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The Nested Dependency Constraint As A Parsing Strategy*

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In his comments on Chomsky's paper "On WH-Movement", Emmon Bach points to an interesting difference in the acceptability of sentences that involve more than one gap (Bach 1977). Whereas (1) is perfectly interpretable, (2) is hard to make sense of:

(1) What instrument₁ is this piece of music₂ easy to play ₂ on ₁?

(2) * What piece of music₁ is this instrument₂ easy to play ₁ on ₂?

(1) and (2) differ with respect to the order of 'fillers' and 'gaps'. Bach notes that the nested pattern in (1) F1 F2 G2 G1 is relatively good, but that the intersecting pattern in (2) F1 F2 G1 G2 is unacceptable. He suggests that the difference in acceptability can be explained in terms of processing mechanisms.

There seems to be a very general constraint against intersecting filler-gap dependencies in the languages of the world, which has often been noted in the literature (Berman, quoted in Kuno & Robinson (1972), Baker (1977) et al.). Fodor (1978) provides an extensive discussion of constructions with multiple filler-gap dependencies in English. In this paper I will look at nested and intersecting dependencies in two other languages, Swedish and Norwegian. I propose that the overall preference for nested patterns can be explained by a general parsing principle and I will discuss under what conditions intersecting readings are available.

The Nested Dependency Constraint

After looking at a wide range of constructions in English which involve multiple filler-gap assignments, Fodor concludes that intersecting dependencies, resulting from the interaction of movement and/or deletion rules, are ruled out everywhere except when the construction is clearly unambiguous for morphological, semantic or pragmatic reasons. She formulates the constraint as a No Ambiguity constraint:

(3) Nested Dependency Constraint (NDC)

If there are two or more filler-gap dependencies in the same sentence, their scopes may not intersect if either disjoint

or nested dependencies are compatible with the well-formedness conditions of the language. (Fodor p. 448)

When there is no ambiguity at stake, English allows intersecting dependencies. This happens for instance when the fillers are of different grammatical category, as in (4).

- (4) $\left[\begin{array}{c} \text{Which crimes} \\ \text{NP} \end{array} \right]$ did the FBI not know $\left[\begin{array}{c} \text{how} \\ \text{AP} \end{array} \right]$ to solve $\underline{\text{NP}}$ $\underline{\text{AP}}$?

Intersecting dependencies may in principle arise in any of the following configurations:



In the following I am going to discuss only the F F G G pattern. This seems to be the most frequent and the one where it is most likely that we may obtain comparable data from a number of languages. With regard to the configuration F G G F and the unusual (unattested?) G F F G, we note that they may arise through the interaction of one leftward movement rule with one rightward movement rule. There seems to be a general asymmetry in the obligatoriness of movement rules. Leftward movement rules such as Relativization and Question formation are obligatory (given that WH words are base-generated) and unbounded; rightward movement rules, on the other hand, such as Heavy NP Shift and Extraposition, are optional and bounded. It is generally known that the application of these rules is dependent on the size of the moved constituent. Frazier & Fodor (1978) point out that it is the relative length of the moved and intervening constituents that matters. It is preferable to have short constituents before long constituents. It seems in general that rightward movement rules show more individual variation in acceptability judgments among speakers. For this reason I will limit the discussion in this paper to structures that arise from applications of obligatory rules only, namely the F F G G pattern.

In English this pattern may be created by the interaction of WH-movement, Topicalization, Tough-movement, and Too/Enough deletion. Double applications of WH-movement are generally considered ungrammatical (the WH-island Constraint) but Fodor notes that for speakers who accept such sentences, it is the nested reading that is available, as shown in (5) (Fodor's (57)).

- a ?
 (5) Which girl did you ask the secretary who Bill had written to _ about _ ?
 b *
 ?
 F F G G
 *

More speakers tend to accept movement of a WH-constituent out of infinitival WH-clauses, as in (6), (Fodor's (58)) but still only on the nested reading, diagrammed in a.

