# Filling the silence: Reactivation, not reconstruction

Dario Paape

August 26, 2015

**Submitted to Frontiers in Psychology**

**Abstract**

In a self-paced reading experiment, we investigated the processing of sluicing constructions ('sluices') whose antecedent contained a known garden-path structure in German. Results showed decreased processing times for sluices with garden-path antecedents as well as a disadvantage for antecedents with non-canonical word order downstream from the ellipsis site. A post-hoc analysis showed the garden-path advantage also to be present in the region right before the ellipsis site. While no existing account of ellipsis processing explicitly predicted the results, we argue that they are best captured by combining a local antecedent mismatch effect with memory trace reactivation through reanalysis.

**Keywords:** ellipsis processing, garden-path effect, German, retrieval, reconstruction, self-paced reading

## 1 Introduction

Besides verb-phrase ellipsis, sluicing (Ross, 1969) is probably the most-studied ellipsis variety in both theoretical linguistics (e.g. Chung et al., 1995; Merchant, 2001; Potsdam, 2007) and psycholinguistics (e.g. Poirier et al., 2010; Dickey & Bunger, 2011; Yoshida et al., 2013). In sluicing, an entire clause is left out and a wh-element remains behind, as in (1).

(1) John saw Mary, but I don't remember when ___.
___ = John saw Mary

Sluicing is anaphoric: to interpret (1), the semantics of the antecedent (*John saw Mary*) must somehow be inserted into the gap behind the word *when* to derive the meaning *I don't remember when John saw Mary*. We write 'meaning' because deriving an interpretation is the fundamental goal of sentence processing, not because it is necessarily clear that the relevant representation of the antecedent is semantic in nature. There is an ongoing debate as to whether syntactic structure is also present at ellipsis sites (cf. Cai et al., 2013, and references therein), or whether one should adopt a more discourse-centered approach to the gap-filling

process (e.g. Hardt (1993); Kehler, 2000). Since the evidence to date, at least in our view, does not unequivocally favor any of these views, we will not take a stance with regard to the representation question. We will, however, use syntactic terminology throughout the article for ease of reference.

Even with the question of *what* is inserted into the gap set aside, another point of debate has been *how* it ends up there. Ross (1967) was perhaps the first to explicitly propose a deletion approach to ellipsis (in this case, verb-phrase ellipsis): the missing bit of structure is assumed to be underlyingly present, but its phonological representation is erased under identity with the antecedent.[1] From a processing perspective, this means that a reader of (1) would have to first infer that deletion has applied, then identify the antecedent and finally reconstruct it at the gap. Things would proceed very similarly under a different approach, taken by Williams (1977), which assumes that ellipsis involves a copying mechanism. This view also assumes invisible syntax at the gap, but the terminal symbols of this structure are null elements (Wasow, 1972). The ellipsis is interpreted by copying the terminals (that is, words) from the antecedent to the appropriate positions within the gap.

A different picture emerges if one takes an approach such as that of Hardt (1993), which is explicitly non-syntactic in nature and treats ellipsis as an unstructured proform that refers to a stored meaning in a discourse model. The notion of copying does not enter into the picture; ellipsis acts rather like a pointer or a hyperlink into memory than as an entity of its own. This conception can be related to the processing of other types of anaphors: It is not commonly assumed that in a sentence such as *The man from England drank tea, but he didn't drink coffee*, the pronoun *he* will contain the syntactic structure of the NP *the man from England* at any level of representation. Instead, an identity of *reference* between the two expressions seems to obtain (cf. Grinder & Postal, 1971, p. 269).

Note that the opposition between copying and the 'memory pointer' approach is orthogonal to that between syntactic and semantic/discourse representations (cf. Phillips & Parker, 2014). Semantic representations could also be copied, just as syntactic representations could be pointed to. The processing literature has focused mainly on the copying/pointing dichotomy, even though some studies have also tested whether there is syntactic priming from ellipsis sites, with mixed results (Cai et al., 2013; Xiang et al., 2014). Murphy (1985) appears to have been the first to systematically look for effects of antecedent length on reading times for elliptical clauses, in this case the sentence *Later, his uncle did too* in (2).

(2) a. Jimmy swept the floor. Later, his uncle did too.

b. Jimmy swept the tile floor behind the chairs free of hair and cigarettes. Later, his uncle did too.

