Reconstruction and Scope

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Studies of sentence processing have quite naturally tended to focus on individual syntactic relations or types of relations -- the building of constituent structure (see Frazier, 1987, for a review), the identification of fillers and gaps (Fodor, 1989), the binding of anaphors (Nicol, 1988) or, to the extent that they exist at all, investigations of processing quantifiers (Kurtzman and MacDonald, 1993). Basic generalizations about sentence processing have emerged, along with several models motivated by those generalizations. It may now be possible, however, to explore the processing of compound relations, to see how the processor copes with interactions between relations of various types and, ultimately, to map out the relation between distinct subcomponents of the processor. At a general level, this is the goal of the present investigation. Specifically, the studies reported here investigate the binding of reflexives in sentences where the reflexive occurs inside an extracted wh-constituent. The initial studies focus upon sentences with definite NP antecedents for the reflexives and universally quantified antecedents. A further study concentrates on the processing of discourse-linked wh-phrase without reflexives to investigate the point in processing when the discourse ramifications of such phrases are entered into the discourse representation.

Our questions, in the first instance, are descriptive ones. Is a moved reflexive processed like an unmoved one, preferring its antecedent to be the subject of the predicate of which it is a part? Is a reflexive processed differently when its antecedent is quantified than when it is a definite description? Is a quantified antecedent for a reflexive preferred or dispreferred by perceivers? Do implicit discourse assumptions carried by D-linked phrases ("which N") influence sentence-internal processing operations such as reflexive binding?

Binding of anaphors (e.g. "himself") is interesting because it may apply with respect to the original position of the anaphor or with respect to a trace created by moving the anaphor (or a phrase containing the anaphor), if it has been moved at S-structure. In (1a), "George" may act as the matrix binder for "himself."

(1)   a.   Which lie about himself did George think Sally hated _ most?
      b   *George thought Sally hated the latest lie about himself most.

"George" may bind "himself" in (1a) even though, if the anaphor had not been moved (as in (1b)), this would be impossible without emphatic stress on "himself." If "himself" is changed to "herself" so that there is no gender conflict between the

reflexive and the embedded subject, then this subject may be the (embedded) antecedent, as illustrated in (2).

(2)   a.   Which lie about herself did George think Sally hated _ most?
        b.   George thought Sally hated the latest lie about herself most.

In (2a), the anaphor may be bound by the lower subject ("Sally") once the original D-structure position of the anaphor has been 'reconstructed' (see Riemsdijk and Williams, 1986, Barss, 1985 and Plunkett, 1991, for discussion).

    In sum, though a moved anaphor may be bound in a position it occupies only as a result of movement it can also be interpreted as though it had not moved from its original D-structure position. In movement cases interpretation is always dependent on a trace in the S-structure representation.[1]

    We are especially interested in the principles of reflexive interpretation in cases like those above because they allow us to study the interplay of various processing operations. Here we begin to investigate the interpretation of reflexives bound with reference to various positions of the reflexive (matrix - with respect to an intermediate trace of the wh-phrase containing the reflexive in comp - or embedded - with respect to the lowest trace of the wh-phrase). Very little research has been directed at the processing of reflexives. Nicol (1988; Nicol and Swinney, 1989) studied sentences like (3). She presented cross modal priming data suggesting that all and only the grammatically permissible antecedents are activated immediately after processing a reflexive (here only "fireman" would be activated as an antecedent for "himself").

(3)   The landlord told the janitor that the fireman with the gas mask would protect himself if it became necessary.

    Plunkett (1991) collected judgments in a questionnaire study. She examined sentences with moved reflexives like those in (1a), (2a) and (4). The locality conditions requiring an antecedent to be 'nearby' may be checked with respect to either the surface position of the reflexive or the position where the reflexive originated in D-structure in sentences like (4) in which the reflexive has been moved.

(4)   Which picture of himself did George say Henry liked _ most?

In her questionnaire study, Plunkett found a strong tendency for the matrix antecedent ("George") to be preferred.[2] More recently Radó (1994) has shown that perceivers disprefer a moved phrase as antecedent of the reflexive.

    The experiments reported here were designed to extend Plunkett's questionnaire data to a more on-line task, self-paced reading. Our goal was simply to assess whether, in such an on-line task, reflexives find their antecedents in the matrix or the embedded clause. Though early interpretation seems like a likely

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[1] Barss (1985) presents a theory of surface binding which extends binding domains essentially by allowing an anaphor to be bound in the local domain of any trace of the phrase containing the anaphor. Hence, matrix binding of (2) actually implicates the trace in the lower [spec, CP], as in (4) on Barss' theory, though it is the matrix position of the anaphor which determines its Binding Domain.

[2] 80% of respondents preferred a sentence with unambiguous matrix binding to one with an unambiguous embedded antecedent. Only 34.5% chose the lower antecedent in ambiguous cases like this.

explanation for taking the matrix antecedent,[3] we make no attempt here to explicitly test the hypothesis that the effect is due to a preference for early interpretation.

The experiments also have a broader purpose, namely, to initiate investigation of how scopal phenomena interact with other processes, such as binding/interpreting the reflexive. Very few adult processing studies have taken up scopal phenomena. One exception is Kurtzman and MacDonald (1993). They examined the processing of sentences like those in (5) and (6). They argued for (i) a "Single Referent Principle," to account for the strong preference for a wide scope existential reading in (6), (ii) a surface position principle, accounting for preference for forward scope readings (in which the quantifier which is linearly first gets wide scope), and (iii) an effect of thematic roles.

