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Sentence Processing with Empty Categories

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In a recent article, Pickering and Barry (1991) argue against the existence of empty categories (ECs) in human sentence processing. The purpose of this paper is to point out that Pickering and Barry's conclusion is too strong. Rather than arguing against the existence of empty categories, Pickering and Barry's data suggest only that if ECs are used by the sentence processor to link thematic roles to wh-phrases, then, given a wh-phrase, the sentence processor must posit an EC as soon as an appropriate position is licensed by the grammar. Thus empty categories may still serve a linking role between thematic role assigners and wh-phrases. This paper gives one possible parsing algorithm which accounts for Pickering and Barry's data within a framework that includes ECs.

INTRODUCTION

In a recent article, Pickering and Barry (1991) present some interesting data which they use to argue against the existence of empty categories (ECs) in sentence processing. We will argue, however, that these data may

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be explained within the framework of an EC-model of sentence processing given the parsing algorithm proposed below. Gorrell (this issue) has also challenged Pickering and Barry's claim, focusing on possible alternative interpretations of their data. Still, as Gorrell concedes, at least some of Pickering and Barry's observations do seem to present a problem for parsing models that assume the existence of ECs. Therefore, our discussion of this issue will generally assume the data as presented by Pickering and Barry.

Two general classes of constructions are put forward as evidence for Pickering and Barry's (PB's) hypothesis, both of which include verbs with multiple objects. The first set of constructions contrasts sentences in which an argument PP is extracted, with sentences in which the object of the argument PP is extracted:

1a. In which box did you put the very large and beautifully decorated wedding cake bought from the expensive bakery? (PB's 15)
b. Which box did you put the very large and beautifully decorated wedding cake bought from the expensive bakery in? (PB's 16)

The intuition is fairly clear: (1a) is somehow easier (less awkward) to process than (1b). Pickering and Barry propose that the difference between (1a) and (1b) follows from the difference in the length of time that the processor has to hold the relevant wh-phrase in memory before it can be linked to its subcategoriser. Thus the awkwardness of (1b) derives from the fact that the processor has to hold the wh-phrase *which box* in memory until it can be linked to its subcategoriser, the preposition *in*, which follows the complex NP *the very large and beautifully decorated wedding cake bought from the expensive bakery*. Sentence (1a), on the other hand, is processed more easily, since the wh-phrase *in which box* can be linked to its subcategoriser, the verb *put*, before the complex NP is processed.

Given the processing asymmetry exemplified in (1a) and (1b), and assuming the general account of the asymmetry outlined above, Pickering and Barry suggest that a theory which assumes the existence of ECs in sentence processing cannot be maintained.[1] This claim is based on (i) the observation that the prospective ECs in (1a) and (1b) both occur in

[1]In fact, the evidence that Pickering and Barry present has a bearing only on the existence of wh-traces and NP-traces in sentence processing. No evidence is presented which has any bearing on the existence of PRO or *pro* (see, e.g. Chomsky, 1981). Thus, for the purposes of this paper, we will consider Pickering and Barry's hypotheses with respect to wh-traces and NP-traces only.

sentence-final position,[2] and (ii) the implicit (and common) assumption that a wh-phrase filler cannot be associated with an EC until all intervening lexical material has been processed. Hence Pickering and Barry conclude that no EC can be posited in either (1a) or (1b) until the sentence-final position in each. Thus the wh-phrase must remain in memory in both (1a) and (1b) until the end of each sentence, and there is no explanation for the processing difference between the two sentences.

As a result of the difficulty with the EC theory with respect to these data, Pickering and Barry propose that wh-phrases (or any other type of filler) are linked directly with their subcategorisers, as is proposed by a number of grammatical formalisms (see, e.g. Ades & Steedman, 1982; Hudson, 1984; Kaplan & Zaenen, 1988). The difference between (1a) and (1b) is then explained by the fact that the wh-phrase *in which box* in (1a) is an argument of the verb *put*, so that it can be associated (co-indexed) with *put* as soon as this verb is encountered. In contrast, early linking of the wh-phrase in (1b) is not possible, since its subcategoriser, the preposition *in*, does not occur until the end of the sentence. This wh-phrase must therefore be held in memory until the word *in* is processed, which leads to a corresponding increase in processing difficulty.

