INTERPRETING SENTENCES WITH MULTIPLE FILLER-GAP DEPENDENCIES

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INTRODUCTION

The aim of this study is to try to arrive at a better under-
standing of what kinds of strategies people use when they
interpret complex, potentially ambiguous, sentences. It is
hoped that this in turn will shed light on the human sentence
processor in general. In the studies to be reported here, I am
looking at to what extent people rely on and/or use semantic/
pragmatic information and to what extent people use content-
independent structurally or procedurally based interpretation
strategies when they are faced with sentences with complex
dependencies. First some terminological clarification.

Following Fodor (1978) I will use the word _filler_ to refer to
a preposed constituent in constructions like constituent
questions, relativization, topicalization, and _tough_ movement.
In these constructions, there is typically a dependency between
a filler and a _gap_, i e an argument position that is not filled
with lexical material. When I talk about filler-gap dependen-
cies, I only have in mind those dependencies that arise through
the (unbounded) constructions mentioned above. The constituent
question in (1) illustrates what I call a non-local filler-gap
dependency.

(1)   What$_i$ do you think John put __$_i$ in the basket?

I am not looking at the interpretation of gaps that arise
through optional object deletions, as in (2), nor at the kind
of dependency that certain linguists postulate in Raising and
Equi contexts, as illustrated in (3).

(2)   John eats (__).

(3)   John tries $\left[(\text{__}) \text{to leave} \right]$

The types of sentences I am looking at involve multiple filler-
gap dependencies. They all conform to the general pattertn in
(4) and an example is given in (5).

(4) F_1 ... F_2 ... __ ... __ ...

(5)   Which pot is this soup easy to cook __ in __?
        F_1 F_2

When a person hears a sentence like (5), he or she somehow has
to associate each of the fillers with one of the gaps in order
to arrive at an interpretation. In a sentence with two depen-
dencies there are two logically possible ways of linking up the
fillers and the gaps, by a nested assignment or by an inter-
secting assignment. The questions I want to address here are:
What types of restrictions, if any, are there on gap-filling
operations? Where in the process of sentence interpretation do
these restrictions apply? To what extent is filler-gap associ-
ation a syntactic process?

With respect to the last question we can formulate three
hypotheses about the role of syntactic processing in filler-
gap assignment.

   (I)   Single Analysis Hypothesis

          The syntactic processor only computes one assignment.
          If this doesn't make sense, the semantic/pragmatic
          processor takes over and tries to come up with a
          plausible interpretation.

   (II)   Multiple Analysis Hypothesis

          The syntactic processor computes all assignments.
          People may still only be aware of assignments that
          make sense.

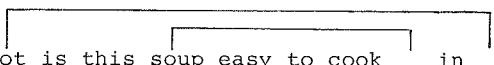   (III) No Syntactic Analysis Hypothesis

          Filler-gap association is not a syntactic phenomenon
          at all. Such associations are computed by the semantic/
          pracmatic processor. 22

Before entering the discussion of these hypotheses, I will provide some background and describe an experiment that addressed the questions above. This way it will hopefully become clear what I mean by relying on semantic/pragmatic information.
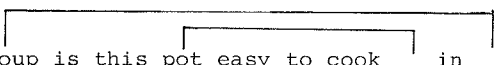
Background

It has been noted in the literature that English sentences like (5) only get interpreted in the way diagrammed in (6), viz with a nested association pattern (Kaplan 1973, Bordelois 1974, Chomsky 1977, Bach 1977, Fodor 1978).

(6)   Which pot is this soup easy to cook __ in __?

If you switch the order of the fillers, as in (7), it is claimed that the only interpretation available is the nested one, although this leads to a silly reading.

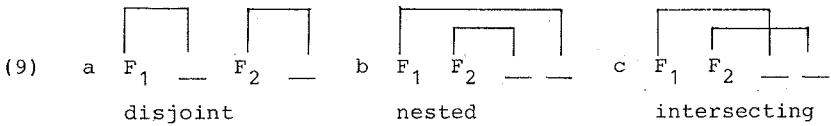(7)   Which soup is this pot easy to cook __ in __?

In her paper Parsing Strategies and Constraints on Transformations, Janet Fodor discusses examples of this type, together with a whole array of other examples that involve multiple filler-gap dependencies. She argues that the preference for nested interpretations follows from a parsing motivated no-ambiguity constraint, which she formulates as in (8).

(8)   The 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 interpretations are compatible with
       the well-formedness conditions of the language.

                                        (Fodor 1978:448)

The effects of this constraint can be summarized by the diagrams in (9), for the types of structures we are interested in here.

