Journal of Memory and Language 97 (2017) 175–186

Contents lists available at ScienceDirect

Journal of Memory and Language

journal homepage: www.elsevier.com/locate/jml

Processing multiple gap dependencies: Forewarned is forearmed

Dan Parker *

Linguistics Program, Department of English, College of William & Mary, United States

ARTICLE INFO

Article history:
Received 7 February 2017
Revision received 16 August 2017
Available online 29 August 2017

ABSTRACT

Many studies have shown that when forming a filler-gap dependency, comprehenders attempt to posit a gap site in advance of the input. However, it remains an open question what information they use to determine gap locations. The current study investigates parallelism in coordinate extraction structures, and asks whether comprehenders use parallelism constraints to structure their expectations about upcoming gap sites. Using a filled-gap paradigm, Experiments 1 and 2 show that comprehenders rely on parallelism to restrict the search for upcoming gap sites to specific locations in sentences with coordinate extraction. Experiment 3 shows that this effect cannot be reduced to processing factors, but may be due to a grammatically-based constraint on parallel extraction. Together, these results shed new light on the source and scope of active processing and parallelism effects in comprehension.

Introduction

The ability to project syntactic structure in advance of bottom-up input reflects a tradeoff between efficiency and accuracy: building structure in advance of the input can relieve processing mechanisms later, but only if that structure is accurate. This tradeoff is evident in the processing of filler-gap dependencies. For instance, in sentences like (1), the noun phrase (NP) *which book* (the 'filler') has been displaced from its post-verbal direct object position (the 'gap' indicated by an underscore). In (1), the parser must relate the filler and the gap for thematic interpretation.[1]

(1) **Which book** did the students like the teacher to read ____ in class?

It is well known that comprehenders attempt to complete filler-gap dependencies as rapidly as possible, in advance of bottom-up information that signals the presence of a gap site. This phenomenon is known as 'active gap-filling' (Crain & Fodor, 1985; Fodor, 1978; Frazier & Flores d'Arcais, 1989; Stowe, 1986). In (1), comprehenders' eagerness to resolve the filler-gap dependency as soon as possible leads the parser to posit a gap in the direct object position of the first verb *like*, before direct evidence of a gap site. If the parser's prediction were correct, structure building mechanisms would be temporarily relieved after the verb *like*. However, since the direct object position is filled with the NP *the teacher*, the parser is forced to revise its prediction and posit a gap in a later position.

Over the past several decades, a number of proposals have sought to characterize the mental mechanisms that support active dependency formation in sentence comprehension. However, despite significant advances in our understanding of active processing, several fundamental questions remain. In particular, it is unclear what information about the filler is carried forward to guide active dependency formation, how general processing principles impact this process, and how much structure the parser is willing to project in advance of the input. This paper addresses these questions by investigating active processing in multiple-dependency constructions. Multiple-dependency constructions provide a unique opportunity to track active processing decisions at multiple points throughout a single sentence, maximizing the window into active processing mechanisms.

Active dependency formation in sentence comprehension

Evidence for active dependency formation in sentence comprehension comes from a variety of measures, including reading times (Crain & Fodor, 1985; Frazier & Clifton, 1989; Omaki et al., 2015; Phillips, 2006; Pickering & Traxler, 2001, 2003; Staub, 2007; Traxler & Pickering, 1996; Wagers & Phillips, 2009, 2014), visual world eye-tracking (Sussman & Sedivy, 2003), cross-modal priming (Nicol & Swinney, 1989), speeded acceptability judgments (Frazier & Flores d'Arcais, 1989), and event-related potentials (Garnsey, Tanenhaus, & Chapman, 1989). Active dependency formation is also attested in many languages, including English

* Address: Department of English, College of William & Mary, P.O. Box 8975, Williamsburg, VA 23187, United States.
E-mail address: dparker@wm.edu

[1] The terms 'gap', 'gap position', and 'gap location' are used theory neutrally in this paper. My argument does not hinge on whether the tail of the filler-gap dependency is or is not treated as an empty category or trace.

http://dx.doi.org/10.1016/j.jml.2017.08.003
0749-596X/

(see aforementioned studies), Dutch (Frazier, 1987), German (Felser, Clahsen, & Münte, 2003), Italian (de Vincenzi, 1991), and Japanese (Aoshima, Phillips, & Weinberg, 2004).

In an early study on active dependency formation, Stowe (1986) compared sentences with a displaced *wh*-phrase, like (2a), with maximally similar sentences that lacked a displaced *wh*-phrase, like (2b). Stowe observed a processing disruption in word-by-word reading times at the direct object *us* in (2a), relative to the same word in (2b). This effect has been termed the 'filled gap effect', and has been widely interpreted as an unambiguous index of active dependency formation. In (2a), the parser posits a gap in the direct object position of the verb *bring*, before it encounters overt evidence of a gap in that position, and processing is disrupted when it discovers that the direct object position is occupied.

(2) a. My brother wanted to know **who** Ruth will bring us home to __ at Christmas.
b. My brother wanted to know if Ruth will bring us home to Mom at Christmas.