- a ?
 (6) Which girl did you have to ask Mother who to introduce _ to _ ?
 b *
 ?
 F F G G
 *

In some languages, for instance Swedish and Norwegian, Questioning and Relativization may apply out of Indirect Questions. Consequently in these languages double applications of WH-movement will provide grammatical examples of the F F G G pattern. It might be that languages that differ with respect to the extent to which they allow leftward movement rules to reapply within a sentence, also differ with respect to what parsing strategies speakers of these languages develop to handle sentences with more than one filler-gap dependency.

First Case Study: Swedish

Relativization and Questioning in Swedish may apply inside an Indirect question, but not inside a Relative clause. In most cases the relativized or questioned element is deleted. If the extraction site is embedded more than two sentences down, a resumptive pronoun may be retained in certain dialects and in colloquial speech but this is not required. Some examples of Relative clauses are given in (7)-(9); () indicates optional element.

- (7) Här är boken [_{S1} som jag läste _ /*den.
 Here is the book that I read _ /*it.
- (8) Här är boken [_{S1} som läraren frågade [_{S2} om jag hade läst _ /*den.
 Here is the book that the teacher asked if I had read _ /*it.
- (9) Här är boken [_{S1} som läraren frågade [_{S2} om vi mindes
 Here is the book that the teacher asked if we remembered
 [_{S3} vem som skrivit _ /(den).
 who that wrote _ /(it).

The presence or absence of a resumptive pronoun in sentences like (9) is influenced by factors such as length and complexity of intervening material. Since the constructions we are investigating here already display a considerable amount of complexity, I will try to avoid additional processing difficulties that may arise from multiply embedded sentences and as far as possible illustrate the point with sentences with at most two embeddings. Examples of nested and intersecting readings are given in (10)-(13).

- a: Här är boken som ingen minns vilken författare de gav /*honom N.P. för _.
 b* _

Here is the book that no one remembers which book they gave /*him the Nobel Prize for .

- a: Här är författaren som ingen minns vilken bok de gav honom/ * _ N.P. för _.
 b* _

Here is the author that no one remembers which book they gave him/* the Nobel Prize for .

- a: Här är flickorna som jag inte minns vilka pojkar läraren bad /*dem dansa med _.
 b* _

Here are the girls that I don't remember which boys the teacher asked /*them to dance with .

- a: Här är flickorna som jag inte minns vilka pojkar läraren bad dem/* dansa med _.
 b* _

Here are the girls that I don't remember which boys the teacher asked them/* to dance with .

As can be seen from these examples, Swedish allows intersecting readings even when both fillers are of the same grammatical category. Intersecting readings are possible even when there are no selectional restrictions on the verb that would make the nested assignment impossible, as shown in (13). However, notice that a resumptive pro-

noun is required whenever an intersecting reading is intended. From (10)-(13) we notice that the alternation gap-pronoun is systematic. If the bindings are nested, a pronoun may not occur. The distributional pattern of gaps and pronouns can be summarized as in (14).



The acceptability pattern in (14) systematically limits the number of possible interpretations of sentences in which there are multiple extractions. Notice in particular that in (c) the pronoun can not be controlled by the closest filler, F2. Consequently, the presence of the pronoun in configuration (c) licenses the parser to discard one plausible filler-gap assignment immediately. The systematic contrast between (a)-(d) provides the parser with enough disambiguating information so that the intended reading can be recovered unequivocally.

The resumptive pronouns in (11) and (13) can not be interpreted as freely referring. They must be coreferent with the phrases that control them. This property distinguishes resumptive pronouns from ordinary personal pronouns, which may always refer outside the sentence. Configurations where the gap precedes the pronoun, as in (e) and (f) are not allowed. This can be explained from the point of view of a left-to-right parser, engaged in processing a sentence with more than one filler. There is some evidence that gaps are filled as soon as they are detected (Fodor 1978, Wanner & Maratsos 1978). Hence in a structure F1 F2 G P, the gap will have been filled before the pronoun is reached. Fodor notes that in English dialects where a mixture of gaps and pronouns is accepted, it is possible to find contrasts in acceptability depending on which of the gaps is removed. Sentences where the pronoun precedes the gap are judged to be more acceptable than sentences with the inverse order, (Fodor p. 464). Before discussing in more detail the effect of the presence of controlled resumptive pronouns on parsing strategies among speakers of Swedish, let us look briefly at Norwegian.