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(9) a F_1 ___ F_2 ___   b F_1 F_2 ___ ___   c F_1 F_2 ___ ___

   disjoint   nested   intersecting

There have been some attempts at explaining why the pattern in
(9 b) is generally preferred in English. Some of these expla-
nations make reference to the structure of Push Down Automata
where items are put on a stack and then taken off in the opposite
order to which they were entered, thus giving a nested pattern.
We will return to this line of explanation later. Fodor does
not adopt this account, but proposes that the NDC follows from
what the parser is trying to do. Fodor uses the term 'the
parser' as a convenient name for the system of processors which
are taken to interact in sentence processing. Fodor assumes
that the parser attempts to construct a well-formed deep struc-
ture for the sentence it is currently parsing. The parser tries
to construct as long streches of well-formed deep structure
possible which can be interputed. Given a structure F_1 ...
F_2 ..., assigning F_2 to the detected gap would result in a
well-formed deep structure. On the other hand, if the parser
assigned F_1 to the gap, it would do so across an unassigned
filler, and would thus not create a stretch of well-formed
deep structure.

Fodor notes that it is quite possible to deviate from the NDC
in English if the two fillers are of different syntactic
category, as in (10).

(10) $\begin{bmatrix} \text{Which crimes} \\ \text{NP} \end{bmatrix}$ did the FBI not know $\begin{bmatrix} \text{how} \\ \text{ADVP} \end{bmatrix}$ to solve $\begin{bmatrix} \ \\ \overline{\text{NP}} \end{bmatrix} \begin{bmatrix} ? \\ \overline{\text{ADVP}} \end{bmatrix}$

However, in Scandinavian languages it is possible to deviate
from the NDC even if the two fillers are of the same category
(Engdahl 1979, Christensen 1981, 1982). Consider the Norwegian
example in (11).

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(11) Lingvister$_i$ finns det mye$_j$ som Petter inte kan snakke med ___$_i$ om ___$_j$.

Linguists, there is a lot that Peter can't talk to ___ about ___.

The preferred interpretation for (11) involves an intersecting
filler-gap assignment, but that apparently does not pose any
problems for speakers of Norwegian. However, if the preference
in English for nested assignments follows from some principle
which reflects the working procedure of the processor, then we
would expect the same to apply to other languages as well, at
least to structurally similar languages. In view of the existence
of intersecting interpretations like the one given in (11) in
Norwegian, the NDC must be taken to be language specific. But
that makes a processing explanation for the NDC less convincing.

In order to begin to sort out the facts about the availability
of nested and intersecting interpretation in Swedish I de-
signed and carried out an experiment during the summer and fall
of 1981. The experiment was intended to test under what con-
ditions people understand sentences with multiple filler-gap
dependencies (MFGD) in a way which requires associating fillers
and gaps in an intersecting fashion. In particular, the exper-
iment aimed at testing to what extent semantic/pragmatic in-
formation, expressed by the selectional restrictions of the
verbs in the sentences, influenced people's interpretations.
Fodor formulates the NDC as a No-ambiguity constraint which
is sensitive to syntactic (categorial) information only. It
applies in cases where there are two or more fillers of the
same syntactic category and prevents the parser from computing
an intersecting assignment regardless of the semantic content
of the fillers and the nature of the verb. On her account, we
would not expect any difference in interpretation due to
semantic/pragmatic factors, as K K Christensen has pointed out.
Rather, we would expect subjects to give uniform nested inter-
pretations in all conditions. In case a sentence is pragmati-
cally biassed towards an intersecting reading as in (7) above,
we would expect subjects to give either the silly reading, which
results from a nested assignment, or no interpretation at all.
On the other hand, if semantic/pragmatic factors do influence

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what interpretations subjects assign to MFG sentences, we would
expect people to report the sensible reading in all cases, re-
gardless of whether it inovlves nested or intersecting assign-
ments. In sentences where there is no bias towards either
assignment or only a weak bias towards one assignment, we would
expect subjects to report either nested or intersecting read-
ings. If there is no preference at all for nested assignments,
we would expect the percentage of nested and intersecting
readings in these conditions to be equal.

Experiments

Experiment I consisted of a paraphrase/sentence-completion
task. 34 native speakers of Swedish varying in age between
19 - 56 years were given booklets containing 25 sentences in
varying order. The subjects were instructed to read the test
sentence carefully until he/she had understood it and then to
paraphrase the sentence, using the words given below the test
sentence as a cue. An example of a test sentence together with
its response cue is given in (12) with English translation
added.

(12) Den här formen är sockerkakan lättast att baka i.
      This pan, the pound cake is easiest to bake in.

      Det är lättast att ...
      It is easiest to ...

Subjects were told that some of the sentences in the experiment
could be paraphrased in more than one way, corresponding to
different readings. Subjects were instructed to write down all
paraphrases they could think of in such case, and to try to do
so in the order they 'got' the different readings. Subjects
were asked to work rapidly but there was no timing of the task.
Subjects took between 12 and 30 minutes to complete the task.