Despite being concerned with verb-phrase ellipsis, we assume that this study is informative with regard to sluicing as well, since the most parsimonious hypothesis would be that all types of ellipsis are processed in the same way. The reasoning behind Murphy's manipulation was that "[l]onger antecedents would

[1] There is no condition of strict identity, however, as several kinds of mismatch can be observed, as in *The car was supposed to be washed but nobody did ~~wash the car~~* (e.g. Merchant, to appear, 2013; Kertz, 2000).

be expected to affect a copying process, since the longer the string that must be copied onto the anaphor, the longer it should take to understand the anaphor" (p. 293). If there was no copying, so the argument goes, then reading times for the second sentence should not differ between (2a,b). Murphy found that reading times for the elliptical sentence were increased by about 260 ms when the antecedent was long rather than short. Interestingly, this difference disappeared when another sentence was inserted between antecedent and ellipsis.[2]

The system Murphy proposes is one in which there are two processes, namely copying and discourse-based 'plausible reasoning', which operate in parallel, with the process that finishes first supplying the antecedent. When the antecedent is far away, the speed and/or availability of copying suffers and readers fall back on plausible reasoning, which by assumption is not influenced by complexity effects. Tanenhaus & Carlson (1990, p. 261) remain unconvinced by Murphy's (1985) evidence for copying, arguing that the length manipulation "also introduced potential scope and attachment ambiguities".[3] The authors favor a pointer-based approach, while allowing for the possibility that there are both a syntax- and a discourse-based process at work.

Two additional important findings come from an experiment by Frazier & Clifton (2000) and a series of experiments by Martin & McElree (2008), all on verb-phrase ellipsis.

(3) Frazier & Clifton (2000), Experiment 1 B

a. Sarah left her boyfriend last May. Tina did too.

b. Sarah got up the courage to leave her boyfriend last May. Tina did too.

(4) Martin & McElree (2008), Experiment 3

a. The history professor understood Roman mythology, ...

b. The history professor understood Rome's swift and brutal destruction of Carthage, ...

... but the principal was displeased to learn that the over-worked students attending summer session did not.

Frazier & Clifton's study used self-paced reading and found no difference in reading times between (3a,b) for the sentence *Tina did too.* Martin & McElree's Experiment 3, which used sentences such as (4a,b), employed a speed-accuracy trade-off paradigm with end-of-sentence acceptability judgments. No effect of antecedent complexity on processing times was observed in this study and two further experiments, which the authors interpret as evidence for a pointer-based approach.

Here is where terminology becomes an issue, as Frazier & Clifton (2001) explain their earlier results by means of a mechanism called Copy $\alpha$. Copy $\alpha$ becomes available when the scope of an ellipsis can be uniquely identified and

[2] Murphy was concerned that the observed complexity effect was simply due to processing spillover from the antecedent sentence into the ellipsis sentence, but the intervening sentence did not show any effects either.

[3] It is not obvious which ambiguities the authors are referring to, or how they would impact processing under an approach without copying. It should be pointed out, however, that interpreting the ellipsis with the long antecedent in (2) requires an additional assumption, namely that the floor became dirty again between the first and the second sweeping.

serves as a shortcut to syntactic structure: instead of being built step-by-step, which would be computationally costly, the silent syntax is copied from the antecedent. As this process is assumed to be 'cost-free', the complexity of the copied structure has no influence on processing time. Frazier & Clifton's use of the copying metaphor is not very intuitive (cf. Martin & McElree, 2008, p. 882f.), as a person using a copy machine would have to invest more time as well as more paper and ink to copy a larger amount of information, in accordance with Murphy's (1985) prediction. Indeed, Frazier & Clifton (2001, p. 17) themselves explain that a pointer would be a possible implementation of Copy $\alpha$ and in a later paper (Frazier & Clifton, 2005) describe Copy $\alpha$ as equivalent to 'sharing' one structure between antecedent and ellipsis (cf. also Murguia, 2004). We will thus treat pointer-based approaches, Copy $\alpha$ and 'sharing' as variants of one and the same idea, namely that the antecedent's structure is available in memory and can be retrieved from there as-is, without any additional costly computations.

Phillips & Parker (2014, p. 91) make note of several methodological problems in both of the above studies. Frazier & Clifton's (2000) experiment used only a small number of experimental items, all of which had the ellipsis at the very end of a sentence, where wrap-up effects might mask an influence of antecedent complexity. Additionally, comprehension questions were not asked after every trial and never targeted the interpretation of the ellipsis. The ungrammatical sentences in Martin & McElree's (2008) study replaced the subject of the elliptical clause by an inanimate NP (*the overly worn books*), thus making the judgments fairly easy and possibly leading subjects to engage in superficial processing. Given these concerns, Phillips & Parker judge the results to be inconclusive, but also point out that it would be difficult to design an experiment that would provide convincing evidence for or against complexity effects.