Second Case Study: Norwegian

Norwegian is very similar to Swedish but differs in at least one relevant respect, namely the extent to which resumptive pronouns occur. There seems to be some speaker variation, but the normal case is that sentences with resumptive pronouns are considered 'colloquial' or not quite grammatical. In sentences with multiple

filler-gap dependencies it is in general the nested reading that is available, as shown in (15) a.

- a
 (15) Dette er piken som laereren spurte hvilken gutt vi trodde var sint på .
 b*

This is the girl that the teacher asked which boy we thought was mad at .

However, intersecting readings are not excluded, as can be seen in (16) and (17).

- a
 (16) Dette er forfatteren som laereren spurte hvilke vers vi trodde hadde skrivit .
 b*

This is the author that the teacher asked which poems we thought had written .

- a
 (17) Hvilke elever husker du hvilke oppgaver laereren ba løse ?
 b*

Which students do you remember which problems the teacher asked to solve ?

Notice that nested assignments to these sentences would result in readings that violate the selectional restrictions of the verbs. In contrast with Swedish sentences (16) and (17) are not improved if a resumptive pronoun is inserted.

- c ?
 (16) Dette er forfatteren som laereren spurte hvilke vers vi trodde han hadde skrivit .

For Norwegian the constraint seems to be a true No Ambiguity constraint; whenever semantic or morphological factors rule out a nested dependency, an intersecting interpretation is allowed. That is, when the filler-gap dependencies can be recovered, an intersecting pattern may be created. Morphological factors such as verb agreement are used to achieve this. This is shown in (18)

and (19) where the verb agrees in number with its subject whether this is phonologically realized or not.

- a Dette er
 (18) piken^{sg} som laereren spurte hvilke gutter^{pl} vi trodde | var glæ^{sg} i | .
 b * |
 c | | | var glæ^{pl} i | .

This is the girl that the teacher asked which boys we thought ___ liked ___.

- a Dette er
 (19) pikené^{pl} som laereren spurte hvilken gutt^{sg} vi trodde | var sinte på^{pl} | .
 b * |
 c | | | var sint på^{sg} | .

These are the girls that the teacher asked which boy we thought ___ were mad at ___.

Assuming that gap-filling takes place immediately, when the gap after trodde in (18) is detected, the parser may associate it with the closest filler, gutter. As soon as the mismatch in number agreement with the verb phrase var glæ is noted, the parser is forced to revise that assignment. Compare the intersecting readings in (18) and (19) with (15), which as we noted earlier only has a nested reading. (15) is repeated here with the relevant morphological features indicated.

- a Dette er
 (15) piken^{sg} som laereren spurte hvilken gutt^{sg} vi trodde | var sint på^{sg} | .
 b * |

When the fillers agree in number and number agreement can not be used to disambiguate the sentence, only the nested reading is available. The same holds if the verb is unmarked for number, as in (20). Judgments on this type of sentences are not completely clear but the

F F G ..., the NDC in effect justifies an automatic assignment F F G. Without a constraint like the NDC, when the parser analyzed a string F F G ..., it would have to make a decision about which filler to associate with the encountered gap. In this respect the NDC reduces the momentary processing load by only allowing the parser to make one assignment. Notice that the NDC enables the parser to resolve a pending filler-gap assignment locally and immediately. The closest filler is always associated with the next encountered gap. Most likely this 'local decision principle' will be highly valued by a parser engaged in real time processing.

It seems that in many languages Questioning and Relativization are characteristically unbounded, which allows for a desired amount of expressive power. Apparently the human parser can not cope with totally free assignments of filler-gap dependencies resulting from unbounded rules. Given the speed at which sentence comprehension must take place in ordinary dialogues, the listener must begin interpreting long before the entire sentence is available for analysis. In the case of sentences with multiple extractions, this will involve making decisions on-line about filler-gap associations. Consequently a principle like the NDC, which justifies local decisions, will be highly motivated from the parser's point of view. Since structured material places less of a burden on immediate memory, it is not surprising that the parser seems to prefer to structure incoming material as soon as possible, for instance by attaching it into a phrase marker (Frazier 1979). Hence the preference for assigning a detected filler to the closest gap can be explained from general processing considerations, and we may restate the NDC as a general parsing strategy:

- (22) Associate the most recent filler with the next gap.