Pickering and Barry's other primary source of data comes from the processing of recursive constructions. Pickering and Barry present a theory

[2]Pickering and Barry present two arguments against a heavy-NP shift analysis of (1a) (which would put the EC adjacent to the verb). The first is that heavy-NP shift cannot account for such an effect in all cases, since verbs with two NP objects do not allow heavy-NP shift (e.g. dative-shifted *give*). While this is true, it does not rule out a heavy-NP shift analysis of the examples given by Pickering and Barry which involve NP and PP objects. The second argument turns on the notion that "it is highly probable that extraction is impossible in combination with heavy-shifting" (p. 235). The following sentence is given as support of this claim.

i. *[Which box]$_i$ did you put in e_i, the very large and beautifully decorated wedding cake bought from the expensive bakery?

(cf. You put in the box, the very large and beautifully decorated wedding cake bought from the expensive bakery)

While this example shows that an NP cannot be extracted from the PP after the direct object of the verb has been shifted, it fails to show that the entire PP cannot be extracted. That is, Pickering and Barry's arguments fail to rule out a heavy-NP shift analysis of (ii):

ii. [In which box]$_i$ did you put e_i the very large and beautifully decorated wedding cake bought from the expensive bakery?

However, since this criticism does not apply to all of the effects observed by Pickering and Barry, the balance of this paper will simply assume that the effects documented by them are not attributable to heavy-shifting. See Gorrell (this issue) for further discussion of the empirical merit of Pickering and Barry's claims with respect to the distinction between (1a) and (1b).

of recursive constructions and give contrasts based upon this theory that they claim cannot be explained in a parsing theory which posits ECs. Their argumentation is complicated by the fact that their theory of recursive constructions fails to account for many related examples of syntactic complexity from the literature (see pp. 155–159). However, even under other more complete complexity theories, some of the data that they present still make the point. Two such sentences are given in (2):

2a. The cat which the dog which the farmer owned chased fled. (PB's 45)
b. John found the saucer on which Mary put the cup into which I poured the tea. (PB's 42)

Pickering and Barry correctly observe that (2a) is much more difficult to process than (2b). If the parser cannot associate wh-phrases with their subcategorising verbs as soon as these verbs are encountered, the difference between (2a) and (2b) is not predicted under most current theories of recursive construction complexity. However, if a wh-phrase can be linked immediately to its subcategorising verb, then these theories of complexity predict that (2b) is substantially easier than (2a), as desired.[3] Thus Pickering and Barry view the contrast between (2a) and (2b) as corroborating evidence in favour of the conclusion that empty categories are not utilised in sentence processing.

While Pickering and Barry's data are interesting, their conclusion is too strong. In particular, it may be that, contrary to their assumption, a wh-phrase filler (or, more generally, any filler) can be associated with an EC before intervening lexical material has been processed. Thus, given a filler that needs to be associated with a thematic role (for example), it may be that a gap is posited as soon as an appropriate subcategoriser licenses a position for that filler, whether or not the intervening lexical requirements of that subcategoriser are filled (cf. Tanenhaus & Carlson, 1989; Tanenhaus, Boland, Garnsey, & Carlson, 1989). Once such a gap is posited, the intervening lexical material can then be processed and attached between the subcategoriser and the gap, leaving the trace to the right of these constituents. Note that this analysis does not involve heavy-shifting of constituents, because the trace ends up to the right of the intervening lexical material.

Consider this analysis with respect to gap-positing in (1a). Under such an analysis, as soon as the verb *put* is processed, an EC associated with the PP filler *in which box* is posited. However, the required EC in (1b)

[3]See pp. 155–159 for detailed explanations of the differences between (2a) and (2b) under both Pickering and Barry's theory of recursive constructions and another such theory.

cannot be posited until the sentence-final preposition *in* is processed, so the contrast between the two is explained, as desired.[4] A similar analysis holds for Pickering and Barry's other critical data. Since all of the data that Pickering and Barry present can be accounted for by means of a parser that posits gaps as soon as a grammatically appropriate attachment site is made available, ECs may still take part in sentence processing, contrary to their claim.

The remainder of this paper is structured as follows. The next section describes a "first resort" gap-positing algorithm and demonstrates how such an algorithm accounts for the multiple object extraction contrast in (1). Then, we give an overview of the recursive construction data presented by Pickering and Barry as evidence against the use of ECs and show that, in fact, their theory of recursive constructions is empirically inferior to other current theories of syntactic complexity. This section then shows how the remaining relevant recursive construction contrasts noted by Pickering and Barry can be handled under the parsing algorithm proposed here, given a more complete theory of syntactic complexity. Concluding remarks are found in the final section.