(5)   Every boy climbed a tree.
(6)   A tree was climbed by every boy.

These factors are intended to simultaneously apply in a competition framework. For various readings to compete, they must already be represented in memory. Apparently the means by which the processor arrives at the various permissible LFs for a sentence was not Kurtzman and MacDonald's primary concern. Instead of looking at what factors compete to produce the finally-preferred analysis of sentences, the attempt here is to investigate the process of arriving at an LF representation in the first place.

In our experiments, we included sentences with the quantifier "every" because of the impact such quantifiers have on LF (through Quantifier Raising). We did not have detailed predictions about what effect the quantifier would have in our experiment, but merely included it to see if it would matter and if it would interact with a matrix vs. embedded antecedent for the reflexive. As it turned out, the quantifier did have interesting and interpretable effects, which we will discuss after presenting data.

1.   Experiment 1

Method

To validate Plunkett's finding that matrix antecedents of reflexives are chosen in preference to embedded antecedents in questions like (4), we performed a self-paced reading study. Twenty-four sentences like those in (4) were constructed, as illustrated in (7).

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[3] Intuitions suggest the highest subject may be interpreted as the antecedent of "himself" in (4) immediately, before the lower comp (the clause- initial position following "say" in (4)) is encountered. This suggests that the different components of anaphor binding identified by Plunkett (1991) are accomplished at different times. The first, feature identification, involves matching the relevant morphological features of the antecedent and reflexive. This may be done immediately when the anaphor is encountered. The other stage requires c-command and locality relations between the antecedent and anaphor to be checked to ensure that they conform to the requirements of binding theory. It is this second stage which implicates the trace in intermediate comp and which we would expect, therefore, to occur only after the highest verb ("say") had been encountered.
    Alternatively, intuitions that the highest subject is immediately taken to be the antecedent might indicate that current views of binding are mistaken with respect to the assumption that binding is dependent on the trace in the lower comp.

(7)   a. Which rumor about herself did / the actress / claim / the newspaper /made up?
       b. Which rumor about herself did / the newspaper / claim / the actress / made up?
       c. Which rumor about herself did / the matron / claim / the actress / made up?
       d. Which rumor about herself did / every actress / claim / the newspaper / made up?
       e. Which rumor about herself did / the newspaper / claim / every actress / made up?
       f. Which rumor about herself did / the matron / claim / every actress / made up?

In the a-form, the subject of the entire sentence was the only legitimate antecedent for the reflexive, which always occurred inside the questioned constituent. In the b-form, the only legitimate antecedent occurred as the embedded subject. In the c-form, both subject noun phrases were potential antecedents for the reflexive. Thus, the matrix antecedent of the reflexive must be chosen in (a), the embedded antecedent in (b), and either in (c). The (d-f) forms were constructed by replacing the definite determiner in the antecedent phrase (or in the case of ambiguous sentences, the embedded potential antecedent) with "every." Thus "the actress" in (a-c) above, becomes "every actress" in forms (d-f). All experimental sentences are presented in the appendix. The universally quantified sentence-forms were included as a probe for the interaction of binding and quantification.

The experimental sentences, together with 86 sentences from other unrelated experiments and filler sentences, were divided into six lists. Each list contained one version of each experimental sentence, and each contained four instances of each sentence form (a-f). Sentences were presented on a computer-controlled display, phrase by phrase as indicated by the / marks in (7), under the control of the subject. Each time the subject pressed a thumb button, the current phrase was replaced by the next one at the same location on the display. Reading time was measured. Each sentence was followed by a two-choice question. Each question of an experimental sentence asked about the correct antecedent of the reflexive term, expressing the head of the wh-phrase containing the reflexive as a definite singular (e.g., "Who was the rumor about"), and providing two definite singular alternative choices, one on each side of the video monitor (e.g., "The actress... The newspaper"). Subjects responded by pulling a lever under the correct answer.

Thirty-six undergraduates at the University of Massachusetts participated in the experiment for course credit.

Results

The reading time data in milliseconds were divided by the number of characters in each region, to result in a ms/char reading time measure. These data together with the question-answering accuracy are presented in Table 1.

The reading time measures were analyzed in an analysis of variance treating region (1-5), specifier (definite determiner vs. quantifier), and antecedent (matrix, embedded, ambiguous) as factors. There was no overall difference between sentences with definite determiners and with quantifiers (both averaging 89 ms/character). The differences among antecedent conditions were significant, with matrix antecedent sentences averaging 85 ms/char, embedded 93 ms/char, and

ambiguous 89 ms/char (F1(2,70) = 5.78, p < .01; F2(2,46) = 3.85, p < .03). A difference of 4.88 ms/char between any two means was needed for significance at the 5% level. Thus, only the extreme difference (between matrix antecedent sentences and embedded antecedent sentences) can be fully trusted. The differences among regions were highly significant, but of little interest; reading time was very slow in terms of ms/char for Region 3, the verb, but this region unlike the others contained only a single word, which inflates the ms/char measure. The interaction between regions and antecedent condition approached significance (p < .06). However, it probably reflects a distinct pattern of reading times for the ambiguous sentences, since the interaction between regions and matrix vs. embedded antecedent was totally nonsignificant (F < 1).

