# Incremental syntactic processing and the Right Roof Constraint[*]

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## 1 Introduction

In this brief note, I will discuss the prospects of a processing-oriented account of the Right Roof Constraint (RRC), a topic I spent the better part of two years discussing with Professor Johnson at length. To preview my conclusion: I suggest that given current understanding of how incremental syntactic analysis proceeds, it is unlikely that the RRC can be reduced entirely to the difficulty associated with constructing an incremental parse of right-extraposed constituents. Instead, to the extent that the RRC is the result of processing pressures, it seems more likely a grammaticized reflection of those pressures (Fodor 1979, Grosu 1973, Berwick & Weinberg 1986).

### 1.1 The empirical generalization

Let me begin by stating the empirical generalization to be explained:

(1)     *Right Roof Constraint (RRC)*
        Rightward movement may move an element X to the right edge of the cyclic node that most immediately contains X, but no further.

                                                            (McCloskey 1999: 207)

(1) is McCloskey (1999)'s formulation of the Roof Roof Constraint, which expresses an observation about the somewhat stringent locality conditions on rightward movement that goes back to Ross 1967 (see also Akmajian 1975 and Grosu 1973). Let us assume that at least CP constitutes a cyclic node. If at least CP is a cyclic node, then the RRC expresses a solid empirical generalization: there seems to be relatively broad (if not universal) agreement that rightward movement to a higher clause is severely limited (but cf. Rochemont 1992). At the outset I should add that

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whether other phrasal nodes are also cyclic (and so create a barrier to rightwards movement) remains an open question. In particular, although DPs are commonly assumed to be cyclic nodes, sub-clausal locality restrictions imposed by the RRC are particularly controversial (Overfelt 2015, Strunk & Snider 2008). I will only focus on rightward movement across a tensed clause boundary.

The RRC, then, is responsible for the perception that the (a) examples in (2)–(4) are more well-formed than the (b) examples:

(2)    a.    I will claim that someone __ arrived yesterday [who was responsible for the murder.]

        b.    *I claimed that someone __ will arrive yesterday [who was responsible for the murder.]          Extraposition from NP:RC

(3)    a.    I will claim that you arrested __ yesterday [someone who was responsible for the murder.]

        b.    *I claimed that you will arrest __ yesterday [someone who was responsible for the murder.]          Heavy NP shift (HNPS)

(4)    a.    I will claim that someone __ arrived yesterday [from the shadowy assassin's guild.]

        b.    *I claimed that someone __ will arrive yesterday [from the shadowy assassin's guild]          Extraposition from NP:PP

In each of (2)–(4), the constituent in brackets has been extraposed from the position marked with the underscore; I'll use 'extraposition' to generally refer to this potentially heterogenous class of rightward displacement operations. Following the psycholinguistic tradition, I will refer to the base position of the extraposed constituent as a gap, and the extraposed constituent as a filler (e.g., Fodor 1978). I do not take this terms to imply any particular theoretical analysis of the extraposition operation, or indeed, to even imply that the three types of extraposition in (2)–(4) necessarily involve the same grammatical mechanism.

(2)–(4) are constructed so that the adverb that intervenes between the extraposed filler and its gap either attaches low, inside the embedded clause (the (a) examples), or high, in the matrix clause (the (b) examples). When the adverb modifies the matrix clause, the extraposed constituent is correspondingly forced to occupy a structural position inside the matrix clause. This creates a violation of the RRC, because extraposition has displaced the filler to a position (a matrix adjunction site) above the most minimal cyclic node containing the gap (the embedded CP). No such violation need arise in the (a) examples; this underlies the apparent acceptability differences between these structures.

One of the most interesting features of the RRC is that suggests much tighter locality restrictions on rightward displacement than are associated with leftward

movement. At least superficially, fillers that are displaced leftwards can be sited in positions outside of their minimal containing cyclic node (potentially mediated by cyclic movement); indeed, a leftward moved filler can be indefinitely far away from its gap as long as there are no island boundaries that intervene on the dependency. This essential left-right asymmetry is stipulated in various accounts of locality conditions of extraposition: Baltin's (1981) Generalized Subjacency is one very explicit example, but there are many others (see also Baltin 1983, Culicover & Rochemont 1990, Drummond 2009, Rochemont 1992, among many others).

