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# Modularity and the Representational Hypothesis

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# MODULARITY AND THE REPRESENTATIONAL HYPOTHESIS

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A central goal of linguistic research is to uncover the underlying principles of grammar and to reveal the structure of the human mind. Traditionally it has been assumed that research on language comprehension may contribute to this goal by helping to tease apart grammatical and nongrammatical aspects of language and, given explanatory theories of processing, perhaps it will lead to explanations of certain grammatical principles. Here I will suggest that psycholinguistic research may also help to evaluate competing grammatical frameworks. The form of the argument is extremely simple: certain aspects of the human sentence processing mechanism make sense only given particular assumptions about the grammars of natural languages. To be compelling, of course, the argument must rest on a theory of the processing mechanism which is both empirically-motivated and explanatory.

Consider what it would mean to have an explanatory theory of sentence processing. Experimental research indicates that there is considerable uniformity in the principles governing the syntactic analysis of sentences. Hence, a theory of sentence processing must explain why this is the case (e.g., why different individuals adopt the same strategies and why they adopt the particular set of strategies they do, and not easily imagined alternatives). The theory must also show how these strategies, together with the grammar of a particular language, may account for the successful processing of radically different language types. Further, it should offer some insight into the architecture of the processing system, i.e., the number and nature of the subsystems involved, and the relation between them.

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In principle, any of various types of psycholinguistic evidence might bear on the selection of a grammatical framework. However, in practice, the distinct representational claims of various grammatical theories can often be coupled with distinct processing claims to account for the available psycholinguistic evidence. This is especially true in the case of isolated psycholinguistic hypotheses that are not embedded in more general theories of sentence processing, since in this case altering either the representational or the processing claims will have few ramifications. Thus, in practice, it is likely to be empirically motivated explanatory theories of sentence processing, not isolated psycholinguistic data or hypotheses, that will bear on the choice of grammatical framework. Further, and again only as a matter of practice, investigations focusing on the explanation of the architecture of the human sentence processing system are most likely to turn up psycholinguistic evidence relevant to evaluating grammars. The reason for this assessment is straightforward: distinct grammatical theories typically define different natural classes of potential processing modules and claims about grammatically-based natural classes tend to be difficult to mimic by altering one's processing assumptions.

In what follows, I will present a concrete illustration of this type of argument. I will begin with a cursory description of various experimental studies on the syntactic processing of English. The focus will be primarily on the evidence concerning the modular nature of the processing mechanism. I must emphasize at the outset that I will take a modular theory to be one in which distinct processing subsystems exist, each associated with its own processing task accomplished on the basis of characteristic processing principles and information sources. A processing module need not be autonomous in the sense of Forster (1979) and thus the relation between modules need not be one of strict linear ordering, with the input to one module being the output of the preceding one. After reviewing the empirical evidence and sketching the outlines of a theory of sentence processing, we will turn to questions concerning the explanatoriness of the model, paying particular attention to those aspects of the model which remain unexplained and mysterious unless we appeal to certain properties of grammars. The final section will directly address the relation between a theory of grammar and a theory of human sentence processing.

1. In several papers, my colleagues and I have argued for the following theory of sentence processing. When a perceiver receives an input sentence, the first word of the sentence is attached to the root S using the fewest syntactic nodes consistent with the grammar. Each subsequent item is minimally attached into this partial structure, i.e., incorporated using the fewest syntactic nodes possible. When two equally minimal analyses exist, the parser adopts the one permitting the input item to be attached as a sister to more recently encountered material, rather than as a sister to more distant items or to subsequent items. These "Minimal Attachment" and "Late Closure" strategies predict that the

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a- forms of (1) and (2) should be easier to process than the b-forms, where the initial analysis of the ambiguous string (underlined) will have to be revised when the disambiguating material arrives. (See Frazier, 1978; Frazier and Fodor, 1978; Fodor and Frazier, 1980, for discussion of these strategies.)