I ignore here the problems involved in identifying fillers and gaps (see Fodor 1978) and concentrate on the problem of the assignment of fillers and gaps that have already been recognized. The parser's preference for picking the **most recent** filler presumably follows from the relative availability of the fillers. Assuming that material in the phrase currently being parsed is more available than earlier material, the parser will try to find a filler there, when possible, i.e. within the same 'phrasal package' (for this notion, cf Frazier & Fodor 1978).

Principle (22) will hold literally for a language like Swedish, where the alternation gap/pronoun is not arbitrary and where intersecting interpretations are allowed only in the configuration F1 F2 P G2.

The presence of the pronoun will block any attempts from the parser to associate F2 with the first likely empty position. The parser will hence proceed until it reaches G2, which is the next gap. The pronoun rules out one plausible filler-gap assignment and prevents the parser from computing this interpretation.

Notice that principle (22) correctly predicts gap-filling not only in sentences with multiple extractions but that it also accounts for Fodor's findings that in a sentence with one filler but where there are two gaps, either of which can be associated with the filler, the 'first reading' is often the one where the first gap gets filled. Compare (23), (Fodor's (15), (Δ) = doubtful gap).

(23) Who did Mary promise (Δ) that she would marry (Δ)?

In general it is not possible to predict 'first readings' purely on structural grounds. The ordering of subcategorization frames for particular lexical items may determine how often a doubtful gap is detected, as discussed by Fodor. In sentences where a doubtful gap precedes the doubtless gap, as in (24) (Fodor's (7)) the first assignment will have to be reanalyzed, which is confirmed by speakers' intuitions about how they understand these sentences.

(24) What_i do you want Mother to sing (Δ) to Mary about —_i?

So far in the discussion I have focussed on the disambiguating effect of the presence of the resumptive pronoun. Since resumptive pronouns can not be distinguished phonologically from ordinary personal pronouns, the more general question of pronoun interpretation must be addressed. The process of assigning referents to pronouns in speech understanding is a complex procedure which presumably is influenced by factors such as preceding context, relative stress, and pragmatic considerations. The examples we have looked at so far have been simple in that they only contain one pronoun. Conceivably any number of pronouns may occur in the sentence. When the parser reaches a pronoun in a structure F1 F2 P ..., it consequently has the option either to assume that it is a freely referring pronoun, or that it is a resumptive pronoun, controlled by a preceding filler. At this stage in the processing, either choice may cause considerable reanalysis when more of the sentence is available. If the parser assumes that the pronoun is freely referring, i.e. makes the assignment F1 F2 P G2]_s, F1 will remain unassigned and the parser has to back up and reanalyze P as bound by F1. If the parser initially makes the other assumption,

$\overbrace{F1 F2 P}$..., it may turn out that the rest of the sentence contains two gaps, F1 F2 P G2 G1, in which case the first linking of P to F1 must be undone.

I think it would be extremely worthwhile to supplement the present theoretical discussion with experimental studies of how people actually go about gap-filling and pronoun linking. In particular I think the following questions are worth looking at more closely: Does the parser always entertain the hypothesis that a pronoun may be bound, or is this a back-up strategy chosen only when no grammatical reading can be found? How do Swedish speakers deal with sentences with multiple extractions in which there are several 'distracting' pronouns, any one of which may be resumptive? (1)

In conclusion, the universal preference for Nested Dependencies can be seen to follow quite straightforwardly from general parsing principles. By always associating the most recent filler with the next gap the amount of unstructured material that the parser has to attend to is reduced. I have suggested that languages may allow intersecting dependencies to the extent that these are recoverable. Languages vary typically according to what mechanisms they use to achieve the necessary disambiguation. We have found that for instance Norwegian uses morphological properties such as number agreement. In Swedish we found a regularized alternation between gaps and pronouns, which provides the information that enables the listener to immediately detect the intended reading.

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Footnote

(1) These questions might be approached experimentally by looking at eye movements during reading as a possible indicator of when and how reanalysis takes place.

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