Additional evidence for active gap-filling comes from processing disruptions at the verb when the filler is a semantically implausible argument of the verb. For instance, Traxler and Pickering (1996) tested sentences like (3) using eye-tracking while reading, and found increased reading times at the verb for implausible filler-verb combinations, e.g., *garage* ... *shot*, relative to plausible filler-verb combinations, e.g., *pistol* ... *shot*. Garnsey et al. (1989) tested similar sentences using event related potentials, and observed a greater N400 amplitude at the verb for implausible filler-verb combinations, relative to plausible filler-verb combinations. Like the filled-gap effect, this semantic anomaly effect suggests that filler-gap processing is 'active', since the processing disruption precedes any evidence of a gap site.

(3) That's the **pistol / garage** with which the heartless killer shot the hapless man __ yesterday.

Active dependency formation can be viewed as a response to two constraints. First, filler-gap dependencies are unbounded, i.e., the distance between the filler and gap can span a potentially large amount of material. In response, the parser must maintain a representation of the filler in memory until it can be integrated later. Second, the tail of a filler-gap dependency is often signaled only by the absence of a verb's sub-categorized constituent, i.e., a break in the phrase structure. Since the filler must be stored in memory until integration, and since there is a stringent limit on the amount of information that can concurrently occupy working memory (Cowan, 2001; McElree, 2006; McElree & Dosher, 1989), the parser is motivated to close open filler-gap dependencies as soon as possible to reduce the burden on working memory (e.g., Gibson, 1998).

More recently, research on active dependency formation has focused on how grammatical licensing requirements impact active processing. For instance, Yoshida, Dickey, and Sturt (2013) investigated active structure building using constructions that temporarily allow a sluicing interpretation. Sluicing involves a *wh*-phrase and the omission of a full clause. Yoshida and colleagues tested sentences like (4), in which the fronted *wh*-NP is initially compatible with a sluicing parse, e.g., (4a), but the fronted *wh*-PP is not, e.g., (4b). Yoshida and colleagues reasoned that if the parser actively posits a sluicing parse where grammatically possible, and if the parser also attempts to resolve anaphoric relations in real time, then there should be a gender-compatibility effect at the reflexive in (4a), due to the match between the reflexive and the subject of the sluiced clause *grandmother*, but not in (4b). Results from self-paced reading confirmed this prediction, which Yoshida and colleagues interpreted as evidence that comprehenders actively projected a sluicing structure, but only when it was grammatically permissible, and that the projected structure was sufficiently detailed to license the reflexive.

(4) a. Jane's **grandfather/grandmother** told some stories at the family reunion, but we couldn't remember which story about **himself** from the party his brother was so very impressed with.
b. Jane's **grandfather/grandmother** told some stories at the family reunion, but we couldn't remember with which story about **himself** from the party his brother was very impressed.

Phillips (2006) and Wagers and Phillips (2009) also argued that active dependency formation is motivated by grammatical constraints. Phillips (2006) tested parasitic gap constructions, which involve a filler that is linked to two gaps. An important property of parasitic gap constructions is that one gap, typically located inside a syntactic island (i.e., the parasitic gap) must be licensed by a gap in the main clause (i.e., the licensing gap) under specific structural conditions. In the sentences that Phillips (2006) tested, the parasitic gap ($\_\__{pg}$) was located in a complex subject NP, and the licensing gap ($\_\__{lg}$) was located in the main clause verb phrase (VP) following the subject NP, as in (5a). The contrast between (5a) and (5b) shows that the parasitic gap is licensed only when the subject NP involves an infinitival clause.

(5) a. The school superintendent learned **which schools/students** [$_{\text{Subject NP}}$ the proposal to expand $\_\__{pg}$ upon the current curriculum] would overburden $\_\__{lg}$ during the following semester.
b. *The school superintendent learned **which schools/students** [$_{\text{Subject NP}}$ the proposal that expanded $\_\__{pg}$ upon the current curriculum] would overburden $\_\__{lg}$ during the following semester.

Parasitic gaps present a challenge for incremental processing. Upon encountering a potential parasitic gap, the parser cannot know in advance whether there will be a licensing gap in the main clause. Using a plausibility manipulation as a probe of active processing, Phillips (2006) observed slower reading times at the infinitival verb, e.g., *expand* in (5a), in the implausible condition, e.g., *which students*, relative to the plausible condition, e.g., *which schools*. No such contrast was found in the corresponding finite clause conditions. This contrast suggests that the parser posits a parasitic gap only when it is licensed in a subject NP that involves an infinitival clause. Phillips argued that for this to be achieved, the parser must predict the upcoming main clause structure to decide that a parasitic gap is grammatically licensed.

Wagers and Phillips (2009) tested the hypothesis that active processing is driven by the need to satisfy grammatical constraints as rapidly as possible during real-time comprehension using sentences with across-the-board (ATB) extraction. ATB extraction involves a single filler that participates in multiple dependencies, as shown in (6). ATB extraction in coordinate phrase constructions like (6) is subject to a structural licensing requirement known as the Coordinate Structure Constraint (CSC; Ross, 1967), which requires that each coordinate contain a gap, as illustrated in (7).

(6) The **wines/cheeses** which the gourmets were energetically discussing __ or slowly sipping __ during the banquet were rare imports from Italy.
(7) a. *The wines which the gourmets were discussing __ or sipping the beer were imported.
b. *The wines which the gourmets were discussing the beer or sipping __ were imported.