Given this state of affairs, we think it worthwhile to look back at Frazier & Clifton's (2001) distinction between a syntactic structure that is computed step-by-step and one that is retrieved from memory. What happens when the antecedent is structured in a way that is known to fool the 'normal' incremental parsing mechanism, that is, if it contains a garden path? Assuming a serial parsing architecture, recovering from a syntactic misanalysis involves reanalyzing the ambiguous region and assigning the same structure that would be computed for an unambiguous control sentence. Since the final memory representations for ambiguous and unambiguous sentences are the same, pointer-based approaches and Copy $\alpha$ would predict that there should be no difference in processing times at the ellipsis site. If, on the other hand, ellipsis is not resolved by linking the gap to a complete structure in memory, different scenarios are possible. One would be that the antecedent is accessed in memory as a word string, and that syntax and semantics are assigned to this string in the usual way, that is, incrementally. Now, if the sentence processor has no way of 'remembering' that it was garden-pathed by the antecedent, there is a chance that it will be garden-pathed again at the ellipsis site, given that the exact same string is being parsed. The only account of ellipsis processing we know of that would plausibly predict this kind of behavior is the one proposed by Kim et al. (2011), in which "derivations in an initial conjunct [are allowed] to do double-duty in a second conjunct" (p. 346).

This 'parse twice' approach might seem counterintuitive, but is in fact no less parsimonious than Frazier & Clifton's Copy $\alpha$, given that it needs no special machinery besides access to an ordered list of words in memory. One would not

expect the garden-path effect at the ellipsis site to be of the same strength as the one observed for the antecedent, just as one would not expect the reading time for *when* in (1) to be equal to that of *John saw Mary*. Several steps involved in lexical access can be omitted during ellipsis processing, which presumably targets word lemmas instead of lexemes (Simner & Smyth, 1999). Additionally, ellipsis normally occurs in environments that feature a high amount of syntactic parallelism. If a parallel structure is expected, the relevant routines may be activated beforehand or at least be assigned a higher rank when the parser decides which structure to build at the ellipsis site, which can be seen as an instance of syntactic priming (Dubey et al., 2008; Dickey & Bunger, 2011). Given this assumption, however, it might be that in case of a garden path the preferred but incorrect structure will feature into the calculation, making the ellipsis more difficult to process than in cases where the antecedent's structure is unambiguous. While Arai et al. (2014) found evidence that resolving an ambiguity in a prime sentence makes processing of the same ambiguity in the target sentence easier when the same verb is repeated (see also Branigan et al., 2005), it is unclear whether ellipsis constitutes 'repetition'.

In our experiment, we used a known garden-path structure in German to test the – equivalent – predictions of pointer- and sharing-based approaches against those of a reconstruction-based approach of ellipsis processing. The former two predict that garden-pathing within the antecedent clause should have no effect at the ellipsis site while the latter predicts that the pattern observed at the point of disambiguation will reappear, although the effect size may be significantly smaller.

# 2 Material & Methods

## 2.1 Stimuli

Meng & Bader (2000) have shown that German readers prefer to assign a subject interpretation to a sentence-initial NP that is ambiguous between a subject and an object reading, which results in a garden path when it is disambiguated towards an object role (cf. also Hemforth, 1993, among others). This effect is stronger when disambiguation is achieved through agreement on the finite verb rather than through case marking on another NP. As shown in (5), we used indefinite NPs instead of the wh-marked NPs employed by Meng & Bader. Case marking on the *sympathizer* NP is either ambiguous (a/b) or unambiguous (c/d). The auxiliary *hatte(n)*, 'had', agrees either with the singular *sympathizer* or with the plural *rebels* NP, thereby signalling either OVS (a/c) or SVO word order (b/d). The result is a 2 × 2 design with the factors word order and case marking. Diamonds indicate the boundaries of presentation regions in the experiment, subscripts indicate region coding for the statistical analysis.

(5) a. Ambiguous / OVS

Eine Sympathisantin der Opposition$_{\text{np1}}$ ◇ hatten$_{\text{aux}}$ ◇
A sympathizer.fem.**nom/acc** of the opposition **had.pl**
die Rebellen$_{\text{np2}}$ ◇ ...
the rebels.nom/acc

b. Ambiguous / SVO

Eine Sympathisantin der Opposition$_{\text{np1}}$ ◇ hatte$_{\text{aux}}$ ◇
A sympathizer.fem.**nom/acc** of the opposition **had.sg**
die Rebellen$_{\text{np2}}$ ◇ ...
the rebels.nom/acc

c. Unambiguous / OVS

Einen Sympathisanten der Opposition$_{\text{np1}}$ ◇ hatten$_{\text{aux}}$ ◇
A sympathizer.masc.**acc** of the opposition **had.pl**
die Rebellen$_{\text{np2}}$ ◇ ...
the rebels.nom/acc

d. Unambiguous / SVO

Ein Sympathisant der Opposition$_{\text{np1}}$ ◇ hatte$_{\text{aux}}$ ◇
A sympathizer.masc.**nom** of the opposition **had.sg**
die Rebellen$_{\text{np2}}$ ◇ ...
the rebels.nom/acc