The stimulus materials, which had been selected through a
pretest, all conformed to the structure illustrated in (4).
There were no questions among the test items because subjects
might find them hard to paraphrase according to the model.
Instead, all sentences were topicalizations. The leftmost

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filler was in all cases a topicalized NP. The second filler
also of the category NP was either the subject of a <u>tough</u>
predicate, the head of a relative clause, or an interrogative
phrase introducing an indirect question. Extractions out of
indirect questions and relative clauses are possible in Swedish
(cf Engdahl & Ejerhed (1982) for illustrations). The types of
constructions were systematically varied across conditions.
There were 5 sentences in each of 5 conditions. The conditions
varied with respect to how much they were constrained by prag-
matic bias and which association pattern was facilitated. The
5 conditions are illustrated by the examples in (13) through
(18).

(13)   <u>Strong nested bias</u> (SN)

    Teckenspråk finns det till och med några apor som man
    Sign language there are   even   some apes that one

    lärt att använda.
    has taught to use.

(14)   <u>Strong intersecting bias</u> (SI)

    Strömming är den här kniven omöjlig att rensa med.
    Herring this knife is impossible to clean with.

(15)   <u>Weak nested bias</u> (WN)

    Småbarnen är faster Hulda den sista man kan
    The small kids, aunt Hulda is the last person one can

    be ta hand om.
    ask to take care of.

(16)   <u>Weak intersecting bias</u> (WI)

    Lisa vore Kalle lämplig att gifta bort
    Lisa, Kalle would be suitable to give-away-in-marrigage
                         ' verheiraten '
    med.
    to.

(17)   Scouterna minns jag inte vilka turister man
    The scouts, I don't remember which tourists one

    uppmanade att ta reda på.
    told   to look for.

(18)   <u>No bias</u> (NB)

    Mina föräldrar är det få personer jag vill presentera för.
    My parents, there are few people I'd like to introduce to.

The criterion for assigning a sentence to one of the strong conditions, SN or SI, was that the selectional restrictions of the lexical items made just one assignment possible. I will refer to this as semantic/pragmatic knowledge, but it might be equally appropriate to talk about conceptual knowledge.

The criterion for the sentences in the weakly biassed conditions, WN and WI, was that, although one reading was not completely excluded (as in the case of strong bias), one of the readings was significantly more plausible due to socio- cultural knowledge shared by the subjects.

Finally, in the unbiassed condition, UE, it was required that both fillers satisfy the selectional restrictions associated with both gaps and that both filler-gap assignments be equally plausible. (See the appendix for a list the test sentences.)

Experiment II consisted of the same test sentences administered to 10 subjects in an oral test. Instructions were as in Exp I. The experimenter (myself) read the sentence out aloud. The subject repeated the sentence. The experimenter then gave the cue phrase and the subject completed the sentence in one or two ways.

Results

The results are summarized in Table 1 for Exp I, written presentation to 34 subjects, and in Table 2 for Exp II, oral presentation to 10 subjects. The questionnaires were scored according to response type: N for a single nested reading, I for a single intersecting reading, NI for multiple readings in the order nested intersecting, IN for multiple readings in the opposite order. The tables give percentage of response types in the various conditions. As can be seen from a comparison of the tables, the results in Exp I and II were very similar. According to a Spearman rank correlation test over the 25 items, corrected for ties, the correlation was .96. There was a higher percent null responses in the oral version, 5.6% as compared to 2.4% for the written version. This difference may be due to short term memory limitations in the auditory task, leading to problems with sentences of 12 - 14 words length. The No response + error column also includes sentences where subjects changed the word order of a sentence so that it no longer could be scored according to the norm.

(19) Table 1 : Percentage responses, written test, 34 subjects

Response type	I	IN	NI	N	No resp + errors	IN + NI
Condition Strong Intersect	93.6	2.3	0.0	2.3	1.8	2.3
Strong Nested	0.0	0.0	0.0	100.0	0.0	0.0
Weak Intersect	39.4	14.2	9.4	33.5	3.5	23.6
Weak Nested	0.0	0.6	5.3	91.2	2.9	5.9
No bias	25.3	8.9	20.0	42.3	3.5	28.9

Total number of responses in each condition: 170

(20) Table 2 Percentage responses, oral test, 10 subjects

Response type	I	IN	NI	N	No resp + errors	IN + NI
Condition Strong Intersect	86	6	0	4	4	6
Strong Nested	0	0	0	100	0	0
Weak Intersect	32	22	10	30	6	32
Weak Nested	0	0	0	92	8	0
No bias	18	8	12	52	10	20

Total number of responses in each condition: 50

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As can be seen from the table, the respcnses in the strongly
biassed conditions, SN and SI, were very uniform, as well as in
WN. In SN, there were no deviations from the pragmatically most
plausible reading, nor any multiple readings. No failures to
respond occurred in this condition. A few I readings occurred
in WN, but always as the second reading, i e in the NI order.
The number of N readings in the SI condition is very low, and
the overwhelming majority replied with a single I reading.