(1) a. John knew $[_{NP}$ the answer by heart. (minimal attachment)

b. John knew $[_{S}[_{NP}$the answer was correct. (nonminimal)

(2) a. Since Jay always jogs a mile] this seems like a short distance to him. (late closure)

b. Since Jay always jogs] a mile seems like a very short distance to him. (early closure)

Recording subjects' eye movements as they read sentences like those in (1) and (2) has provided rather detailed evidence supporting these strategies (Frazier and Rayner, 1982; Kennedy and Murray, in press). The b-forms are more difficult to process than the corresponding a-forms regardless of whether one looks at the average reading time per character, at the average duration of fixations preceding vs. following the point of disambiguation or at the probability of making a regressive eye movement. On every measure the b-forms are more difficult to process than the corresponding a-forms and this difficulty is associated with the predicted region of the sentence (i.e. the disambiguating region following the ambiguous words).

The initial constituent structure analysis of an input string is accomplished on the basis of phrase structure information and strict subcategorization information (see Clifton, Frazier and Connine, 1984) but is not influenced by the relative pragmatic plausibility of alternative syntactic analyses. Thus, despite the fact that performers are more likely recipients of flowers than are florists,[1] perceivers show clear effects of having been garden-pathed in sentences like (3b) as well as (3a). This is predicted by the Minimal Attachment strategy, since the main clause analysis of sent the flowers requires the postulation of fewer syntactic nodes than does the reduced relative analysis. Further, there is no evidence of perceivers having been garden-pathed in (3c), where the structurally-preferred main clause analysis is confirmed by subsequent context.

(3) a. The florist sent the flowers was very pleased.

b. The performer sent the flowers was very pleased.

c. The performer sent the flowers and was very pleased with herself.

Similarly, if one pragmatically biases a fully ambiguous sentence toward either a minimal attachment analysis, as in (4a) where the VP-attachment of the PP is very sensible, or towards a nonminimal analysis, as in (4b), perceivers will ultimately assign the pragmatically most plausible analysis to the sentence, but it will take them longer to do so when this conflicts with the structurally

preferred analysis, as in (4b). (See Rayner, Carlson and Frazier, 1983.)[2]

(4) a. The spy $[_{VP}$saw $[_{NP}$the man $[_{PP}$with binoculars but the man didn't see him. (minimal attachment)

b. The spy $[_{VP}$saw $[_{NP}[_{NP}$the man $[_{PP}$with a revolver but the man didn't see him. (nonminimal)

These data can be readily explained on the assumption that there are two distinct processing modules: a syntactic processor concerned with assigning a constituent structure analysis to an input on a basis of the information contained in phrase structure rules and strict subcategorization frames, relying on strategies such as Minimal Attachment and Late Closure; and, a "thematic processor" which uses real world knowledge to identify the pragmatically most plausible thematic frame associated with heads of phrases. On this assumption, it follows automatically that a sentence will be easier to process when the frame chosen by the thematic processor is consistent with the initial syntactic analysis of the input, than in cases where the two conflict. Notice that we have satisfied our criteria for establishing distinct processing modules: two processing tasks are accomplished on the basis of distinct principles and distinct information sources.

With these background assumptions, I wish to turn now to evidence suggesting that there is modularity within the syntactic processor, i.e., that distinct processing modules are involved in the syntactic analysis of sentences. Many investigators have proposed systems predicting that when a gap (empty position in the phrase marker) is detected, perceivers will assign the most recent potential filler to that gap (e.g. Fodor, 1978; Wanner and Maratsos, 1978). This correctly predicts that a sentence like (5a) will be more difficult to process than (5b), since in (5a) no subsequent gap will occur to which the head of the relative clause could be assigned. Hence, the initial recent-filler assignment in (5a) will have to be revised.

(5) a. This is the girl the teacher wanted ___ to talk. (distant filler)

b. This is the girl the teacher wanted ___ to talk to ___. (recent filler)

Frazier, Clifton and Randall (1983) showed that 'distant filler' sentences like (5b) do take longer to comprehend than 'recent filler' sentences like (5a). Further, the same pattern was obtained in 'unambiguous' sentences such as those in (6), which in principle may be disambiguated by the control properties of the verb.