If it is empirically correct that right-displaced fillers are subject to stricter locality requirements than their leftward-displaced counterparts, then this asymmetry seems to cry out for a processing-oriented explanation. Why else should the locality constraints on displacement operations be sensitive to the linear direction of that displacement? By 'processing-oriented,' I mean any account of this observation that attributes the directional locality asymmetry implied by RRC to some aspect of the incremental processing or construction of syntactic structure (as opposed to a constraint on the well-formedness of the outputs of such a process). These types of explanations are tempting to pursue because in reversing the linear order of the filler and gap, extraposition creates a very different problem for an incremental parser than does leftward movement. Leftward movement overtly locates the filler before its gap, allowing the parser to engage predictive, forward-looking 'gap-finding' routines once a filler has been recognized (e.g., Wanner & Maratsos 1978, Stowe 1986). In contrast, rightward movement generally leaves no overt cue to the displacement at the gap site, and the filler is encountered only after the gap site has been processed. In a sense, then, filler-gap dependencies are fundamentally prospective, forward-looking dependencies, and gap-filler extraposition dependencies are generally retrospective, backwards looking dependencies. Prospective and retrospective dependencies are associated with different processing profiles, presumably due to the different functional demands the two linear orders place on the parser (Phillips et al. 2011). Might the differences in the parsing steps necessary to construct filler-gap and gap-filler extraposition dependencies be the source of the locality asymmetry?

## 1.2 Incremental processing and the Fodor/Rochemont hypothesis

This idea is tempting, and I am by no means the first to moot the idea that the RRC has its roots in sentence processing: Grosu (1973), Berwick & Weinberg (1986), Fodor (1978) and Frazier (1985) all offer takes on this issue from varying perspectives. For present purposes, I would like to focus on one particular version of this hypothesis described by Fodor (1979) and subsequently elaborated by Rochemont (1992).

An anachronistic formulation of the Fodor/Rochemont hypothesis is that i) the parser incrementally processes filler-gap dependencies, ii) it is more difficult for the parse to modify completed structure than incomplete structure, iii) the parser 'cycles' on cyclic nodes, in the sense that structure is considered 'complete' when a complete cyclic node is identified, and iv) gaps cannot be posited in advance of their fillers. If these conditions are met, then the RRC results: once the parser recognizes a complete cyclic node, its analysis will be frozen at that point and so resist further modification. By (iv), we do not expect that analysis to contain a gap (as the filler has not been encountered), and so the parser will essentially lock in an analysis of the cyclic node that has no gap. Step by step, this goes something like:

(5)    a.    [$_{CP}$ I claimed [$_{CP}$ that someone arrived ...
       b.    [$_{CP}$ I claimed [$_{CP}$ that someone will arrive ] yesterday ...
       c.    [$_{CP}$ I claimed [$_{CP}$ that someone will arrive ] yesterday [$_{PP}$ from the shadowy assassin's guild]]

At point (5a) in the incremental parse, both CPs are open to modification. No gap has been associated with someone because the filler has not been encountered and therefore there is no evidence for this analysis. In (5b), the adverb is encountered, and it must modify the matrix clause. This 'high attachment' has the effect of causing the parser to 'complete' the embedded CP, freezing the analysis of that phrase as-is (indicated by italics). When the extraposed PP (5c) is encountered, the parser has no incomplete structure into which it can be attached (setting aside the analysis where the PP is construed as a VP-modifying matrix adjunct). Because the parser cannot find an open attachment site for the unfortunate extraposed PP, a perception of unacceptability results. In essence, the parser has been catastrophically, irreparably garden-pathed, as it cannot find a home for the extraposed material when doing so requires modification of an already-completed constituent.

Rochemont observes that this hypothesis would be a viable explanation of the RRC only insofar as the four component assumptions made above are each independently motivated (see also Fodor 1979, 1978 on more general considerations on the viability of this type of functional explanation for movement constraints). At least three of these four assumptions enjoy a good degree of independent motivation. For one, that the parser incrementally processes filler-gap dependencies is now entirely uncontroversial (Fodor 1978, Stowe 1986, among many others); there is a substantial body of experimental and intuitive evidence to support this assumption.

Equally important: there is good evidence for a slightly modified version of (iv). That is, the parser does not appear to incrementally posit gaps for extraposition unless there is very strong evidence to do so. For example, Staub et al. (2006) offer eye-tracking-while-reading data that suggests that readers do not predictively posit

a gap for HNPS at the verb or adverb in structures like (6a), which has a verb that is merely very likely to take a direct object (e.g., *watch*); instead, readers only do so in examples like (6b) where the verb is obligatorily transitive (e.g., *praised*; examples in (6) from Staub et al. 2006):

(6)  a.  *Optionally transitive*
         Jack watched from the stands his daughter's attempt to shoot a basket.
     b.  *Obligatorily transitive*
         Jack praised from the stands his daughter's attempt to shoot a basket.