The WI and NB conditions display a much more varied response
pattern. First we note that it is in these conditions that we
find a signaficant number of multiple readings, that is, these
were the sentences that subjects found to be genuinely ambig-
uous, 23.6% in WI and 28.9% in NB.(1)

A non-parametric analysis of variance, based on the number of
I readings in each condition, showed that the conditions dif-
ferd significantly, both ^{by} subjects, (p< .001 by a Friedman
test) and ^{by} items (p< .001 by a Kruskal-Wallis test). A pair-
wise analysis showed the SI condition to be significantly
different from all others, in particular from the WI condition
(p< .005 by a one-tailed Wilcoxon test for subjects, both in
the written and in the oral test, and p=.001 by a Mann-Whitney
U test for items in the written task, p=.016 in the oral test).
There was no significant difference between the SN and WN
conditions but the difference between these and the NB con-
dition was significant. With respect to the number of I read-
ings, there was no significant difference between WI and NB.
However, the order of reported multiple readings varied signif-
icantly between these conditions. In WI, subjects report in the
order IN more often than in the order NI, whereas in NB, sub-
jects respond in the NI order twice as often as they respond
in the IN order (p< .008 by a Mann-Whitney U test by items.)
(The relative low percentage multiple readings over-all (approx-
imately 25%) together with the low item per subject ratio in
each condition (5) did not permit a meaningful analysis by
subjects.) The tendency to report in different orders in WI and
NB is a very interesting finding. However, it is not clear that
the order of reported readings is a reliable measure. Although
subjects were instructed to 'try to report the readings in the

order they got them,' the results presumably reflect a post-processing effect. Several factors may have interfered with the results. In order to be able to say something more conclusive about whether there is a systematic difference in which reading subjects get first in the various conditions, we need a more accurate technique that ideally applies on-line and is less susceptible to subjective judgments.

It is conceivable that subjects in an experiment like this would adopt either of two (possibly task-influenced) strategies, i e either consistently report multiple readings or consistently report only one reading. This was not the case in the present experiment. The total number of multiple readings varied from 0 (for 5 subjects) to 7 (for 2 subjects). The distribution of multiple readings was relatively homogeneous. (A X^2 analysis showed the variance to be non-significant).

Discussion

We will now look at how our three initial hypotheses fare with respect to the results from Exp I and II. Hypothesis I, the Single Analysis Hypothesis, assumes that the syntactic processor is somehow and for some reason (to be discussed later) constrained to use a gap-filling routine that always computes a nested assignment. If this reading doesn't make sense, then by default the hearer may use the semantic or pragmatic information available in the sentence in order to come up with a sensible interpretation. One could of course propose various refinements of exactly how this interaction between syntax and semantics proceeds, when the semantic information is used in the default condition, etc. The fact that sentences usually are meaningful probably plays a role in making the subject try to construct an interpretation. This might have been heightened by the fact that subjects were told that this was an experiment

about sentence comprehension. There were no clear nonsense sentences in the experiment.

Hypothesis I accounts well for the uniform N responses in SN and WN. However, it fits less well with the high percentage of I readings and multiple readings in the NB condition. Given that a nested assignment in this condition always led to a meaningful sentence, we would not have expected any deviations from the N pattern.

The relatively high percentage I readings and multiple readings in the WI condition is a further indication that even a slightly anomalous reading may result in the search for an alternative assignment that makes more sense. But then we would expect to get the response type NI as the single alternative to N readings contrary to what is the case in WI, where in fact IN readings are more frequent than NI readings. But, as already mentioned, it is not clear that the subjects' own reporting of order of reading is a reliable measure.

On the second hypothesis, the Multiple Analysis Hypothesis, the syntactic processor is not constrained to nested assignments but compute all assignments. Exactly how this would look depends on if one assumes serial or parallel processing. Further more, we need to distinguish extraustive and self-terminating processing. Given a serial self-terminating procedure, the processor would start with only assignment. If it leads to a sensible interpretation, then that reading is reported and the process terminates. This would predict that only one reading is reported in the NB condition, contrary to what was in fact the case. If the serial processing were exhaustive, it would fit that response pattern better. Assuming that the processor computes all assignments in parallel, we can explain the multiple readings in the WI and NB conditions. The fact that the percentage of multiple readings is rather low (20% in NB, 32% in WI) could be accounted for by assuming that the parallel processing terminates as soon as one acceptable reading is reported. Unfortunately, the type of experimental technique used here does not permit any definite conclusions about the working

mode of the processor. How can we distinguish the serial non-deterministic account from the parallel processing account? If we could show that by manipulating the relative salience of either of the fillers, we could make the assignment that first uses this filler, the preferred assingment, then this might count in favour of the serial account. Frazier, Clifton and Randall (1981) report two experiments which they argue show that the salience of a filler plays a role in simple filler-gap dependencies in English. For MFG sentences it would be interesting to investigate whether increased salience of F_1, the leftmost filler, would be correlated with a preference for an intersecting assignment. This is what one would expect if it is the salience of the filler, rather than the recency, that determines its availability. In the oral task, one could look at sentences in the NB condition and vary the amount of stress on F_1. In the written task one could maybe vary the amount of descriptive content given to F_1, to see if this influences the subjects' first or preferred reading (this of course presupposes that a satisfactory technique for identifying first readings has been found).