"FIRST RESORT" GAP-POSITING

In order to account for Pickering and Barry's data, we propose that gaps can be posited as soon as their positions are licensed by the grammar. This proposal is made explicit in the following "first resort" gap-positing principle (cf. Fodor, 1978):

3. Given a filler γ_i in the structure for the current input string, attach an EC α_i in a position P iff (a) P is fully licensed by applicable modules of the grammar (e.g. $\bar{X}$-theory, θ-theory, Case theory, etc.) and (b) P and the γ_i–α_i complex are compatible with respect to syntactic category.

[4]In fact, under the assumption that ECs are posited as soon as they are licensed (see pp. 151–155), an EC would initially be posited as the direct object of *put* in (1b). This analysis turns out to be incompatible with the rest of the sentence, so it must be revised in order to arrive at a successful parse of (1b). Importantly, this re-analysis does not explain the contrast in (1), because, as Pickering and Barry observe, shortening the NP object reduces the processing difficulty substantially:

iii. Which box did you put the cake in? (PB's 12)

Thus it is the length of the object NP which best predicts the processing difficulty in (1b), not the required re-analysis.

Consider the predictions of this gap-positing algorithm with respect to direct-object gaps. Given a wh-NP, an associated EC will be posited in direct-object position of an (English) transitive verb as soon as that verb is encountered, because the direct-object position is fully licensed by the verb under $\bar{X}$-theory, θ-theory and Case theory. This prediction is supported by a number of recent studies using a variety of experimental paradigms [e.g. Crain & Fodor, 1985; Garnsey, Tanenhaus, & Chapman, 1989; Hickok, Canseco-Gonzales, Zurif, & Grimshaw, 1991 (also reported in Hickok, 1991); Kurtzman, Crawford, & Nychis-Florence, 1992; Nicol & Swinney, 1989; Stowe, 1986; Swinney, 1991; Swinney & Osterhout, 1990; Swinney, Ford, Frauenfelder, & Bresnan, in press; Tanenhaus et al., 1989].[5]

While previous researchers have proposed similar first resort gap-positing algorithms in order to account for direct-object gap effects [see, e.g. Fodor (1978) for an algorithm within a serial parsing framework, and Gibson and Clark (1987) within a parallel framework], such an algorithm has not been applied (at the verb) to indirect PP argument or second object cases, because of the intervening (lexical) direct object. However, under the above gap-positing algorithm, it turns out that an indirect PP argument (second object) gap can be posited as soon as the verb is encountered, because the position for the indirect PP argument gap is grammatically licensed at the verb, just as in the case of the direct-object gap.[6] Thus the novel aspect of the present proposal is that first resort gap-positing can be extended to cases like (1a) where ECs can be projected in positions that are not adjacent to the verb when the structure is complete, and that intervening constituents can still be processed in their normal positions,

[5]Note that because the subject position is an argument position and therefore needs a θ-role, this position is not fully licensed until the θ-assigning verb appears. Thus according to the gap-positing algorithm in (3), subject gaps in English will only be posited after the verb is encountered. This prediction is consistent with an experiment reported in Stowe (1986), which failed to find a filled-gap effect for filled subject gaps.

[6]As noted by Pickering and Barry, none of the work on reactivation (a priming effect produced by the filler in the position of its EC; see, e.g. Swinney *et al.*, in press) examines the possibility that an indirect PP argument filler might be reactivated at the verb rather than at the actual (sequential) position of the EC, because these studies all conflate direct-object position with the actual EC position. If it turned out that an indirect PP argument filler is *not* reactivated at the verb, but rather at the position of the EC, then this would constitute evidence against both Pickering and Barry's and our own analysis, since both predict reactivation at the verb. Some preliminary evidence reported in Nicol (1992), however, suggests that such fillers are reactivated at the verb.

leaving the trace to the right.[7] Hence we are proposing that the parser can build structure *to the left* of a gap that has already been attached.

Such a proposal might at first seem unnatural, because attachments are normally assumed to be permitted only on the right edge of the current parse tree. However, it turns out that there is no principled reason to block attachments to the left of the right-most edge of the tree when the right-most branch dominates only non-lexical material.