(6) a. This is the girl the teacher forced ___ to talk. (recent filler)

b. This is the girl the teacher tried ___ to talk to ___. (distant filler)

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We argued that the unambiguous sentences in (6) behave like the ambiguous sentences in (5) because, from the perspective of the sentence parsing mechanism, they are ambiguous, i.e., lexical control information is not consulted at the time when an initial filler-gap assignment is made. We also hypothesized that the Recent Filler Strategy is really a consequence of the processor assigning to each gap the most salient potential filler; other things being equal, the most recent, i.e., the most readily accessed filler in memory. This predicts that increasing the salience of the distant filler, e.g., by explicitly marking it as a filler by including an overt relative pronoun, should facilitate the processing of the 'distant filler' sentences, but not the 'recent filler' sentences. This prediction was confirmed for both the ambiguous sentences in (5) and the unambiguous sentences in (6), lending further support to the view that the difficulty in these two sentence types has a common source. Stress, of course, is predicted to have a similar effect though this prediction has not been confirmed experimentally. (A separate study was conducted to insure that the difficulty of the unambiguous distant filler sentences could not be attributed simply to the presence of two adjacent gaps in this sentence type, see Frazier, et. al.[3])

This study suggests that the initial syntactic analysis of a sentence involves constructing a constituent structure representation of the input sentence, heuristically coindexing any empty categories with the most recent or salient potential filler. At some later point, initial filler-gap assignments will be checked to insure the control properties of particular lexical items are satisfied, as well as other structure evaluation conditions governing the permissable relations between empty categories and other phrases. This general view predicts that other structure evaluation conditions, e.g., syntactic locality conditions, (e.g., subjacency or, descriptively, the Complex Noun Phrase Constraint) will not necessarily constrain the initial assignment of filler-gap dependencies. Chuck Clifton and I are in the process of testing this prediction; our current results suggest this is the case. Consider the sentences in (7).

(7) a. What did the girl win (___) at ___?
b. What did the girl excel ~~at~~ ___?

The verb win is optionally transitive. If the presence of the optional gap following win serves to decoy the sentence processor, then sentence (7a) should be more difficult to process than (7b), where there is no decoy gap following the obligatorily intransitive verb excel. Assuming this prediction is confirmed, we may then determine whether the Complex Noun Phrase Constraint constrains the initial assignment of filler-gap dependencies by examining sentences like those in (8).

(8) a. What did the girl who won (___) receive __?
b. What did the girl who excel~~led~~ receive __?

When the processor encounters the potential gap following win in (8a), this gap should decoy the processor if it does not immediately consult island constraints, since the noun phrase what may be assigned to this gap (though, of course, this assignment will later have to be revised). However, if the processor does consult the full set of syntactic well-formedness constraints of the language before making initial filler-gap assignments, then it will discover that there is no appropriate filler for this potential gap and thus the processor should not be decoyed by this gap. Of course, there is always the possibility that the mere presence of an optional gap interferes with processing, independent of the availability of a potential filler for that gap. Hence, we are only interested in any difference between (8a) and (8b) that is larger than that found in simple declarative sentences like those in (9), where there is no potential filler for a postverbal gap.

(9) a. The girl won (___) all the time.
b. The girl excelled all the time.

Using word-by-word visual presentation and a timed grammaticality judgment task, Chuck Clifton and I tested sentences like those in (7), (8) and (9). The results of the initial study

TABLE 1

GRAMMATICALITY JUDGMENT TIME

| | RT in gram. judgment | % correct |
|---|---|---|
| No island | | |
| (7a) decoy | 1220 | 71% |
| (7b) no decoy | 1148 | 75% |
| Island | | |
| (8a) decoy | 1245 | 68% |
| (8b) no decoy | 1200 | 78% |
| Control | | |
| (9a) decoy | 1170 | 89% |
| (9b) no decoy | 1171 | 85% |

are presented in Table 1. A decoy effect was observed in sentences like those in (7) and in (8), but not in (9). These results suggest that the processor does not necessarily consult all relevant syntactic conditions before making initial filler-gap assignments. I must emphasize that these results are preliminary. The theoretically crucial decoy effect is only marginally significant in (7) and (8)[4]. However, the results have been replicated.

Before turning to the implications of these studies for questions of modularity, I wish to briefly mention the results of another timed grammaticality judgment experiment (Frazier and

Clifton, 1984). The principles discussed so far predict that a complement clause analysis of an input should be preferred to either a purpose clause or rationale clause analysis, since the complement analysis permits the clause to be minimally attached as a sister to the most recently encountered material. (I assume that purpose clauses and rationale clauses are Chomsky-adjoined to VP and S, respectively.) Thus, the complement clause (a-forms) of (10) and (11) are predicted to be easier to process than the corresponding b-forms.