Table 1

Reading Time (ms/char) and Accuracy, Experiment 1

Condition	Region					Mean	Percentage Correct
	1	2	3	4	5		
(a) Def Det, Matrix	66	65	119	61	88	84	95%
(b) Def Det, Embedded	63	73	130	69	103	94	78%
(c) Def Det, Ambiguous	67	76	115	60	105	89	68%
(d) "every," Matrix	65	67	123	65	88	86	92%
(e) "every," Embedded	65	72	130	66	97	92	60%
(f) "every," Ambiguous	65	71	121	60	101	89	72%

Note: Region 1, Wh-phrase; Region 2, matrix antecedent; Region 3, verb; Region 4, embedded antecedent; Region 5, remainder of sentence; Mean for Regions 2-5. "Accuracy" for Ambiguous items is the proportion of choice of the Matrix (first) possible antecedent.

The question-answering accuracy also reflected the difficulty of comprehending sentences with embedded antecedents, as contrasted with matrix antecedents (69% vs. 93% correct, F1(1,35) = 52.16, p<.01; F2(1,23) = 39.81, p< .01). In addition, it showed a significant inferiority of answering questions after sentences with the quantifier "every" as compared to the definite determiner. Inferiority was greater for embedded than for matrix antecedents (interaction F1(1,35) = 5.89, p < .02; F2(1,23) = 6.74, p <.02). We will refer to this specific difficulty for sentences with a quantified embedded antecedent as the "Quantifier Effect." Finally, there was a clear preference for adopting the matrix (in this case,

244   Frazier, Plunkett and Clifton

the initial) antecedent in the ambiguous sentences. This was comparable in size for sentences with "every" and for those with a definite determiner ("the").

Discussion

Plunkett's finding of a preference for matrix antecedents over embedded antecedents was confirmed in both the reading time data and the answer-accuracy data for unambiguous sentences and answer-preference data for ambiguous sentences. Experiment 1 also uncovered an interesting interaction between binding and the presence of the quantifier "every," namely, accuracy was particularly low for embedded quantified antecedents.

The presence of a quantifier in the experimental sentences might decrease comprehension accuracy (and conceivably increase comprehension times) because the quantifier introduces a bound variable interpretation of the anaphor, at least in the unambiguous sentence forms. But note that a bound variable reading is also required when "every" occurs in the (unambiguous) matrix antecedent sentences. If bound variable readings were particularly complex, why didn't the accuracy of bound variable sentences with matrix antecedents drop dramatically just as the accuracy for bound variable sentences with embedded antecedents did? Thus simply assuming high complexity for a bound variable reading will not explain the data.

The difficulty of comprehending quantified sentences (the "Quantifier Effect") seems to hold only for quantified embedded antecedents, not quantified matrix antecedents or ambiguous reflexive sentences with a quantifier in the embedded subject position. If the presence of an operator ("every") between the wh-phrase and its lowest trace were responsible for the observed Quantifier Effect, then the effect should hold equally for matrix and for embedded antecedents - in both cases "every" would constitute an intervening operator (see Rizzi, 1990, for one theory where it is dispreferred for a binder to intervene between an operator and its variable.)

Perhaps the Quantifier Effect simply reflects the difficulty of piling up too many mental operations at one point in the sentence. In all the experimental sentences, the processor must build considerable phrase-structure at the beginning of the embedded clause, then identify the trace position and bind the trace. In the sentences with an embedded quantified subject, NP-prefixing and QR must also apply in order to construct a configuration appropriate for restricted quantification. In the sentences with a quantified antecedent, another operation - binding of the reflexive and construction of the bound variable interpretation must also apply within the embedded clause.

Specifically compare (8a), where the matrix antecedent binds the reflexive, with (8b), which illustrates the embedded antecedent structure. The distribution of processing complexity may differ in the two sentences. In (8a) extraction is out of the lower clause whereas binding of the reflexive and raising of the quantifier occur in the upper clause. Thus, processing operations seem to be spread more evenly across the sentence in (8a) than in (8b) where all these operations cluster together in the processing of the lower clause. In general it seems that processing is more difficult when processing operations cluster together, (see Frazier, 1985). We might dub this the "Complexity Hypothesis," given in (9). It could in principle explain the difficulty of (8b).

(8)   a. [Which picture of [himself]$_i$]$_k$ did [every$_m$][[e$_m$[janitor]]$_i$ say
           [e$_k$[Mary liked e$_k$ most]]]?
        b. [Which picture of [himself]$_i$]$_k$ did Mary say
           [e$_k$[[every$_m$][[e$_m$]janitor]]$_i$ liked e$_k$ most]?

(9)   **Complexity Hypothesis**: Processing operations are rendered more
        complex when they occur in clusters rather than evenly spread throughout
        the sentence.

The Complexity Hypothesis predicts that there is nothing special about the
processing of (8b) other than the co-occurrence of many operations at one time.
Thus, similar effects should occur in processing of sentences like those in (10). In
(10b) the complex noun phrase contains a binding relation, Quantifier Raising and
an A'-A relation in a single domain, i.e. the Complex NP. Thus, the Complexity
Hypothesis predicts that the difficulty of (10b) relative to (10a) should be
comparable to the difficulty observed above in (8b) relative to (8a) (also relative to
(8b) without a quantified NP in the lower clause).