In this context it is worth noting that failure to report multiple readings in any one case can not be taken as evidence that subjects did not perform some syntactic processing pre-requisite to the non-reported reading. Subjects might well have noticed the alternative assignment 'at some level' without being aware of it. Flores d'Arcais (forthcoming) reports a series of experiments that show that subjects monitoring for errors, report syntactic errors much less frequently than semantic and pragmatic anomalies. However, using eye movement recordings he found that subjects fixate on the region con-taining syntactic errors significantly longer than in the correct control cases and that fixation times for syntactic errors are equally long whether subjects detect and report the error or not. It is thus concievable that even in the strongly biassed conditions, SI and SN, subjects perform the same kind of syntactic analysis as in the other conditions, but that one analysis doesn't transmit sufficiently for a representation of the meaning to be formed. Evidence for this hypothesis could maybe be found in an eye movement study. If we found the same

fixation and regression pattern for a given subject in the
cases where he/she reports one reading as when he/she reports
two readings, this would at least be highly suggestive evidence
that the same syntactic analysis is performed in both cases,
although only in one of the cases is the subject aware of con-
sidering two readings.

The third hypothesis, the No Syntactic Analysis hypothesis,
claims that filler-gap assignment isn't a syntactic process at
all, but that listener's rely entirely on semantic/pragmatic
information about the fillers and the gap positions in order to
associate them. The type of processing involved in making a
filler-gap assignment would be guided by the same type of fac-
tors which influence how people choose referents for pronouns.
(See Ejerhed (1982) for an illustration of this type of
approach to filler-gap assignment, implemented in a phrase
structure grammar for Swedish.)

It might also be argued that these MFG sentences present such
a complex task that they are sent off right away to something
like Forster's General Problem Solver, and that no syntactic
processing takes place at all. This is rather unlikely, how-
ever, in view of the fact that syntactic analysis most likely
is automatic (Forster 1979, Flores d'Arcais (forthc) and that
it cannot be switched off at will.

However, there are some results from the experiment that are
not accounted for by hypothesis III. On this account, we would
not expect any N readings in the WI condition at all, but there
are in fact as many as 33.5%. Furthermore, on this hypothesis
it remains unexplained why there should be any IN readings at
all in WI (14.2%). For the NB condition, this hypothesis pre-
dicts that we should get roughly the same number of I readings
as N readings. The results were that subjects reported N
readings about twice as often as I readings in this condition.

One way to try to refute hypothesis III would be to provide
positive evidence for some syntactic effect, depending on
filler-gap association. For instance, if it turned out that
people detect syntactic or morphological deviations in positions
which require that they have performed some kind of gap-filling
operation, then one could argue that gap-filling is not totally

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separated from syntactic analysis. Suppose subjects would de-
tect morphological mismatches between a filler and the context
of the gap, as illustrated in (21), assuming that the sentence
is pragmatically biassed towards an intersecting assignment,

(21) F_1 ...F_2 ... ___ V ...
       $\left[+\alpha \right]$ $\left[-\alpha \right]$

then that would at least be an indication that gap-filling
takes place at some level of representation that is sensitive
to syntactic/morphological constraints. Since Swedish has both
number and grammatical gender agreement in predicate comple-
ments, this can be tested. For single filler gap dependencies,
Swedish speakers clearly do detect mismatches, but it needs
to be proven that the same holds for MFG sentences.

However, even positive outcome on such a test would not refute
hypothesis III, I think. It will still be possible to maintain
that gap-filling is a non-syntactic phenomenon, even if it
occurs in parallel with syntactic processing. In the absence
of better criteria for syntactic processing and without any
on-line experiments on MFG sentence interpretation, I find it
hard to say anything conclusive about whether gap-filling is
a syntactic process or not.

In the context of discussing morphological evidence, I will
just mention a few results from a pilot experiment to the
present study. In the pilot test, I included sentences of the
NB type where one assignment was excluded for reasons of mor-
phological disagreement. A morphological bias towards an inter-
secting reading could take the form illustrated in (22).