The motivation behind blocking (lexical) attachments to positions properly contained in the current parse tree is derived from the input ordering constraint in (4):

4. The structure for an input string must represent the lexical material from that string in the same order in which it appears.

In other words, the linear order of the words in the input string must be preserved in the structure that is built for that input. If the right branch of the structure for the current input (parsing left to right) dominates a lexical item, then attachments of a further lexical item can only be made to the right of this position, so that the order of the two lexical items does not get reversed in the parse of the input. Consider a parser that does not abide by this constraint with respect to the ungrammatical NP in (5):

5. *the with the limp man

Prepositional phrase modifiers must follow their head nouns in English (with the exception of certain idioms). Because a PP precedes its head noun in (5), this NP is ungrammatical. However, a left-to-right parser that allows attachments of lexical material in a position to the left of the right-most lexical item can arrive at a grammatical parse of (5). Following Kimball (1973; 1975) and many others since, we assume that the human parser has both top-down (predictive) and bottom-up components. Hence the parser can arrive at the structure in (6) for the fragment *the with the limp*, where the head of this structure is the hypothesised noun labelled h:

6. $[_{NP}\ [_{Det}\ \text{the}\ ]\ [_{N'}\ [_{N'}\ [_{N}\ h]]\ [_{PP}\ \text{with the limp}]]]$

[7]As Pickering and Barry note, the EC need not be an argument of the verb. This is demonstrated by the lack of difficulty associated with the processing of (iv), similar to the processing of (1a):

iv. When do you think John ate the very large and beautifully decorated wedding cake bought from the expensive bakery? (PB's 17)

Note that the lack of difficulty in processing (iv) is predicted by the gap-positing algorithm in (3), because the verbal adjunct position is licensed by the verb, and therefore its associated EC can be posited immediately at the verb.

At this point, the noun *man* is input. If this noun is allowed to attach in a position to the left of words that have already been parsed, as the head of the NP built thus far, a structure for the input string *the man with the limp* will result:

7. $[_{NP}$ $[_{Det}$ the $]$ $[_{N'}$ $[_{N'}$ $[_{N}$ man $]]$ $[_{PP}$ with the limp$]]]$

Since this is not an allowable structure for the input NP, the parser must not be permitted to make such an attachment.

However, when the right edge of the parse tree dominates no lexical material, there is no reason to block an attachment to nodes to the immediate left of this edge. For such a case, consider the parse of (1a), repeated here:

1a. In which box did you put the very large and beautifully decorated wedding cake bought from the expensive bakery?

Immediately upon encountering the verb, the argument structure of *put* is accessed (Shapiro, Zurif, & Grimshaw, 1987), and, following Kimball (1973; 1975) among others, we thus assume that the human parser hypothesises the appropriate argument structures to the right, as is depicted in (8) (irrelevant details omitted):[8]

8. $[_{S'}$ $[_{PP}$ in which box $]$ did you $[_{VP}$ $[_{V}$ put$]$ $[_{NP}$ $h_1]$ $[_{PP}$ $h_2]]]$

The verb *put* subcategorises for both an NP patient and a PP destination, so hypothesised categories for each – h_1 and h_2 respectively – are predicted to the right of the head verb *put*. Since the argument PP position is fully licensed by the θ-assigning verb, and since the category of the wh-phrase *in which box* matches that PP position, the hypothesised category h_2 can be filled with a trace which is co-indexed with the filler wh-phrase, resulting in (9):

9. $[_{S'}$ $[_{PP}$ in which box $]_i$ did you $[_{VP}$ $[_{V}$ put $]$ $[_{NP}$ $h_1]$ $[_{PP}$ $e_i]]]$

Because the gap e_i is non-lexical, attachments to the hypothesised NP position h_1 can still be made. Thus there is no principled reason to block the attachment of the NP *the very large and beautifully decorated wedding*

[8]In fact, it is an open question whether or not the bare structure(s) corresponding to the arguments of a verb are built before those arguments are phonologically realised (e.g. does the parser build NP and PP nodes when *put* is encountered even before the head of those phrases has appeared in the input?). For present purposes, all that needs to be assumed is that if a wh-phrase can satisfy an argument of a verb, then that argument can be projected. However, for expository purposes, we will assume that structures corresponding to all of the arguments of a verb are projected immediately upon encountering that verb.

cake bought from the expensive bakery to the inner hypothesised NP object site in (9). After this attachment, the final structure for (1a) is given in (10):

10. $[_{S'}$ $[_{PP}$ in which box $]_i$ did you $[_{VP}$ $[_{V}$ put $]$ $[_{NP}$ the very large and beautifully decorated wedding cake bought from the expensive bakery $]$ $[_{PP}$ $e_i]]]$

Given the gap-positing algorithm outlined above, we can now account for the contrast between (1a) and (1b):

1b. Which box did you put the very large and beautifully decorated wedding cake bought from the expensive bakery in?

