager NOM sloppy dishwasher NOM alcoholic DAT looks like that
sitteiru
knows that insisted
'The bartender insisted that the manager knows that the sloppy dishwasher looks like an alcoholic.'
2g. No topic, transitive, inherent dative
Hyooronka -ga purodyuusaa -ga situkoi repootaa -ga tiji -ni situmonsita to sitteiru
commentator NOM producer NOM persistent reporter NOM governor DAT questioned that knows
to syutyoosita
that insisted
'The commentator insisted that the producer knows that the persistent reporter questioned the governor.'
3a. Topic, intransitive:
Syasinka -wa asisutanto -ga yuumeina joyuu -ga kiteita to sasayaita to sinjiteiru
photographer TOP assistant NOM famous actress NOM come that whispered that believes
'The photographer believes that the assistant whispered that the famous actress is coming.'
3b. Topic, transitive
Gaido -wa gekijooannaigakari -ga urusai kankookyaku -ga kankyaku -o zyamasita to sasayata
guide TOP usher NOM noisy tourist NOM audience ACC disturbed that whispered
to sinjiteiru
that believes
'The guide believes that the usher whispered that the noisy tourists disturbed the audience.'
3c. No topic, intransitive
Kaunseraa -ga kinodokuna gosyujin -ga okusan -ga gakkarisiteiru to sasayaita to sinjiteiru
counselor NOM poor husband NOM wife NOM disappointed that whispered that believes
'The counselor believes that the poor husband whispered that the wife is disappointed.'
3d. No topic, transitive, structural accusative
Tiisai onnanoko -ga tomodati -ga warugaki -ga otooto -o ketta to sasayaita
little girl NOM friend NOM bully NOM younger brother ACC kicked that whispered
to sinjiteiru
that believes
'The little girl believes that the friend whispered that the bully kicked (her) younger brother.'

3e. No topic, transitive, inherent accusative
Hyooronka -ga kooensya -ga seijika -ga ayasii uranaisi -o tayotteita to sasayaita
commentator NOM aide NOM politician NOM strange fortune teller ACC relied on that whispered
to sinjiteiru
that believes
'The commentator believes that the aide whispered that the politician relied on the strange fortune-teller.'
3f. No topic, transitive, structural dative
Otoosan -ga toreenaa -ga syookyokutekina otokonoko -ga uma -ni notta to sasayaita
father NOM trainer NOM timid boy NOM horse DAT rode that whispered
to sinjiteiru
that believes
'The father believes that the trainer whispered that the timid boy rode the horse.'
3g. No topic, transitive, inherent dative
Sihainin -ga baatendaa -ga ueitoresu -ga gehinna kyaku -ni hanasita to sasayaita
manager NOM bartender NOM waitress NOM vulgar customer DAT talked that whispered
to sinjiteiru
that believes
'The manager believes that the bartender whispered that the waitress talked to the vulgar customer.'
4a. Topic, intransitive
Takusiidoraibaa -wa darasinai hassyagakari -ga jookyaku -ga byookida to sengensita
taxi driver TOP lazy dispatcher NOM passenger NOM fell ill that announced
to utagatta
that doubted
'The taxi driver, he doubted that the lazy dispatcher announced that the passenger fell ill.'
4b. Topic, transitive
Sensei -wa nyuusukyasutaa -ga sityoo -ga hurui gakkoo -o heisasita to sengensita
teacher TOP newscaster NOM mayor NOM old school ACC closed down that announced
to utagatta
that doubted
'The teacher doubted that the newscaster announced that the mayor closed down the old school.'
4c. No topic, intransitive
Wakai kyooju -ga TA -ga gakusei -ga konransita to sengensita
young professor NOM teaching assistant NOM students NOM panicked that announced
to utagatta
that doubted
'The young professor doubted that the teaching assistant announced that the students panicked.'
4d. No topic, transitive, structural accusative
Kankyaku -ga rajioanaunsaa -ga yuumeina sukeetosensyu -ga sukeetogutu -o kowasita to
spectator NOM radio announcer NOM famous ice skater NOM skate ACC broke that
sengensita to utagatta
announced that doubted
'The spectator doubted that the radio announcer announced that the famous ice skater broke a skate.'
4e. No topic, transitive, inherent accusative
Manukena hannin -ga kisya -ga keisatukan -ga siryooteikyoosya -o atenisita to
foolish criminal NOM journalist NOM policeman NOM informant ACC counted on that
sengensita to utagatta
announced that doubted
'The foolish criminal doubted that the journalist announced that the policeman counted on the informant.'
4f. No topic, transitive, structural dative
Syutujoosya -ga hyooronka -ga zuuzuusii kontestokuiin -ga sinsain -ni kisusita to sengensita
runner up NOM announcer NOM impudent contest winner NOM judge DAT kissed that announced
to utagatta
that doubted
'The runner-up doubted that the commentator announced that the impudent contest winner kissed the judge.'
4g. No topic, transitive, inherent dative
Hyooronka -ga supookusuman -ga syoodootekina senkyokoohosya -ga kyoosooaite -ni
commentator NOM spokesman NOM impulsive candidate NOM opponent DAT
denwasita to sengensita to utagatta
phoned that announced that doubted
'The commentator doubted that the spokesman announced that the impulsive candidate phoned his opponent.'

APPENDIX B: EXPERIMENTAL ITEMS FOR EXPERIMENT 2

1a. SC/RC, accusative
Dooryoo -ga [kowai joosi -ga [[raikyaku -ga *pro* musisita] hisyo -o] hihansita to] itta
coworker NOM [strict boss NOM [[visitor NOM *pro* ignored] secretary ACC] criticized that] said
'The coworker said that the strict boss criticized the secretary whom the visitor ignored.'