(10)   a. John destroyed [the snapshot of [herself]]$_k$[that Anna had taken e$_k$].
        b. John destroyed [every]$_m$[[e$_m$] snapshot of [herself]]$_k$[that Anna had
           taken e$_k$]

Another possibility is that the embedded antecedent sentences were
somehow less plausible semantically than the matrix antecedent sentences. To
evaluate this possibility, a rating study was conducted, along with a replication of
Experiment 1, Experiment 2, designed to test the Complexity Hypothesis.

Finally, it is possible that phrasing the questions of Experiment 1 in terms
of singular definite NPs might have introduced confusion when the antecedent of
the reflexive was a quantified NP. It is not apparent to us how this could have
differentially affected questions of sentences with matrix and embedded
antecedents, but we changed the form of the questions in Experiment 2 in an
attempt to eliminate the potential problem.

2.   Experiment 2

Rating study

Fifty-seven undergraduates each rated approximately 100 sentences (the
exact number differed slightly for different subjects) on a seven-point plausibility
scale (1 = highly implausible, 4 = neither plausible nor implausible, 7 = highly
plausible). These sentences included 27 wh-question sentences like those in
(7a,b,d,e) and 12 relative clause sentences like those in (10). Each wh-question
sentence occurred in four forms: matrix vs. embedded antecedent of reflexive,
crossed with definite determiner or "every" as specifier of the antecedent. Each
relative clause sentence occurred with a definite determiner or "every." A given
subject saw only one form of each sentence, and saw equal numbers of sentences in
each form.

The mean ratings of the forms chosen for Experiment 2 were 4.62 for form
(7b) (embedded, definite determiner) and 4.28 for form (7e) (embedded, "every"),
where 4 was intended to be the neutral point on the scale, and larger numbers

Frazier, Plunkett and Clifton

indicated higher plausibility. Although these forms were chosen to be close in plausibility, they did differ at a nearly-significant level, $t(11) = 2.18$, $p < .06$.[4]

All 12 of the relative clause sentences were used in Experiment 2. They had mean ratings of 4.41 with the definite determiner and 4.37 with "every."

Reading time study

Method. Forty undergraduate students were tested using the same self-paced reading procedures described for Experiment 1. They read twelve wh-question sentences like those shown in (11a,b), and twelve relative clause sentences like those in (12a,b).

(11)   a. Which rumor about herself did / the newspaper / claim / the actress / made up?
        b. Which rumor about herself did / the newspaper / claim / every actress / made up?

(12)   a. John destroyed / the snapshot / of herself / that Anna / had taken.
        b. John destroyed / every snapshot / of herself / that Anna / had taken.

The sentences were presented in separate frames, as indicated by the / marks in the examples, in the same manner as in Experiment 1. Each subject saw only one version of each sentence, half with a definite determiner and half with "every." Over all subjects, each sentence occurred equally often in each version. The wh-question sentences occurred only with the embedded antecedent for the reflexive. These 24 sentences were embedded in a list of 103 sentences. Each sentence was followed by a two-choice question. To avoid the problem discussed in Experiment 1 (in which only singular NPs were used in the questions), a plural NP was used when the antecedent of the reflexive was quantified (e.g., "Who were the rumors about") and a bare plural NP corresponding to the quantified NP was offered as one of the alternative answers (e.g. "The newspaper... Actresses").

Results. The reading times and percentage correct answers appear in Table 2. No differences between sentence forms with the definite determiner and with "every" were significant in the analysis of reading times.

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[4] Only these two forms were used in the experiment. For completeness, the mean ratings were 4.97 for form (7a), matrix definite determiner, and 4.24 for form (7d), matrix "every."

Table 2

Reading Time (ms/char) and Accuracy, Experiment 2

Condition	Region					Percentage Correct
	1	2	3	4	5	
(8a) Def Det, Wh-Question	53	69	133	56	69	80
(8b) "Every," Wh-Question	53	69	130	61	71	67
(10a) Def Det, Relative Clause	56	69	73	89	73	62
(10b) "Every," Relative Clause	56	64	78	83	72	63

Note: For Wh-questions: Region 1, Wh-phrase; Region 2, non-antecedent NP; Region 3, verb; Region 4, embedded antecedent; Region 5, remainder of sentence. For Relative Clause: Region 1, Subject + verb; Region 2, antecedent NP; Region 3, PP with reflexive; Region 4, Relative pronoun + subject; Region 5, remainder.

The wh-question and relative clause sentences were not directly compared, because no effort had been taken to match the two sentence sets for length or other factors.

The percentage correct data indicated that wh-question sentences with the "every" quantifier (11b) were less well comprehended than with a definite determiner (11a), 80 vs. 67% correct. No such effect of the quantifier was observed for the relative clause sentences like (12), 63 vs. 62% correct. This pattern is not predicted by the Complexity Hypothesis, and was supported statistically by a significant interaction between sentence form and specifier, $F1(1,39) = 5.34$, $p < .03$; $F2(1,22) = 6.71$, $p < .02$.