In (1a), the wh-phrase can be linked to the verb *put* via an empty category as soon as this verb is encountered. On the other hand, in (1b), the wh-phrase must be retained in memory until the sentence-final preposition *in* is processed (i.e. while the complex direct object NP is being processed). Thus the distance measured in the number of words between the wh-phrase and its EC is not the crucial factor in determining the complexity of examples like (1); rather, it is the distance between the wh-phrase and the attachment point of the EC. Hence the difference between (1a) and (1b) is that, in (1a), the EC is attached to the verb phrase, whereas in (1b) the EC is attached to the PP.

RECURSIVE CONSTRUCTIONS

In addition to making claims about the non-existence of gaps, Pickering and Barry also provide a partial theory of syntactic complexity, following up on some ideas presented in Chomsky (1965). This theory of syntactic complexity may be summarised as follows. Sentences which contain multiple nestings of filler-verb (or filler-preposition) dependencies in Chomsky's (1965) sense are more difficult to process than those that do not contain such nestings, other factors being equal. Furthermore, sentences that contain multiple self-embeddings of these dependencies are more difficult to process than those that do not contain such self-embeddings. In support of these generalisations, Pickering and Barry give the following examples from English ("#" indicates unacceptability):[9]

11a. I saw the farmer $[\text{who}]_1$ $[\text{owned}]_1$ the dog $[\text{which}]_2$ $[\text{chased}]_2$ the cat. (PB's 44)

b. # The cat $[\text{which}]_1$ the dog $[\text{which}]_2$ the farmer $[\text{owned}]_2$ $[\text{chased}]_1$ fled. (PB's 45)

[9]Following Chomsky (1965), we assume that sentences can be grammatical yet unacceptable (unparsable) for reasons independent of the grammar, e.g. memory limitations.

c. John found the saucer [on which]$_1$ Mary [put]$_1$ the cup [into which]$_2$ I [poured]$_2$ the tea. (PB's 42)
d. # John found the saucer [which]$_1$ Mary put the cup [which]$_2$ I poured the tea [into]$_2$ [on]$_1$. (PB's 61)
e. [Which pot]$_1$ is [this rice]$_2$ easy to [cook]$_2$ [in]$_1$? (PB's 70)
f. [Which pot]$_1$ is [this rice]$_2$ from the town [which]$_3$ our friend used to [visit]$_3$ easy to [cook]$_2$ [in]$_1$? (PB's 71)
g. # [Which pot]$_1$ is [this rice]$_2$ from the town [which]$_3$ our friend [who]$_4$ is hard for people to [like]$_4$ used to [visit]$_3$ easy to [cook]$_2$ [in]$_1$? (PB's 72)

In sentence (11a), the filler-verb dependencies are not nested, so that this sentence is easy to process. In sentence (11b), on the other hand, the filler-verb dependencies are nested one inside the other. Furthermore, the nesting in (11b) is self-embedding, so that this sentence is hard to process. A similar contrast holds between (11c) and (11d): In sentence (11c), the dependencies are not nested under Pickering and Barry's gap-free syntactic model, while in (11d) the dependencies are nested and self-embedded.

While sentence (11e) contains a nesting of a filler-verb inside a filler-preposition dependency, this nesting is not self-embedded, so that (11e) is not difficult to process. Sentence (11f) contains an additional level of nested dependencies and is thus more difficult to process than (11e). However, because there are no self-embeddings in (11f), this sentence is still processable. The extreme difficulty that people have with (11g) is explained under Pickering and Barry's assumptions by the fact that this sentence contains a self-embedding in addition to multiple nestings.