1b. RC/SC, accusative
Kootyoo -ga [[sensei -ga [syoojo -ga *pro* tunetta to] itta] otonasii syoonen -o] semeta
principal NOM [[teacher NOM [girl NOM *pro* pinched that] said] well-behaved boy ACC] blamed
'The principal blamed the well-behaved boy whom the teacher said that the girl pinched.'

1c. SC/RC, dative
Repootaa -ga [syatyoo -ga [[kinbenna juuyaku -ga *pro* sinda] hi -ni] awateta
reporter NOM [company president NOM [[hard-working director NOM *pro* died] day DAT] cried
to] itta
that] said
'The reporter said that the company president cried on the day when the hard working director died.'

1d. RC/SC, dative
Gunsyuu -ga [[syaainka -ga *pro* [omosiroi eigastaa -ga hurahurasita to] itta] syukan
spectator NOM [[photographer NOM *pro* [funny movie star NOM tripped that] said] moment
-ni] waratta
DAT] laughed
'The spectators laughed at the moment when the photographer said that the movie star tripped.'

2a. SC/RC, accusative
PTA -ga [kootyoo -ga [[seito -ga *pro* hometa] sinsetuna sensei -o] musisita to] syutyoosita
PTA NOM [principal NOM [[students NOM *pro* praised] kind teacher ACC] ignored that] insisted
'The PTA insisted that the principal ignored the kind teacher whom the students praised.'

2b. RC/SC, accusative
Bokusi -ga [[sikyoo -ga [roomahoooo -ga maeni *pro* kiita to] syutyoosita] oruganhiki -o]
minister NOM [[bishop NOM [Pope NOM once *pro* heard that] insisted] organist ACC]
saiyoosita
hired
'The minister hired the organist who the bishop insisted that the Pope heard once.'

2c. SC/RC, dative
Oji -ga [zuuzuusii musuko -ga [[haha -ga *pro* hanasita] hito -ni] situmonsita to]
uncle NOM [impudent son NOM [[mother NOM *pro* talked] person DAT] questioned that]
syutyoosita
insisted
'My uncle insisted that the impudent son asked a question of the person to whom my mother spoke.'

2d. RC/SC, dative
Gekai -ga [[kangohu -ga *pro* [urusai kanja -ga okita to] syutyoosita] masuii -ni]
surgeon NOM [[nurse NOM *pro* [noisy patient NOM woke up that] insisted] anesthesiologist DAT]
situmonsita
questioned
'The surgeon asked a question of the anesthesiologist to whom the nurse insisted that the noisy patient woke up.'

3a. SC/RC, accusative
Osyaberina hisyo -ga [juuyaku -ga [[kisya -ga *pro* abaita] syatyoo -o]
talkative secretary NOM [director NOM [[journalist NOM *pro* exposed] company head ACC]
mamotta to] sasayaita
protected that] whispered
'The talkative secretary whispered that the director protected the head of the company whom the journalist exposed.'

3b. RC/SC, accusative
Kyooju -ga [[hisyo -ga [koosi -ga *pro* sikatta to] sasayaita] atarasii josyu -o]
professor NOM [[secretary NOM [lecturer NOM *pro* criticized that] whispered] new assistant ACC]
kaikosita
fired
'The professor fired the new assistant whom the secretary whispered that the lecturer criticized.'

3c. SC/RC, dative
Kooensya -ga [zurui seijika -ga [[osyokujiken -ga *pro* okita] hi -ni] joohatusita
aide NOM [tricky politician NOM [[corruption incident NOM *pro* broke out] day DAT] disappeared
to] sasayaita
that] whispered
'The aide whispered that the tricky politician disappeared on the day when the corruption scandal broke out.'
3d. RC/SC, dative
Utukusii miboojin -ga [[saibantyoo -ga *pro* [satujinsya -ga syoogensiteiru to] sasayaita]
beautiful widow [[NOM judge NOM *pro* [murderer NOM testify that] whispered]
syukan -ni] taoreta
moment DAT] collapsed
'The beautiful widow collapsed at the moment when the judge whispered that the murderer is testifying.'
4a. SC/RC, accusative
Bengosi -ga [kainusi -ga [[neko -ga *pro* hikkaita] bukiyoona juui -o] kokusosita to]
lawyer NOM [owner NOM [[cat NOM *pro* scratched] clumsy veterinarian ACC sued that]
sengensita
announced
'The lawyer announced that the owner sued the clumsy veterinarian whom the cat scratched.'
4b. RC/SC, accusative
Juuyaku -ga [[katyoo -ga [jinjibutyoo -ga *pro* kaikosita to] sengensita]
director NOM [[section head NOM [personnel division-head NOM *pro* fired that] announced]
wakamono -o] mata saiyoosita
young man ACC] again hired
'The director re-hired the young man, whom the section head announced that the head of personnel fired.'
4c. SC/RC, dative
Kityoo -ga [booryokutekina haijakku -ga [[joomuin -ga *pro* hanasita] jookyaku -ni]
captain NOM [violent hijacker NOM [[flight attendant NOM *pro* talked] passenger DAT]
donatta to] sengensita
yelled that] announced
'The captain announced that the violent hijacker yelled at the passenger to whom the flight attendant talked.'
4d. RC/SC, dative
Oya -ga [[isya -ga *pro* [kodomo -ga oboreta to] sengensita] wakai raihugaado -ni] donatta
parent NOM [[doctor NOM *pro* [child NOM drowned that] announced] young lifeguard DAT] yelled
'The parent yelled at the young lifeguard to whom the doctor announced that the child drowned.'

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