(22) F_1 ... F_2 ... ___ V ...
       $\left[SG \right]$ $\left[PL \right]$ $\left[SG \right]$

In a large number of cases (50% oral presentation, 35% written
presentation) subjects changed the form of the verb phrase so
that it would permit a nested interpretation. In the oral test,
at least, it became evident that they were not aware of the
fact that they had changed the original sentence. I also tested

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some sentences of the structure given in (23), in which both
gaps occured in prepositional phrases as in example (24).

(23) $F_1 \ldots F_2 \ldots P \underline{\quad} P \underline{\quad}$

(24)   Barnavårdsnämnden vet jag inte vilka problem
        The child care department, I don't know what problems
        man kan prata med ___ om ___.
        you can talk to ___ about.

This sentence is biassed towards an intersecting assignment.
However, several subjects reported it with the order of the
PPs switched around, thus making a nested assignment possible.

The preference for nested assignments and the Push Down Store

From looking at the overall results it becomes evident that
there is a strong preference for assigning nested interpreta-
tions in the absence of strong pragmatic counterindications.
This shows up for instance in the contrast between the two
weak conditions. In the WN condition, there are hardly any I
readings reported. When they are reported, it is always in the
order NI. In the WI condition, however, we get a total of 57.1%
N readings (at all) and 33.5% simple N readings. The percen-
tage N readings in the NB condition is almost double the per-
centage I readings. The question is now, where shall we locate
the cause for this difference?

Fodor, as mentioned above, takes the preference for nested
interpretations to follow from the working strategy of the
parser. The NDC, on her account, serves to simplify gap-filling
routines and is used on-line to exclude one otherwise acceptable
analysis before, as she puts it, 'the parser has expended any
effort on computing it! This might fit the English facts, but
it doesn't account for the Scandinavian facts where inter-
secting readings are available without any noticeable extra
effort (cf 93.6% I readings in the SI condition) consequently,
it is less plausible to use a processing explanation for the
English facts.

The nested assignment pattern would follow automatically, as several people have pointed out (Kaplan 1973, Bach 1977, Ades & Steedman 1982), if the human sentence processor used a push down store facility on which it put constituents that could not immediately be entered into the structure under construction, i e fillers, in the terminology used here. Because of the last-in-first-out property of push down stacks, the fillers would always be accessed in inverse order to the order in which they were put on the stack.

In a series of recent experiments, W Levelt has found evidence that speakers use a push down type organization in complex pro-duction tasks which can be modelled by an ATN grammar (Levelt 1981). He argues that this follows in turn form very general 'minimization strategies' which have the joint effect of minimizing the load on short term memory. In the task at hand, describing a route through a spatial array with branching nodes, applying a last-in-first-out principle minimized the size of the return jumps to choice items, i e branching nodes. To what extent can this explanation be carried over to the domain of sentence comprehension? In some sense, a detected gap will work just like a choice item in Levelt's task. At he point of re-cognizing a gap, the listener must choose which filler to associate with it. It is not evident, however, what the measure 'size of the return jump' would correspond to in the case of sentence processing, unless you assume that the speaker main-tains some kind of linear representation of the sentence. Since most sentences involving MFG dependencies will have two or more clauses, it will most likely be the case that when the gap is detected, most of the previous context will already have been shunted off. The fillers must still be, in some sense, 'avail-able'. (I think it is highly desirable that one tries to get beyond the metaphorical talk about fillers being 'available' and establich some correlate to this theoretical construct. In the absence of more precise terminology, I will continue using metaphors.) Suppose that what happens when a clause is shunted, is that the filler remains in some kind of working store. The application of Levelt's model to sentence processing would then be the claim that this working store is a push down store. However, this can not be the full story, as the acceptable

sentences with intersecting dependencies show. To account for
(10) where the fillers were of different syntactic category,
we would have to assume that there are different stores for
different syntactic categories, maybe not a totally implasusible
assumption. However, it is hard to see how this multiplication
of stores can be extended to the intersecting dependencies in
the Swedish examples in conditions SI, WI, and NB. There is
no difference in syntactic category between the fillers, and
nevertheless an intersecting reading is possible and in some
cases even the only possible.

Fodor give some further arguments against the PDA hypothesis.
First, she notes that there is ample psycholinguistic evidence
that people are in general very bad at coping with center-
embedded structures. This goes against the assumption that the
sentence processor be equipped with an PD store facility.

Second, Fodor claims that the NDC holds for gap first depen-
dencies too, i e for the structures G G F F and F G G F, and
that it's not clear how one could put a gap on store. To the
last remark, one could maybe reply by assuming that gaps are
recognized as gaps of a certain category, and that the infor-
mation entered in the store is something like 'missing a NP'
(cf the use of derived 'slashed' categories in Generalized
Phrase Structure Grammar, Gazdar 1981, 1982)[2]. The facts about
gap-first dependencies are a lot less clear, unfortunately.
As an illustration of the claim that a G G F F pattern always
receives a nested interpretation, Fodor gives an example with
two extraposed realtive clauses, as in (25).