Pickering and Barry observe that under a framework which includes ECs, sentence (11c) contains two nested filler-verb dependencies. The structure for (11c) containing ECs is given in (12):

12. John found the saucer [on which]$_i$ Mary put the cup [into which]$_j$ I poured the tea e_j e_i.

As a result of this self-embedded nesting, (12) should be difficult to process, much as (11b) is. Because a processing theory that allows fillers to be directly associated with their subcategorisers results in no self-embedded nesting for (12) [see (11c) above], Pickering and Barry conclude that a parsing framework that does not make use of empty categories makes better predictions with respect to the processing of sentences like (11c).

In summary, Pickering and Barry, following Chomsky (1965), have noted a tendency for sentences with multiple (self-embedded) nestings to be more difficult to process than sentences without such nestings. In addition, they suggest that (11c) represents a counter-example to this

tendency, if one assumes the existence of ECs. We will argue, however, that an EC model can account for all the data in (11) under the gap-positing algorithm proposed earlier (see p. 151). But first, it is worthwhile to point out that, apart from the issue concerning the existence of ECs, Pickering and Barry's complexity theory is not empirically adequate. For example, while sentence (11b) is unacceptable to English speakers, (13) is acceptable to most speakers (Eady & Fodor, 1981; Gibson, 1991):

13. I saw the cat [which]$_1$ the dog [which]$_2$ the farmer [owned]$_2$ [chased]$_1$.

Although (13) contains exactly the same nested filler-verb dependencies as (11b), (13) is acceptable to most speakers, while (11b) is clearly unacceptable. As Pickering and Barry's account of relative difficulty relies exclusively on the nesting of filler-verb dependencies, the relative ease associated with the processing of (13) is unexplained in their framework.[10]

Pickering and Barry's analysis of syntactic complexity also fails to explain English sentential subject phenomena:

14a. That John smokes is annoying.
b. # That for John to smoke would be annoying is obvious.
c. I believe that for John to smoke would be annoying.

While sentences like (14a), which contain a single sentential subject, are perfectly acceptable, nesting a sentential subject inside another sentential subject results in unacceptability, as is demonstrated by (14b) (Kimball, 1973). Furthermore, this unacceptability disappears if the sentential subject is the subject of an embedded clause, as is demonstrated by (14c) (Gibson, 1990; 1991). There are no filler-verb dependencies in these examples, so that Pickering and Barry's observations do not apply. However, a theory of complexity should explain these effects [see also Kimball (1975) and Gibson (1990; 1991) for examples of grammatical yet unacceptable sentences from Japanese (an SOV language) that do not involve filler-verb dependencies].

Moreover, a theory of complexity like Pickering and Barry's that is concerned only with the number of structural nestings that are present in a given sentence predicts that the relative ordering of the nested constructions should be irrelevant to the acceptability of the sentence. That is, whether or not one type of dependency appears inside or outside another should not affect the acceptability of a sentence in which the dependencies appear. However, consider the sentences in (15):

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[10]See Gibson (1991) for a theory of syntactic complexity that makes the correct predictions for all of Pickering and Barry's sentences as well as the additional effects noted here.

15a. The possibility that the man who I hired is incompetent worries me.
b. # The woman who the possibility that the man is incompetent worries hired him.
c. That the food that the man served tasted good pleased him.
d. # The man that for the food to taste good would please was the host of the party.

Sentence (15a) demonstrates that it is acceptable to nest a relative clause inside the sentential complement of an NP. However, (15b) shows that the reverse is not true: Nesting a sentential complement inside a relative clause results in unacceptability (Cowper, 1976; Gibson, 1991). Examples (15c) and (15d) demonstrate that a similar effect applies to the relative clause and sentential subject constructions (Gibson, 1991). Such patterns render unworkable any approach which relies only on counting the number of nestings of each type of construction, as does that of Pickering and Barry.

Despite the drawbacks of their complexity theory, Pickering and Barry have correctly observed that the difference between (11b) and (11c) (repeated below) is unexplained under a parsing theory which (i) requires the existence of ECs and (ii) requires that these ECs be posited only after all intervening obligatory arguments have been completed.

11b. The cat $[\text{which}]_1$ the dog $[\text{which}]_2$ the farmer $[\text{owned}]_2$ $[\text{chased}]_1$ fled.
c. John found the saucer $[\text{on which}]_1$ Mary $[\text{put}]_1$ the cup $[\text{into which}]_2$ I $[\text{poured}]_2$ the tea.