Similarly, Levy et al. (2012) present evidence from self-paced reading that readers experience more difficulty with extraposed relative clauses than in-situ relative clauses. This suggests that comprehenders do not in general anticipate extraposed material, which in turn supports the assumption in (iv). Like Staub et al. (2006), however, Levy and colleagues observed that readers can predictively anticipate an extraposed relative clause for NPs like *only those producers* compared to *the producers*; in their data, introducing *only those* seems to have imposed a near-obligatory requirement for some kind of postnominal modification. Thus it seems that unless it is grammatically necessary, comprehenders will refrain from incrementally positing a gap in anticipation of an extraposed constituent. This constitutes independent evidence for (iv). If we take this seriously, then (iv) also has an important corollary: processing extraposition will, in the general case, create a garden path of some sort, insofar as previously created structure will need to be retroactively modified to accommodate a gap position for extraposed material when that material is encountered. The exceptions should be when the grammar forces the parser to predictively create a gap position before the filler is encountered, as in (6b). I return to this observation below.

So we have every reason to believe that filler-gap processing is incremental (assumption (i)), and good evidence that the parser is conservative in the sense that it will not generally anticipate gaps in advance of fillers (assumption (iv)). Given just these two assumptions, processing extraposition would seem to routinely create a garden path of some sort for the comprehender.

## 1.3  From the garden path of extraposition to ungrammaticality

If the reasoning above holds, then the Fodor/Rochemont hypothesis does receive some measure of independent justification. Whether or not it ultimately provides a satisfying account of the RRC then turns on the question: is the garden path associated with extraposition severe enough, when it crosses a closed cyclic node, to be the underlying source of the RRC? One observes that there is something of a gulf between the observation that the parser generally commits itself incremen-

tally to an extraposition-free parse (the upshot of the preceding section), and the conclusion that reanalyzing that parse to accommodate extraposed structures can be so difficult as to appear ungrammatical to analyst after analyst in the relevant literature.

Assumption (ii) of the Fodor/Rochemont hypothesis is that reanalyzing completed structure entails measurable difficulty. The core of this assumption is the claim that syntactic reanalysis can sometimes be difficult and create a perception of unacceptability, and it is crucial (see footnote 2 above). This assumption receives a great deal of independent support; I refer the reader to Fodor & Ferreira 1998 for an excellent overview of the topic. Here I wish to make two points concerning the relationship between reanalysis and perceived acceptability. First, the difficulty associated with syntactic reanalysis varies dramatically across different examples (Frazier & Clifton Jr 1998). Importantly, some garden paths do create a palpable sense of ungrammaticality/unacceptability. Consider the ambiguities in (7):

(7)  a.  *NP/S ambiguity*
         I heard <u>the professor with the fedora</u> was making fun of my button-down collar.
     b.  *NP/Z ambiguity*
         While the syntactician dressed <u>the poor assistant professor</u> sized up his collar in the mirror.
     c.  *MV/RR ambiguity*
         The syntactician <u>raced</u> into the classroom laughed.

In all of the examples in (7), the underlined phrase is incrementally ambiguous, and in each case, the ambiguity is resolved to the dispreferred analysis; in other words, I expect the reader to have been garden pathed in each example. From (7a) to (7c) there is a cline of difficulty: the difficulty in recovering from that garden path is barely noticeable in (7a), to catastrophic in (7c). The second point to make concerning the relationship between syntactic reanalysis and acceptability is that the impact of reanalysis on acceptability is surprisingly durable; in experimental contexts, it demonstrably impacts intuitive judgments of acceptability. Importantly for present purposes, existing evidence suggest that it does so to a comparable degree for speeded judgments and more slow, deliberate judgments alike (Ferreira & Henderson 1991, 1993, Tabor & Hutchins 2004, Van Dyke & Lewis 2003, Warner & Glass 1987). In light of findings such as these, I do find it plausible that a persistent and pathologically difficult garden path could have been systematically misanalyzed as having a grammatical basis (and doubly so if the analysts were possessed of a strong prior inclination to attribute unacceptability to a grammatical source). The perception of indelible unacceptability does not, in itself, settle the question of

whether that unacceptability is seated in the grammar (i.e., that it has a representational basis) or instead results from the operation of the processing mechanisms that assemble grammatical structure in real time (see also Abney 1996, Frazier 2008, Hofmeister et al. 2013, Lewis & Phillips 2015 and Sprouse 2008 for other perspectives on this issue).