(10) a. The principal chose an older student PRO to go to the conference.
b. The principal chose an older student PRO to take ___ to the conference.
(11) a. Billy programmed the computer PRO to do all his homework.
b. Billy programmed the computer PRO to escape doing his homework.

These predictions were confirmed, providing additional evidence for the proposed processing system. Of more interest, however, are sentences like (12) an (13) which were also tested, since these sentences provide a test of the processor's initial classification of empty categories.

(12) a. John lent some books to Mary PRO to read on vacation.
b. John borrowed some books from Mary PRO to read on vacation.
(13) a. John lent some books to Mary PRO to keep Billy from destroying them.
b. John borrowed some books from Mary PRO to keep Billy from destroying them.

In effect, the PRO in these sentences is thematically determined, since satisfying the semantic restrictions of a purpose clause or rationale clause typically requires the controller to be the goal, in purpose clause sentences with verbs like those in (12), and the agent, in rationale clause sentences like (13). We may thus determine whether it is the position of the possible controllers or the thematic structure of the matrix verb which determines the initial interpretation of thematically determined PRO, to see whether this empty category is treated on par with wh-trace and obligatorily controlled PRO in the initial analysis of a string. The results, presented in Table 2, clearly indicate that it is thematic structure, not the structural position of a phrase, that is important: (12a), where the more recent phrase is the correct controller for PRO took longer to process than (12b), contrary to what we would expect according to a recent filler strategy; and, in (13), there was a significant difference in the comprehension times depending on whether the subject corresponded to a source or a goal, despite the fact that the ultimately correct controller was in the same structural position in both cases. Thus, we have initial evidence that thematically or pragmatically controlled PRO is distinguished from other empty categories in the initial analysis of a sentence.

TABLE 2

GRAMMATICALITY JUDGMENT TIME

| | Sentence Type | RT | % Correct |
|---|---|---|---|
| (10a) | Complement | 987 | 96 |
| (10b) | Purpose Clause | 1042 | 78 |
| (11a) | Complement | 1054 | 85 |
| (11b) | Rationale Clause | 1077 | 76 |
| (12a) | Purpose Clause: Object Goal | 1012 | 89 |
| (12b) | Purpose Clause: Subject Goal | 980 | 88 |
| (13a) | Rationale Clause | 966 | 84 |
| (13b) | Rationale Clause | 1025 | 88 |

Taken jointly, the above studies support a modular theory of syntactic processing. Initially, a constituent structure analysis of an input is assigned on the basis of phrase structure and strict subcategorization information, according to the structurally based strategies of Minimal Attachment and Late Closure. Empty categories that could be analyzed as a wh-trace or an obligatorily controlled PRO are heuristically coindexed with the most recent (salient) potential filler, presumably because these categories will not be licensed unless there is some potential binder or controller for the empty category. By contrast, empty categories that could not correspond to either a trace or an obligatorily controlled PRO are treated differently; presumably these gaps are initially identified as being pronominal. At some point, the indexed structures resulting from these processes must be checked against the full set of structure evaluation conditions of the grammar, e.g., binding theory, bounding theory, etc. Though at present we do not have clear evidence about the precise time course of these operations or the domain over which they operate, it is apparently only at this stage of structure evaluation that information about control and about locality conditions is consulted.

2. We turn now to questions about the explanatoriness of the model. First, why should the syntactic processing mechanism abide by strategies like Minimal Attachment, Late Closure and the Most Recent filler strategy? Notice that each of these strategies may be viewed as a consequences of a more general tendency for the parser to adopt the first available syntactic analysis of an input. In the cases of Minimal Attachment, this follows from the fact that the nonminimal attachment analysis of an input will always require the accessing of more rules than the minimal attachment

analysis (see Frazier and Fodor, 1978). Hence, assuming it takes more time to access more rules, the minimal attachment analysis of an input will automatically be chosen if the processor adopts the first syntactic analysis available to it. The late closure analysis of an input may also be attributed to a first analysis strategy, since attaching an input item as a sister to material just received will presumably demand less memory search than identifying material that occurred earlier and structuring the input item with material following it would entail delaying analysis until the subsequent material has been received and analyzed. On the assumption that more recent fillers may be retrieved from memory more rapidly than more distant fillers, the recent filler heuristic may also be attributed to the tendency for the processor to adopt the first available analysis. Thus, assuming the first analysis strategy may itself be attributed to the time pressures operative in sentence processing, we have an explanation for each of the strategies assumed in this model.