Under the complexity theory given in Gibson (1990; 1991), it is assumed that there is a memory cost associated with locally unsatisfied thematic requirements of a structure. In particular, arguments which require thematic roles but have not yet received such roles (parsing left to right) are associated with memory cost, as are locally unassigned lexical requirements. Under this theory, the maximal memory cost associated with the processing of (11b) occurs after the NP *the farmer* has been processed. At this point, there are five local thematic violations, since all of the NPs *the cat, which*$_1$, *the dog, which*$_2$ and *the farmer* require thematic roles but have not yet received such roles.

Under a version of the Gibson (1991) theory, which both includes ECs and requires that they are posited only after all intervening obligatory arguments have been completed, the maximal processing complexity of sentence (11c) is the same as that for (11b), thus incorrectly predicting the two sentences to be similar in processing difficulty. In particular, at the point of processing the verb *poured*, there are two PPs which require thematic roles but do not locally receive them – the wh-phrases *on which* and *into which*. Furthermore, there are three unsatisfied lexical requirements at this point: The verb *put* requires a PP destination argument, while the verb *poured* requires both an NP patient and a PP destination argument. Thus there are five local thematic violations, and (11c) is predicted to be of the same processing complexity as (11b). But, contrary to this prediction, (11c) is much easier to process than (11b).

However, in a parsing theory that allows gaps to be posited immediately when the thematic role assigner is encountered, a difference between (11b) and (11c) appears. Consider such a theory with respect to the structure that results after the word *put* has been processed and an EC has been projected in (11c):

16. $[_S\ [_{NP}$ John $]\ [_{VP}$ found $[_{NP}$ the saucer $[_{S'}[_{PP}$ on which $]_i\ [_S$ Mary $[_{VP}$ put $[_{NP}\ h\ ]\ [_{PP}\ e_i]\ ]]]]]]$

In this structure, the PP *on which* receives a thematic role from the verb *put* via the EC, so that the only remaining thematic violation is that associated with the necessary NP argument of the verb *put*. At this point, the NP *the cup* is input and attached in the argument NP position, to the left of the gap e_i, reducing the processing cost further still.

Next, the input string *into which I poured* is attached as a modifier of the NP *the cup*:

17. $[_S$ John found the saucer $[_{S'}\ [_{PP}$ on which$]_i$ Mary put the cup $[_{S'}\ [_{PP}$ into which $]_j\ [_S$ I $[_{VP}$ poured $[_{NP}\ h\ ]\ [_{PP}\ e_j\ ]]]]\ [_{PP}\ e_i]]]$

As with the previous wh-PP, the PP *into which* receives a thematic role from its co-indexation with the gap e_j, so that no cost is associated with this argument nor the corresponding lexical requirement of *poured*. The only cost associated with this structure derives from the as yet unsatisfied NP lexical requirement of the verb *poured*. At this point, the NP *the tea* is attached into the hypothesised NP position to the right of both ECs, and the parse of the sentence is complete.

Thus the processing cost associated with (11c) never reaches more than two local thematic violations under the proposed gap-positing algorithm. The processing of (11b), however, is unaffected by how ECs are posited, and therefore (11c) is predicted to be significantly easier to process than (11b) under a parsing theory that allows traces to be posited as soon as their thematic role assigner can be identified. Of course, if fillers are linked directly with their thematic role assigners as Pickering and Barry suggest, then the processing complexities of (11b) and (11c) also differ in the desired way under Gibson's (1991) complexity theory. But crucially, this difference does not depend on the non-existence of gaps.

CONCLUSIONS

Pickering and Barry have presented an interesting set of data which they use to argue against the "psychological reality" of ECs. However, their conclusions from these data are too strong. This paper has suggested an alternative account within a framework that includes empty categories. On the proposal outlined here, the ECs associated with wh-phrases (and other types of moved constituents) can be projected as soon as a grammatically permissible attachment site is licensed – that is, the parser need not wait until the actual sequential position of the EC in the input string.

Finally, it should be clear at this point that the two analyses – that of Pickering and Barry and our own – are empirically indistinguishable with respect to the type of data under consideration here: Wherever Pickering and Barry assume a wh-phrase attaches directly to a particular constituent, we make the corresponding assumption that an EC can be projected at the constituent in question. Thus, it seems that the debate over the existence of ECs will not be resolved in light of this sort of psycholinguistic data. We are not discouraged by the situation, however, because Pickering and Barry's empirical observations have led both camps to a better understanding of human sentence processing – a desirable consequence regardless of the outcome of the representational debate.

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