## 1.4   Cyclic nodes and accessing syntactic encodings

To now, I have argued that three out of the four assumptions underlying the Fodor/ Rochemont hypothesis are very well motivated. Importantly, given what we know about syntactic reanalysis, it is not far-fetched to imagine that a systematic and pathologically difficult garden path could be so difficult to reanalyze that it could have been systematically misanalyzed as having a grammatical basis. This leaves us with assumption (iii) of the Fodor/Rochement hypothesis, that the parser commits to an analysis once a cyclic node has been identified, therefore making reanalysis particularly difficult. This I will argue is the assumption that we do not have good evidence for, and thus, this is where the hypothesis founders. On a number of theories of reanalysis, one major constraint on syntactic reanalysis is the parser's ability to reaccess the to-be-amended structure in memory (Ferreira & Henderson 1991, Frazier & Clifton Jr 1998, Sturt 1996, Van Dyke & Lewis 2003). In some theories, this is made difficult because this structure has decayed or otherwise become unavailable (Ferreira & Henderson 1991, Staub 2007, Sturt 1996, Van Dyke & Lewis 2003); on other theories it is because the parser has actually removed and/or deleted that structure in question (Kimball 1973, Weinberg 2000). The distinction between these two views is not critical here; on either view, we are left with the claim that the parser cannot locate the structure that must be reanalyzed, and so reanalysis cannot be successful. From this perspective, we may slightly reframe assumption (iii) of the Fodor/Rochemont hypothesis: we must assume that the syntactic structure of a completed cyclic node is dramatically less available for reaccess or reactivation at the point at which the filler is encountered than would material inside of an open syntactic domain. This would make constructing an extraposition dependency across a cyclic node especially difficult, thereby explaining the RRC.

Is this a plausible assumption? Unfortunately, at present our best evidence suggests that it is not. In fact, available evidence seems to suggest rather the opposite: material inside of cyclic nodes appears to hang around longer than it should during incremental processing, interfering with subsequent syntactic processing when it really ought not to. In a series of influential studies, Julie Van Dyke and colleagues investigated examples structurally similar to (8):

(8)     The pilot remembered that the lady who said that the man was smelly yes-
        terday afternoon moaned about a refund for the ticket.

Upon reaching the embedded verb *moaned*, the parser must identify the appropriate
subject phrase *the lady* in order to integrate it with the verb. Van Dyke's experiments
show that a linearly intervening but structurally inaccessible subject encoding *the
man* creates interference during this process, and is sometimes erroneously attached
(Van Dyke & Lewis 2003, Van Dyke 2007; see also Arnett & Wagers 2017). Thus,
syntactic material inside of a 'completed' syntactic node appears to be visible or
available to the parser, to the point that it intrudes on syntactic processing when it
is not grammatically licensed to do so.

    This is not an isolated phenomenon. Similar interference or intrusion effects
have been observed with verb agreement dependencies (Dillon et al. 2013, Wa-
gers et al. 2009), reflexive-antecedent dependencies (Parker & Phillips 2017), NPI
dependencies (Drenhaus et al. 2005, Vasishth et al. 2008, Xiang et al. 2009), and
filler-gap dependencies (Dillon et al. 2017, McElree et al. 2003, Van Dyke & McEl-
ree 2006, Wagers 2008). In all cases, we find evidence that syntactic material inside
of 'closed' cyclic domains remains available to some degree in working memory. It
can interfere with subsequent processing and even illegally participate in syntactic
dependencies. If it were indeed true that the material inside of closed cyclic do-
mains were rendered entirely unavailable in some fashion, these results would be
surprising. Insofar as these findings suggest that the syntactic encodings associated
with closed or completed cyclic nodes remain available, it suggests that assumption
(iii) is not plausible. Syntactic encodings can outlive their usefulness and interfere
with subsequent processing when not licensed by the grammar; thus there is no firm
reason to suspect that an extraposed filler could not find a gap position inside a fin-
ished cyclic node if such a thing was, in fact, licensed by the grammar. I qualify
this conclusion by acknowledging is an area where we have relatively little data.
Although it is true that syntactic material inside of closed cyclic domains can per-
sist and interfere, in absolute terms the effect of this interference is relatively small
(Wagers 2013). It remains possible that the relative availability of material in open
versus closed cyclic domains differs dramatically; further research is necessary to
establish this.

    A final observation before I close this short note. Given the processing evidence
reviewed above, the Fodor/Rochemont hypothesis makes an interesting prediction
about the acceptability of rightward movement. If the parser predictively creates a
gap in anticipation of extraposed material, then RRC violations should be alleviated
because the parser will not fall prey to the garden path associated with extraposition.
The examples in (9) use the cues that (we think) allow the parser to predictively

posit a gap for extraposition: obligatorily transitive verbs, and *only those* (Staub et al. 2006, Levy et al. 2012):

(9) a. Everyone agreed that you should hire __ yesterday [someone who actually knows Python 3.0.]
  b. Everyone agreed that only those people __ will arrive yesterday [who know how to use Google Maps.]

To my ear, these examples do not noticeably ameliorate the RRC violation. If these judgments prove reliable, this would provide further evidence against the specific version of the Fodor/Rochemont hypothesis pursued here.

## 2 Conclusion

I have argued that the Fodor/Rochemont hypothesis does not receive strong support given existing models of the parser. Although many of the component assumptions of this hypothesis are plausible and well-supported, findings concerning the availability of syntactic encodings in working memory during incremental processing do not lend support to the claim that material inside closed cyclic nodes is especially unavailable for further modification, a key assumption of this hypothesis.

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