(25)   No one ($\_$)$_i$ puts things ($\_$)$_j$ in the sink
        [that would block it]$_j$ [who wants to go on being a
        friend of mine]$_i$. (Fodor 1978:(60))

(26)   *No one ($\_$)$_i$ puts things ($\_$)$_j$ in the sink
        [who wants to go on being a friend of mine]$_i$
        [that would block it]$_j$.

Fodor takes contrast between (25) and (26) to be due to the
NDC. However, it is not clear that relative clause extra-

postion fits our definition of filler gap dependencies, since
relative clauses are not obligatory constituents in the sence
that certain NPs and PPs are obligatory in some contexts. (25)
without the relative clauses would be a well-formed sentence.
Thus, one could argue that this is not a case of (syntactic)
gap filling, but rather an instance of semantic interpretation.
On the other hand, people most likely would detect number mis-
matches between the head NPs and the extraposed clauses, so by
the same reasoning we applied earlier to filler-gap association,
that should be the same type of process, related in the same
fashion to the syntactic processor. There is another rightward
dependency that does involve a gap in our sense, namely Heavy
NP Shift. Although it is unlikely that you would ever find a
sentence with two shifted heavy NPs, it may interact with left-
ward dependencies to give rise to the pattern F G G F as in
(27), also taken from Fodor.

(27)   * This form$_i$ foreign students are required to
          state __$_j$ on __$_i$ [that they have never previously
          visited the US]$_j$.

In order to test whether the NDC applies to gap first depen-
dencies in Swedish, I constructed a number of examples, modelled
on (25) - (27). By varying semantic/pragmatic factors as well
as morphological agreement, I attempted to make the intersecting
reading the most plausible. Unfortunately, the results are
totally inconclusive. When sentences involve iterated appli-
cations of optional processes, like extraposition, then it is
extremely hard to get judgments on relative acceptability.
These sentences easily become awkward and complicated. Since
there is always the option of not extraposing, speaker prefer
taking this option. The processes that give rise to filler
first dependencies, on the other hand, are obligatory (clearly
so for question formation and relativization, less clearly so
for topicalization). There is no alternative way of expressing
the message if one wants to stay within the limits of a single
sentence. Christensen (1982) offers the following sentence as
an example of permissible intersecting assignments in a F G G F
structure in Norwegian.

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be seen from the fact that in the present experiment people did not hesitate to assign an interpreting interpretation to the structure F F __ __ in the SI condition. From the present experiment it is not possible to tell whether speakers would have preferred a F F Pro __ structure in these cases, since the subjects did not have any options. I am planning to investigate this further in some follow-up experiments. I want to look more closely at

(a)   how widespread the use of the disambiguating pattern in (29) is.

(b)   whether it can be shown that the presence of a resumptive pronoun facilitates comprehension and production of these sentences.

Wall & Kaufmann (1980, reported in Zaenen & Maling, 1982) found that resumptive pronouns may facilitate comprehension in difficult contexts. English speakers were presented with sentences with unbounded dependencies either with or without resumptive pronouns at 80%, 60%, and 40% compression. Subjects were asked to write down what they recalled immediately after hearing the sentence. Recall was significantly better for sentences with resumptive pronouns than for comparable sentences with gaps, especially at 40% compression.

To test whether resumptive pronouns also facilitate in the complex task för MFG sentences, I am planning to do an experiment where MFG sentences like in (30) are presented rather rapidly, with or without a resumptive pronoun.

(30)   Mina föräldrar är det få personer jag vill presentera (dom) för.

My parents there are few people I want to introduce (them) to.

Immediately after the presentation of the sentence, subjects will be asked to answer questions like Jag vill presentera vem för vem? (I want to introduce whom to whom?) The purpose of the experiment will be to find out primarily if the presence of the resumptive pronoun leads to an increase in comprehension and secondly if it influences people towards the

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intersecting reading. I would appreciate suggestions for other experiments in this area.

Future experiments

It has become clear that we need to do further experiments in order to determine which of our three initial hypotheses about the role of syntactic processing is supported from data having to do with how people process sentences with multiple filler-gap dependencies, and if any of them can be ruled out entirely. We have seen that we can not draw any direct conclusions about the amount of syntactic processing involved on the basis of the reports of available readings that were the result in the present experiment since these reflect a post-processing stage. Other researchers (e g Flores d'Arcais, Foster, Frazier) have found that syntactic processing is automatic. However, it appears that the syntactic analysis does not always lead to a reading for the sentence that the listener is aware of. Rather, it seems that semantic and pragmatic processing, which presumably are sensitive to what are plausible readings, determine which analyses are processed completely until we become fully aware of a reading. Once we have found a reliable and workable technique for tapping on-line sentence processing, we might expect to find out some interesting things about the interaction of real world knowledge with the linguistic analysis people perform when they try to interpret an utterance.