These accuracy data show the same pattern as the plausibility rating data. However, they cannot be reduced to an effect of plausibility. First, none of the correlations between measures of plausibility (plausibility of the definite determiner or the "every" quantifier form) and measures of accuracy were significant, for either wh-question or relative clause sentences (presumably because of lack of systematic variability in plausibility; all correlations $< .24$, $p > .10$). Second, an analysis of covariance of the difference in accuracy between definite determiner and "every" sentences, using the difference in plausibility ratings as the covariate (and treating items as the random variable) showed that the difference in accuracy was greater for wh-question sentences than for relative clause sentences, $F(1,21) = 6.06$, $p < .03$.

Relative clauses showed lower accuracy than wh-questions (62 vs. 73%; $F1(1,47) = 11.16$, $p < .01$, but $F2(1,23) = 2.21$, $p > .15$). We think this reflects the overall complexity of the particular relative clause structure used. A complex NP (relative clause) occurs with a complex NP as its head and, further, this complex NP head itself contains a (temporarily) unbound anaphor. An NP of this complexity

may be unusual. By contrast, a wh-question is itself not unusual or particularly complex, even when extraction of an embedded object is involved. For the wh-constituent to contain an anaphor is perhaps not particularly common but this is the only unusual feature of the questions. Thus we suggest that the informative finding is not the lower accuracy of the relatives (vs. questions) but their failure to interact with the presence of "every," in sharp contrast to the questions.

Discussion

We have argued that there is a preference to interpret moved anaphors in the matrix clause. This preference can be explained by the preference for early interpretation of the reflexive with respect to the earliest position where it can be licensed and bound, i.e., the position of the trace in Spec CP of the embedded clause in the experimental sentences. The bias against embedded antecedents for (leftward-moved) anaphors is exceptionally strong when the embedded antecedent is specified with an obligatorily raised quantifier ("every"). This quantifier effect was not explained by either semantic plausibility or by the Complexity Hypothesis. Counter to the predictions of the Complexity Hypothesis, no effect of a quantifier was observed in the relative clause sentences. Further, no reading time disadvantage appears at the point of the hypothesized cluster of processing operations.

One explanation for the Quantifier Effect does suggest itself. Imagine that the perceiver interprets the "which"-phrase by constructing a discourse referent for the wh-phrase sometime after processing the matrix clause but before processing the embedded clause. At the end of the matrix clause in a sentence like (7), a discourse entity will be postulated for "rumor" - unless the presence of an already identified quantified antecedent has resulted in a bound variable interpretation. (We assume that bound variables are not represented as discourse referents.) Consequently, the discourse entity in (13) would be postulated at the clause boundary in matrix-antecedent sentences without quantified antecedents, as in (13a), and in embedded antecedent sentences of all types, possibly something along the lines indicated in (13b), since the processor would not yet have discovered the need for a bound variable interpretation of the reflexive inside the wh-phrase. Only with a matrix quantified antecedent would the bound variable interpretation be constructed before an inappropriate discourse assumption was made. In this case, whatever representation is appropriate for a bound variable reading would be constructed but, by hypothesis, it would not include a discourse entity corresponding to "rumor" (indicated by "•" in (13)).

(13)
> •
>
> rumor

a.   For which x (rumor(x))[y(actress(y)) such that y claimed...] where about (x,y)
b.   For which x (rumor(x))[y(female(y))   z(newspaper(z)) such that z claimed...] where about (x,y).

In the case of an embedded quantified antecedent, and only in this case, would the processor need to retract the assumption that the which-phrase introduced a discourse entity into the discourse model. And, therefore, we can explain why the

Quantifier Effect holds only for this sentence type. Let's dub this account the Discourse Assumption Retraction hypothesis (DAR).

Is there any independent evidence for the assumptions underlying DAR? In terms of processing assumptions, we are not aware of evidence either supporting or disconfirming the assumption that a discourse entity is postulated for a which-phrase at the clause boundary. However, DAR does make several predictions that can be tested intuitively.

First, it predicts that the Quantifier Effect should not be limited to sentences containing reflexives. Examples like (14a), pointed out to us by an anonymous reviewer, suggest that this is correct. In (14a) "which boy" wants wide-scope and so does "every girl." Assuming the grammar forces "which boy" to have wide scope, this results in the pragmatically odd situation where there is some boy which every girl married. To remedy the situation, a "functional" interpretation can be assigned to "which boy" (see Engdahl, 1986), permitting for example an answer like "her childhood sweetheart." But this reconciliation of scope requirements and real world expectations about "marry" (one boy to one girl) can be accomplished only by retracting the discourse assumption that "which boy" has a corresponding discourse entity, i.e., a singular entity.

(14)   a.   Which boy did Tom say that every girl married?
         b.   Which boy did Tom say that every girl saw?

If we bias the verb so that a one-one relation between girls and boys is no longer expected, as in (14b), the intuitive difficulty of (14a) is diminished.

The above observations suggest that the retraction of the assumed discourse entity might underlie the difficulty of (14a) and the difficulty of the experimental embedded-quantifier antecedent sentences. In (14b), where the verb "see" allows a single boy to be seen, the wh-operator can be interpreted without retracting the discourse assumption. This account also explains why the best answer for questions like (14a) is a functional answer such as "her childhood sweetheart," "the second boy who asked" or the like. This allows the wh- to take wide scope while still satisfying the expected one-one relation for "marry."