Most contemporary linguistic research proceeds on an assumption that we might dub the "Representational Hypothesis"; namely, that linguistic theory, specifically Universal Grammar, will characterize the specialized representational systems available to humans for representing grammatical information of various types. Thus, while the specification of the details of particular rules or principles may vary for, say, English and Japanese, the representational systems and the format for mentally representing grammatical information will remain fixed across languages. Given this assumption, the hope is that substituting the grammatical specifications appropriate for another language will automatically result in the correct processing theory for that language, without any other alterations whatsoever. Given that the strategies proposed above are stated independently of the particular language being processed and given that their explanation is nonlinguistic and thus independent of the details of a particular grammar, the above proposal can in principle account for the processing of other languages. At present, we have very little detailed evidence about the parsing of languages other than English. The very limited evidence I am aware of is consistent with principles proposed for English, with one exception: in predominantly left-branching languages, the stipulation that the first word of a sentence must be attached to the root S is apparently relaxed.[5]

The theory of sentence processing outlined above is clearly incomplete, but I have tried to indicate that it is empirically-motivated and it is explanatory in the sense discussed above. What has not been explained, however, is the precise architecture of the system. Why, for example, should the constituent structure analysis of a sentence be influenced by phrase structure information, strict subcategorization information (and, presumably, case theory)[6], but not by information about lexical control properties or syntactic locality conditions? If the grammars of natural languages only draw a distinction between gross "components", e.g. between the vocabulary available for couching syntactic generalizations vs. the vocabulary of phonological or semantic principles, this division

makes little sense. By contrast, if the syntax of natural languages is modular, consisting of several distinct types of principles, the division of labor and of information sources indicated by the studies reviewed above seems quite natural: quick decisions about the constituent structure of an input may be made on the basis of quite limited information; relations between positions in this structure may then be determined on the basis of additional information once a constituent structure representation has been constructed for some relevant portion of an input sentence. The computational savings of this modular system is twofold: less information needs to be considered during the initial structure building operations compared to an "autonomous components" system, presumably permitting quick analysis since a constituent structure decision may be made about the attachment of word n+1 regardless of whether all structure evaluation conditions potentially relevant to the analysis of word n have already been checked. Further, assuming that the thematic processor which exploits real world knowledge operates in parallel (simultaneously) with the constituent structure processor, incorrect or inappropriate constituent structure analyses will often be rejected before considerable computational effort is wasted evaluating the relations between the lexical phrases and empty categories in the incorrect structure. Thus concurrent operation of highly specialized processing subsystems may reduce the computational demands of sentence processing, while simultaneously preventing delays of lower level analysis that would be imposed by a system where each processing decision must be checked against all well-formedness conditions before the decision is made.

3. While the properties of the sentence processing mechanism motivated above seem sensible assuming a modular syntax, the assumption of a modular syntax does raise several questions about the relation between the theory of grammar and the theory of human sentence parsing. In earlier versions of generative grammar in which sets of rules (and constraints on their application) defined each of the components of a grammar, one could easily imagine strong and natural constraints on the relation between grammars and parsers. For example, each rule might correspond to a processing operation. Or, each formally distinct rule type might receive some interpretation in a theory of sentence comprehension with the constraint that any two rules of the same formal type must receive the same interpretation. However, given recent modular theories, the only constraint that has been proposed (to my knowledge) is a "type transparency" or "direct implementation" constraint (cf. Berwick and Weinberg, 1984), demanding only that "grammars be realized more or less directly as parsing algorithms" (p. 39), in practice demanding only that the parser assign to each sentence the same representation assigned by the grammar. Perhaps this is correct, but it certainly seems to permit far too many possible parsers to account for the empirical evidence about the uniformity of parsing preferences and relative processing complexity of sentences across different individuals. Thus, we must at least attempt to identify additional constraints on the relation between

theories of parsing and modular theories of grammar.