When it comes to the preference for nested assignments, which shows up rather clearly in this experiment, we need to establish whether computing a nested assignment is in some sense easier to the parser than an intersecting one. We could try to establish baselines for comprehension of sentences which are clearly biassed towards a nested or an intersecting reading, and see if people are quicker at comprehending nested sentences than intersecting ones, even in strongly biassed conditions. If it would turn out to be the case that people take longer to understand a sentence involving intersecting dependencies, this would at least be suggestive evidence that the preference for nested assignments reflects some integrated property of the parser.

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NOTES

1. One sentence, number 15 in the appendix, which according to the pretest belonged to the WI condition, was interpreted much more like the SI sentences (29 I readings, 1 IN, 0 NI, and 3 N). If this sentences was excluded from the WI condition, then the percentage multiple readings in WI rose to 28.7%.

2. Mark Steedman (personal communication) reports that Stephen Isard at the Laboratory for Experimental Psychology at Sussex University has showed how one can handle gap first dependencies with a Push Down Automaton.

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APPENDIX

Test sentences for Exp I and II

Strong intersecting (SI)

1 Strömming är den här kniven svår att rensa med.
  'Herring, this knife is hard to clean with

2 Även småbarn är det otroligt mycket man kan lära.
  'Even small schildren, there is a lot you can teach'

3 Skatter och löner är arbetskamraterna dom sista man bör
  diskutera med.
  Taxes and salaries, your colleagues are the last people
  you should discuss with.

4 Clark Olofsson undrar jag vilka bankrån man hört skryta om.
  'Clark Olofsson, I wonder which bank robberies one has
  heard boast about' (renowned bank robber in Sweden)

5 Byråkrater finns det mycket man inte bör fråga om.
  'Bureaucrats, there is a lot one shouldn't ask about'

Strong nested (SN)

6 Den där runda formen är sockerkakan lättast att baka i.
  'That round pan, the pound cake is easiest to bake in'

7 Ryktet om Brantings homosexualitet undrar jag vem man
  trodde var upphovsman till.
  'The rumour about Branting's homosexuality, I wonder who
  they thought was the source of'

8 Teckenspråk finns det till och med några apor som man lärt
  att använda
  'Sign language, there are even some apes that one has
  taught to use'

9 Den här förklädnaden har jag ännu inte hittat någon jag
  lyckats lura med
  'This costume, I still haven't found anyone I have been
  able to fool with'

10   Läxorna är pappa den siste jag skulle be om hjälp med.
      'The homework, daddy is the last person I would ask to
      help me with'

Weak intersecting (WI)

11   Lisa vore Kalle lämplig att gifta bort med.
      'Lisa, Charlie would be suitable to give-away-in marriage
      to'

12   Lena känner jag en pensionär som vi kan be hjälpa.
      'Lena, I know a retired person that we can ask to help'

13   Tage Danielsson är Dracula svår att föreställa sig som.
      'Tage Danielsson, Dracula is hard to imagine as'

14   Scouterna minns jag inte vilka turister man uppmanade
      att ta reda på.
      'The scouts, I don't remember which tourists we asked
      to find'

15   En sådan molnformation är ett vulkanutbrott det första
      jag skulle tolka som tecken på.
      'Such a cloud formation, a volcanic eruption is the first
      thing I would interpret as'

Weak nested (WN)

16   Fulla gubbar vet jag många som vi varnat för.
      'Drunkards, I know several people that we have warned
      against'

17   Mormor bestämde vi raskt vilket barnbarn vi kunde skicka
      att hälsa på över sommaren
      'Grandmother, we rapidly decided which grandchild we could
      send to visit over the summer'

18   Inbrottstjuvar är en hund lämplig att ha som skydd mot.
      'Burglars, a dog is suitable to have as protection against'

19   Småbarnen är faster Hulda den sista man kan be ta hand
      om.
      'The little kids, aunt Hulda is the last person one can
      ask to take care of'

20   Vakterna på Tivoli går 13-åringar lätt att smussla in för.
'The guards at Tivoli, 13 year olds to smuggle in in front of'

No bias (NB)

21   Mina föräldrar är det få personer jag vill presentera för.
'My parents, there are few people I want to introduce to'

22   Västvaluta går guld lätt att växla till sig för.
'West currency, gold is easy to exchange for'

23   Johan minns jag inte vem gamlingarna brukade jämföra med.
'Johan, I don't remember who the old people used to compare with'

24   Silvia ligger kungen närmast till hands att intervjua om.
'Silvia, the king is the closest person at hand to interview about' (the Swedish queen)

25   Erik är Olle den siste jag skulle be ringa upp.
'Erik, Olle is the last person I would ask to call up'