In (14) and in our experimental sentences, the wh-operator is D-linked (see Pesetsky, 1987, Enc, 1991). This promotes the assumption that a single discourse entity should be postulated for the wh-phrase. In a "who" question, the assumption may be somewhat weaker than in a "which" question. Consequently, it should be easier to process a sentence like (15) than one like (14a). If no discourse entity has been postulated in processing "who" in (15), then the discourse assumption need not be revised when "married" is encountered.[5]

(15)   Who did Tom say that every girl married?

Finally, the DAR predicts that (16) should not be very difficult to comprehend because no discourse assumption will need to be retracted.

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[5] Alternatively, a discourse entity might be postulated but not marked as singular.

250   Frazier, Plunkett and Clifton

(16)   Which kind of boy did Tom say that every girl married?

Our intuitions confirm this prediction.

3. Experiment 3

Several of the above predictions were tested in a self-paced reading study using 16 sentences like (17), with four versions of each. Two (17a,b) contained "which N" as the questioned constituent; two contained "who."

(17)   a. Which boy did Tom say that every girl saw?
        b. Which boy did Tom say that every girl married?
        c. Who did Tom say that every girl saw?
        d. Who did Tom say that every girl married?

Two versions (17a,c) contained a neutral verb ("see") that does not imply any particularly natural one-one relation between members of the set denoted by the subject and the one denoted by the object. Two versions (17b,d) replaced the neutral verb with a biased verb ("marry") which does strongly imply a one-one relation in the expected situation where, say, one man marries just one woman and not five women. All items are presented in the Appendix.

If perceivers postulate a discourse entity during the processing of the matrix clause in the "which N" examples (17a,b) and need to retract this assumption when they encounter the biased verb in (17b), then (17b) should take longer to process than (17a). By hypothesis, in the "who" examples (17c,d) no discourse entity is postulated during the processing of the matrix clause. Hence, there's no reason to expect a difference between the processing complexity of (17d), with the biased verb, and (17c) with the neutral verb.

Method.

Forty-four University of Massachusetts were tested on the 16 experimental sentences interspersed randomly with 74 other one- or two-sentence passages of varying form, after being given a short practice list of sentences. A self-paced moving-window reading procedure was used, in contrast to Experiments 1 and 2 which used centered presentation. The experimental sentences were each presented as a single frame, though some of the filler items were presented as two successive sentences. Eight of the experimental sentences and 28 of the filler sentences were followed by a wh-question (e.g., "Who did every girl see/marry?") which the subject was to answer orally. The experimenter scored the answer as indicating a single boy, a different boy for each girl, a functional relationship e.g. "The boy next door," or 'other.' Reading time for the entire sentence and the classified answers given to questions were saved by the computer that presented the sentences.

Results.

Table 3 presents the mean reading times for the experimental sentences, both in terms of raw ms (uncorrected for length) and in terms of ms/character. Greater store should be placed in the former means, since the ms/character correction is known to overcorrect for length differences like those that exist between the "who" and "which N" conditions of the experiment, but the ms/character measure sometimes results in lower error variance.

Table 3

Whole-sentence Reading Times, ms and ms/char, Experiment 3

	Ms	Ms/Char
Condition 1: Which N ... saw	4634	98.4
Condition 2: Which N ... married	4979	106.4
Condition 3: Who ... saw	4655	109.0
Condition 4: Who ... married	4667	109.5

Numerically, the biased verb ("married") sentences (17b,d) took longer than the unbiased verb ("saw") sentences (17a,c) only in the "which N" question (17b). In the analysis of the uncorrected reading times, the contrast between Condition 2 ("Which N ... married") and the rest was significant by subjects but not items ($F1(1,43) = 7.21$, $p < .02$; $F2(1,15) = 1.65$, $p > .20$). The difference between Conditions 1 and 2 ("Which N ... married" and "Which N saw") was similarly significant, only by subjects ($F1(1,43) = 5.77$, $p < .03$; $F1(1,15) = 3.24$, $p < .10$), and of course the difference between Conditions 3 and 4 was nonsignificant ($F < 1$). The corresponding contrasts were significant in the ms/character measure ($F1(1,43) = 5.51$, $p < .03$; $F2(1,15) = 4.60$, $p < .05$, for the difference between Conditions 1 and 2; $F1(1,43) = 12.96$, $p < .01$; $F2(1,15) = 9.10$, $p < .01$, for the contrast between Condition 1 and the rest). The ms/character measure indicated that Condition 1 was fast compared to the rest, rather than indicating that Condition 2 was slow, but this is probably a reflection of how the measure overcorrects for the greater length of Conditions 1 and 2, compared to Conditions 3 and 4.[6]

The data confirm the predictions of the discourse assumption account of processing D-linked ("which N") questions in showing that the difficulty observed with a 'biased' verb like "marry" appears only with a D-linked "which N" subject. This finding supports the DAR and its explanation of the processing difficulty in the reconstruction examples investigated here.

4. Conclusions

Extending the work of Plunkett (1991), we have presented evidence that matrix antecedents are preferred during the processing of ambiguous reconstruction sentences, and are faster to process when they are unambiguous, compared to embedded antecedent sentences. We attribute the matrix-antecedent preference to the fact that the reflexive-antecedent relation can be established earlier in the matrix antecedent sentences than in the embedded antecedent sentences.

