The use of control information in dependency formation: An eye-tracking study

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ABSTRACT

Recent research has shown much evidence that sentence comprehension can be extremely predictive. However, we currently know little about the limits of predictive processing. In the two eye-tracking experiments, we examined whether predictive information in dependency formation is inevitably given priority over a well-known structural preference in syntactic ambiguity resolution. Experiment 1 used sentences including control nouns like *order* (e.g. *After Andrew's order to wash the kids came over to the house*). If predictive dependency information is given priority over disambiguation preferences, then readers could immediately interpret *the kids* as the ones who have been ordered to wash, thus avoiding the garden path at the main verb *came*. However, garden path effects were found irrespective of control information, although the garden path difficulty was reduced when the lexical control information highlighted the globally correct analysis (as in the above example), relative to when it did not. Experiment 2 replicated these results with *adjunct control*, where the relevant dependency is obligatory (e.g. *After refusing to wash the kids came over to the house*). Again, control information did not influence initial disambiguation, but did affect the difficulty of garden path recovery. Overall, the results suggest that there are limitations on the influence of predictive dependency formation on on-line structural disambiguation.

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Introduction

Recent research has shown much evidence that sentence comprehension can be extremely predictive; incoming words and phrases are matched against expectations based on top-down information, rather than always being recognized in a purely bottom-up manner (see Altmann & Kamide, 1999; Federmeier, 2007; Federmeier & Kutas, 1999; Kamide, Altmann, & Haywood, 2003; Kamide, Scheepers, & Altman, 2003; Lau, Stroud, Plesch, & Phillips, 2006; McRae, Hare, Elman, & Ferretti, 2005; Phillips, 2006; Staub & Clifton, 2006; van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005; Wagers & Phillips, 2009; Wlotko & Federmeier, 2007 among others). However, despite the wealth of evidence that predictive processing takes place, we currently know little about its limits. Are predictions always used in situations where the relevant information is available, and how much priority is given to predictive information in the comprehension process? The present paper examines the limits of predictive processing in relation to syntactic dependency formation. In the two eye-tracking experiments reported below, we examine whether predictive information is inevitably given priority over well-known structural preferences in syntactic ambiguity resolution.

The idea of predictive (or *active*) dependency formation can be illustrated in relation to sentence in (1), which requires a dependency relation between the reflexive pronoun *himself* and its antecedent *the king*.

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(1) After reminding **himself** about the letter, **the king** immediately went to the meeting at the office.

The claim that a dependency is formed *predictively* implies that, once the left-hand element of the dependency (e.g. *himself* in (1)) has been encountered in the input, the parser predicts features of the right-hand element, and then actively attempts to match these features with subsequent input, with the dependency being formed when the match occurs. For example, in (1), the parser might predict a subject noun phrase with a masculine feature, based on the masculine reflexive *himself*, and this matches with the features of *the king* when it appears in the input. In fact, as we discuss below, there is considerable evidence that predictive mechanisms are used in the processing of a number of types of dependency.

One way in which active dependency formation may affect sentence processing is to pre-activate features of a predicted phrase (for example, its gender or number) before that phrase is reached in the input. For example, the pre-activation of features has been argued to apply to the processing of backwards anaphora, where a pronoun precedes its antecedent, as in (2) below:

(2) van Gompel and Liversedge (2003), Experiment 1
a. When **he** was fed up, **the boy** (gender matched) visited the girl very often.
b. When **he** was fed up, **the girl** (gender mismatched) visited the boy very often.

A number of researchers have found evidence for a *mismatch cost* in the processing of backwards anaphora: processing difficulty is found when the features of the first available antecedent (e.g. *the girl*) are not compatible with those of the preceding pronoun (e.g. *he*), as in (2)-(b), relative to when the features match, as in (2)-(a) (see Kazanina, Lau, Lieberman, Yoshida, & Phillips, 2007; van Gompel & Liversedge, 2003). Kazanina et al. (2007) argued that this effect is due to the processor predicting the features of the antecedent in advance.

Converging evidence for active dependency formation comes from a study reported by Kreiner, Sturt, and Garrod (2008). Their experiments involved gender role nouns that were either definitional (e.g. *king*; being male is part of the word's definition), or stereotypical (e.g. *minister*; the role is typically filled by a male, but this is not by definition), and preceding gender-matched (e.g. *himself*) and mismatched (e.g. *herself*) reflexives. In their Experiment 2, they examined backwards anaphor dependencies, as in (3):

(3) Kreiner et al. (2008), Experiment 2
After reminding **himself/herself** about the letter, **the minister/king** immediately went to the meeting at the office.

The results showed a gender mismatch cost for definitional gender nouns at the critical word (e.g. *king*), but there was no such gender mismatch cost for stereotypical nouns (e.g. *minister*). This pattern is consistent with the idea that the gender feature of the matrix subject is predicted actively in advance, based on the information in the preceding subordinate clause (i.e. the gender of *minis-*

ter, whether male or female, is specified by the form of the reflexive; *himself* or *herself*). Kreiner et al. argued that this prediction allowed the strereotypical noun *minister* to be immediately integrated without the need to infer the stereotypical gender information, leading to the lack of a mismatch effect for this condition.

A second, and stronger, influence that active dependency formation may have on sentence processing is that it may change the priorities in syntactic ambiguity resolution. This idea has been explored particularly in studies of filler-gap processing with wh-dependencies. For example, in filler-gap sentences, such as (4)-(a) below, much evidence suggests that when a displaced element, such as *who* in (4)-(a) is detected, the parser prioritizes the postulation of the corresponding gap (___) above other structure-building options, without waiting for specific bottom-up information to confirm this prediction. In doing so, the parser predicts the appropriate grammatical position for the gap. This prioritization of gap-filling is known as the *Active filler strategy* (Boland, Tanenhaus, Garnsey, & Carlson, 1995; Frazier & Clifton, 1989; Garnsey, Tanenhaus, & Chapman, 1989; Pickering & Traxler, 2003; Traxler & Pickering, 1996). Thus, when there is an overt pronoun, such as *us*, in the presumed gap position (i.e. object of *bring*), processing difficulty occurs, as manifested by slower reading times at *us* in (4)-(a) than in (4)-(b) (*Filled-gap effects*: Crain & Fodor, 1985; Stowe, 1986).

(4) Filled-gap experiment sentences (Stowe, 1986)
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.

This Active filler strategy has been argued to interact with structural ambiguity resolution, and can override otherwise strong structural preferences. For example, in (5), both interpretations (5)-(b) and (5)-(c) are logically possible depending on the attachment of *Mary*. According to *Late closure*, and other recency-based heuristics, *Mary* should be attached as the direct object of *tell* as in (5)-(c), and this results in the interpretation of the sentence as a question about which person left the country (according to what Fred told Mary). On the other hand, according to the Active filler strategy, *Mary* has to be attached as the subject of the complement clause as in (5)-(b), as the direct object position of *tell* has already been predicted as the gap position, and is therefore not available for *Mary*. The sentence would then be interpreted as a question about which person Fred told about Mary's leaving the country.

(5) Structurally ambiguous sentence with anaphoric dependency (Frazier & Clifton, 1989)
a. Who did Fred tell Mary left the country?
b. Who$_i$ did Fred tell ___$_i$ Mary left the country?
c. Who$_i$ did Fred tell Mary ___$_i$ left the country?

Frazier and Clifton (1989) argue, on the basis of intuition, that the reading of (5)-(b) is strongly preferred. If Frazier and Clifton's intuitions are correct, this suggests that the Active filler strategy takes priority over Late closure.