One way to view this problem is to think of how the distinct sets of principles in a modular theory could be organized or grouped to define a processing module. Why, for example, do we find control theory and bounding theory exploited by the processing module, and phrase-structure information and strict subcategorization exploited by another one? Why shouldn't we find control theory and subcategorization grouped together, on the one hand, and binding theory and case theory, on the other?

One natural hypothesis is that every processing module must bear a "grammatical signature", i.e., the rules or principles of any processing module must both share some common vocabulary internally and (contain principles that) include some vocabulary distinct from that available to other processing modules. The grammatical signature hypothesis makes what are apparently the right distinctions in the case of the processing modules motivated above. Constituent structure analysis proceeds on the basis of information about strict subcategorization, case and phrase structure. Arguably, the principles capturing this information share the vocabulary of syntactic features (e.g. +N, +V, etc.) and the structural relation that is important to these principles is that of "sisterhood". By contrast, rather than defining and utilizing the relation "sister", the crucial structural relation for binding theory, bounding theory, and control theory is c-command. And, these principles share with each other the vocabulary needed to characterize empty categories. Thus the syntactic processing modules proposed above do bear a 'grammatical signature'. The shared vocabulary of the (real world and thematic frame) information available to the thematic processor is clearly that of thematic relations; presumably the vocabulary distinguishing this module from strictly grammatical processing modules will be whatever features are important in organizing nonlinguistic knowledge about real world objects, events and situations.

I must emphasize that the grammatical signature hypothesis is not only speculative but, at best, it provides only a necessary but not sufficient condition for establishing a processing module. Additional constraints must be sought if we wish to truly explain the architecture of the human sentence processing mechanism. Nevertheless, compared to the set of parsing mechanisms permitted by the 'type transparency' constraint, it severely reduces the class of possible sentence parsing systems.

## NOTES

[1]Crain and Coker (1979) have shown in a paraphrase verification experiment that these pragmatic plausibility relations do influence the ultimate analysis assigned to ambiguous sentence fragments like The florists sent the flowers vs. The performers sent the flowers.

[2]Ferreira and Clifton (1984) have shown that readers are garden-pathed in nonminimal attachment forms of sentences like those in (3) and (4) even when biasing pragmatic information occurs in preceding sentences where it may be fully processed before the ambiguous string is encountered.

[3]Crain and Fodor (1984) argue that the difficulty of unambiguous 'distant filler' sentences such as (6a) can be observed immediately following the gap, contrary to the predictions of the proposal in the text. The discrepancy between their results and those of Frazier, Clifton and Randall (1983) might result from differences in the experimental task and the presentation rates used. Indeed, if the temporal relation between 'structure building' operations and operations of structure evaluation are not specified (i.e. if they are accomplished by distinct processing modules that are not time-locked), we might expect the presentation rate of the input and the computational complexity associated with the input to determine how much, if at all, evaluating the indices on a structure lags behind the construction of a constituent structure representation of some portion of the input string.

[4]If our interpretation of these results proves to be correct, then clearly subjacency cannot be attributed to any parsing explanation claiming that the search space of potential antecedents for a gap must be restricted. For an alternative (though speculative) hypothesis about the processing motivation for the existence of certain syntactic locality conditions, see Frazier (1984).

[5]Ueda (ms.) argues for the operation of Minimal Attachment in Japanese. Relying on Ueda's analysis, Frazier, Rayner and Carlson (ms.) suggest that the only change in the specification of the above processing system which is required for consistently left-branching languages is a relaxation of the 'Partial Top Down' constraint stipulating that the first word of a sentence is attached into a node identified as the <u>root</u> S.

[6]The assumption that case theory constrains initial constituent structure decisions has two consequences in this system. It predicts that the parser doesn't incorrectly take <u>he</u> to be the object of <u>leave</u> in a sentence like: <u>When Roger left he...</u> It also implies that the parser may distinguish between case-marked gaps and other gaps, even in its initial heuristic indexing of empty categories. Hence, the most recent filler for a case-marked gap would be the most recent (unused) filler in $\bar{A}$ position.

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