Evidence has also been presented for the existence of what we have called the Quantifier Effect -- a dispreference for quantified antecedents which shows up only for embedded antecedent sentences. We have presented evidence against either a semantic plausibility or a processing complexity account of the effect. Instead, it seems to result from the need to retract a discourse assumption about the referent of

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[6] Attempts were made to classify the answers to questions, but we did not analyze these data because we were unsure that the classification system was used reliably. For what its' worth, functional answers were given 28%, 27%, 28%, and 36% of the time in Conditions 1, 2, 3, and 4 respectively.

252   Frazier, Plunkett and Clifton

the wh-phrase (as claimed by the DAR hypothesis) when information in the lower clause results in the need for a bound variable interpretation of the reflexive. Predictions of the DAR are confirmed by data on processing sentences without reflexives, capturing the difference between embedded clause verbs compatible with a wide-scope singular interpretation of the wh-phrase, e.g., "see," vs. those not compatible with such an interpretation, e.g., "marry." The data also support predicted differences between "who" and "which" phrases, while intuitive evidence suggests the ease of processing sentences with extracted constituents of overtly functional semantic types "which kind of boy."

The DAR should be tested in a wider range of sentence types than was considered here. If it proves to be correct, this would suggest that some discourse interpretation is assigned to wh-operators by the time an embedded clause boundary is postulated even when the operator (the extracted constituent) does not yet bind a syntactic variable (a gap). This helps to delimit the time course of the processor's operations in interpreting D-linked phrases. It also suggests that perceivers construct discourse representations as part of the shallow automatic processing of a sentence even when the sentence is presented in isolation or without a real discourse context, as in the experiments reported here.

Author Notes

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Frazier, Plunkett and Clifton

APPENDIX: Experimental materials

Experiment 1

1.   a. Which rumor about herself did the (every) actress claim the newspaper made up?
      b. Which rumor about herself did the newspaper claim the (every) actress made up?
      c. Which rumor about herself did the matron claim the (every) actress made up?

2.   a. Which story about himself did the (every) bartender say the waitress told to all the customers?
      b. Which story about himself did the waitress say the (every) bartender told to all the customers?
      c. Which story about himself did the waiter say the (every) bartender told to all the customers?

3.   a. Which photo of himself did the (every) dean know the professors hated most?
      b. Which photo of himself did the professors know the (every) dean hated most?
      c. Which photo of himself did the professor know the (every) dean hated most?

4.   a. Which lie about herself did the (every) singer tell the agents to remain silent about?
      b. Which lie about herself did the agents tell the (every) singer to remain silent about?
      c. Which lie about herself did the agent tell the (every) singer to remain silent about?

5.   a. Which illusions about himself did the (every) little boy think that the teachers believed?
      b. Which illusions about himself did the teachers think that the (every) little boy believed?
      c. Which illusions about himself did the teacher think that the (every) little boy believed?

6.   a. Which present for himself did the (every) kid believe mother shouldn't have bought?
      b. Which present for himself did the mother believe the (every) kid shouldn't have bought?
      c. Which present for himself did the brother believe the (every) kid shouldn't have bought?

7.   a. Which report about himself did the (every) politician say the reporters refused to reveal?
      b. Which report about himself did the reporters say the (every) politician refused to reveal?
      c. Which report about himself did the reporter say the (every) politician refused to reveal?

8. a. Which attack on himself did the (every) candidate think the public couldn't ignore?
    b. Which attack on himself did the public think the (every) candidate couldn't ignore?
    c. Which attack on himself did the incumbent think the (every) candidate couldn't ignore?

9. a. Which flattering letter about herself did the (every) little girl wish Santa Claus had read?
    b. Which flattering letter about herself did Santa Claus wish the (every) little girl had read?
    c. Which flattering letter about herself did Mrs. Claus wish the (every) little girl had read?

10. a. Which embarrassing song about herself did the (every) barmaid claim the handsome guitarist wrote?
    b. Which embarrassing song about herself did the handsome guitarist claim the (every) barmaid wrote?
    c. Which embarrassing song about herself did the attractive guitarist claim the (every) barmaid wrote?

11. a. Which portrayal of himself did the (every) gangster imply the community believed?
    b. Which portrayal of himself did the community imply the (every) gangster believed?
    c. Which portrayal of himself did the policeman imply the (every) gangster believed?

12. a. Which painting of himself does the (every) young artist hope mother will destroy?
    b. Which painting of himself does Mother hope the (every) young artist will destroy?
    c. Which painting of himself does Father hope the (every) young artist will destroy?

13. a. Which prayers for herself did the (every) baglady assume the priest would say?
    b. Which prayers for herself did the priest assume the (every) baglady would say?
    c. Which prayers for herself did the nun assume the (every) baglady would say?

14. a. Which accusation about himself did the (every) old racketeer expect the local police to have heard?
    b. Which accusation about himself did the local police expect the (every) old racketeer to have heard?
    c. Which accusation about himself did the policeman expect the (every) old racketeer to have heard?

256   Frazier, Plunkett and Clifton

15.   a. Which representation of himself did the (every) executive officer think
           the employees would find particularly amusing?
       b. Which representation of himself did the employees think the (every)
           executive officer would find particularly amusing?
       c. Which representation of himself did the employee think the (every)
           executive officer would find particularly amusing?

16.   a. Which analysis of herself did the (every) beautiful patient say Freud
           found convincing?
       b. Which analysis of herself did Freud say the (every) beautiful patient
           found convincing?
       c. Which analysis of herself did Frieda say the (every) beautiful patient
           found convincing?

17.   a. Which caricature of herself did the (every) pretty volunteer say the head
           doctors especially liked?
       b. Which caricature of herself did the head doctors say the (every) pretty
           volunteer especially liked?
       c. Which caricature of herself did the head doctor say the (every) pretty
           volunteer especially liked?

18.   a. Which reflection of herself did the (every) pregnant woman think the
           children considered funny?
       b. Which reflection of herself did the children think the (every) pregnant
           woman considered funny?
       c. Which reflection of herself did the child think the (every) pregnant
           woman considered funny?

19.   a. Which gossip about herself did the (every) Headmistress persuade the
           teachers to ignore?
       b. Which gossip about herself did the teachers persuade the (every)
           Headmistress to ignore?
       c. Which gossip about herself did the teacher persuade the (every)
           Headmistress to ignore?

20.   a. Which controversy over himself did the (every) protestor hear the
           administrators discuss with the press?
       b. Which controversy over himself did the administrators hear the (every)
           protestor discuss with the press?
       c. Which controversy over himself did the administrator hear the (every)
           protestor discuss with the press?

21.   a. Which plan for himself did the (every) high school kid overhear the
           adults arguing about?
       b. Which plan for himself did the adults overhear the (every) high school
           kid arguing about?
       c. Which plan for himself did the adult overhear the (every) high school
           kid arguing about?

22. a. Which party for herself did the (every) shy schoolgirl claim the parents ruined?
     b. Which party for herself did the parents claim the (every) shy schoolgirl ruined?
     c. Which party for herself did the parent claim the (every) shy schoolgirl ruined?

23. a. Which form of protection for himself did the (every) storeowner assume the city provided?
     b. Which form of protection for himself did the city assume the (every) storeowner provided?
     c. Which form of protection for himself did the detective assume the (every) storeowner provided?

24. a. Which picture of himself did the (every) bowler say Marcia liked best?
     b. Which picture of himself did Marcia say the (every) bowler liked best?
     c. Which picture of himself did Martin say the (every) bowler liked best?

Experiment 2

1. John destroyed the (every) snapshot of herself that Anna had taken.

2. The heavyweight fighter believed the (every) rumor about herself that the beautiful agent had spread.

3. Mary hung the (every) portrait of himself that Tim had painted in his youth.

4. The members of the audience laughed at the (every) joke about himself that the comedian told.

5. Pete read the (every) criticism of herself that Sue had put in her diary.

6. The prosecutors denied the (every) story about himself that the prisoner told to the jury.

7. Perry was shocked by the (every) bit of gossip concerning himself that Juanita had divulged.

8. Sue griped about the (every) burden on himself that Mike allowed family members to impose.

9. The company published the (every) poem about herself that the writer had produced.

10. The man agreed with the (every) memory about herself that the woman recalled under hypnosis.

11. Paul had panicked about the (every) criticism of herself that Sue had made while depressed.

12. Tommy carefully considered the (every) remark about herself that Violet had made in private.

258

Frazier, Plunkett and Clifton

13. Which rumor about herself did the newspaper claim the (every) actress made up?

14. Which story about himself did the waitress say the (every) bartender told to all the customers?

15. Which report about himself did the reporter say the (every) politician refused to reveal?

16. Which attack on himself did the public think the (every) candidate would find inexcusable?

17. Which sketch of herself did the handsome restaurant-owner correctly predict that the (every) waitress would like?

18. Which prayers for herself did the priest assume the (every) baglady would say?

19. Which accusation about himself did the local police expect the (every) old racketeer to have heard?

20. Which analysis of himself did Freud say the (every) male patient found convincing?

21. Which caricature of herself did the head doctors say the (every) pretty volunteer especially liked?

22. Which joke about herself did the teachers persuade the (every) student to ignore?

23. Which controversy over himself did the administrators hear the (every) protestor discuss with the press?

24. Which form of protection for himself did the city assume the (every) storeowner provided?

Experiment 3

1. Which boy (who) did Tom say that every girl saw (married)?

2. Which actor (who) did Mary claim that every contestant liked (resembled) most?

3. Which man (who) did the newspaper report that the criminal admired (killed)?

4. Which child (who) did Tim say that every parent despised (punished)?

5. Which car (what) did Henry say that every friend coveted (demolished)?

6. Which girl (who) did Tina that every boy (loved and admired) took to the prom?

7.   Which baby (who) was it rumored that every couple adored (adopted)?

8.   Which gangster (who) did Don claim that every criminal feared (murdered)?

9.   Which rumor (what) did Penelope indicate that every employee believed (started)?

10.   Which newcomer (who) did Sarah say that every bully disliked (attacked)?

11.   Which parent (who) did John maintain that every principal respected (helped)?

12.   Which fund (what) did Sam tell you that every broker recommended (mismanaged)?

13.   Which man (who) did Ian say that every "little brother" was impressed by (assigned to)?

14.   Which race (what) did Frank indicate that every boy enjoyed (won)?

15.   Which course (what) did Dean say that every professor was afraid to teach (known) best for?

16.   Which graduate (who) did the newspaper claim that every company had wanted (hired)?