... laut einem Bericht$_{\text{adj}}$ ◇ maßgeblich unterstützt,$_{\text{vp}}$ ◇ aber ◇
according to a report decisively supported but
die Regierung ◇ konnte ◇ nicht ◇ nachweisen,$_{\text{wh-1}}$ ◇ wie,$_{\text{wh}}$ ◇
the government could not substantiate **how**
so sehr$_{\text{wh+1}}$ ◇ sich$_{\text{wh+2}}$ ◇ die Untersuchungskommission$_{\text{wh+3}}$ ◇ auch
so greatly itself the investigative commission too
◇ bemühte.
struggled

'The rebels had supported a sympathizer (OVS, a/c) / A sympathizer had supported the rebels (SVO, b/d), but the government could not substantiate how, no matter how hard the investigative commission tried.'

The antecedent clause ends at *unterstützt*, 'supported'. It is conjoined with a second clause by *aber*, 'but', which contains a sluicing site (or 'sluice') at *wie*, 'how'.[4] The part of the sentence following the sluicing site was intended as a spillover region. We could have used only conditions a and c to look for an effect of reanalysis, but decided to also include b and d as control conditions since otherwise reanalysis would be completely confounded with the gender of the initial NP. Additionally, even though condition b is initially ambiguous, there should be no reanalysis as readers will assume SVO order by default (cf. Meng & Bader, 2000); we can thus control for temporarily ambiguous antecedents being processed differently from unambiguous ones. Thirty-two sentences were created according to this schema for use in the experiment. A complete list of the experimental materials is given in the appendix. The stimuli were combined with ninety-six filler sentences featuring various constructions.

We expected a garden-path effect to occur at the auxiliary of the antecedent clause in the form of a word order × case marking interaction. Meng & Bader (2000) observed longer reaction times in a grammaticality judgment task for OVS than for SVO sentences, indicating that OVS order is overall more difficult to

[4]All wh-phrases in the experiment were 'sprouted' (Chung et al., 1995), that is, they had no explicit correlate in the antecedent. We only used adjunct wh-phrases since argument wh-phrases are case-marked in German, which would have introduced a potential confound.

process. In (5a), however, the *sympathizer* NP presumably has to be reanalyzed from subject to object, which should further increase processing time. If ellipsis acts as a pointer into memory, there should be no difference between conditions at *wie*, 'how', as neither the scope of the ellipsis nor the availability of a completely analyzed antecedent structure vary between conditions. If, however, the syntax of the ellipsis site has to be constructed by normal parsing routines, the garden-path effect should reappear at this position, though most likely with reduced magnitude.

## 2.2 Participants

Sixty students from the University of Potsdam were recruited for the study. All subjects were native speakers of German and were either paid 6 € or received course credit for the participation. Informed consent was obtained from all participants prior to testing.

## 2.3 Procedure

The sentences were presented using the moving window self-paced reading technique (Just et al., 1982), which was implemented using the Linger software (Rohde, 2003, `http://tedlab.mit.edu/~dr/Linger/`). Participants sat in front of a PC in a quiet room and were instructed to read silently and at their own pace. Sentences were presented in 20 pt Courier New font according to a latin square procedure. At the beginning of each trial, all characters were masked with underscores. Participants completed two practice trials before the experiment proper. The order of fillers and experimental sentences was randomized at runtime. Each trial was followed by a comprehension test which took one of two forms: either a statement about the preceding sentence had to be judged as true or false, or a gap in a statement had to be filled by selecting one out of four options. The comprehension test targeted various kinds of information contained in the stimuli and the ratio of true to false statements for the judgment test was balanced. For a subset of fill-in-the-gap statements appearing after experimental sentences, participants had to supply the critical wh-pronoun.

# 3 Results and Discussion

## 3.1 Data analysis

The data were analyzed using the `R` software environment (R Core Team, 2015) by fitting linear mixed-effects models to individual regions of interest with the `lme4` package (Bates et al., 2014). The models included varying intercepts and slopes by subjects and by items. The code and data will be released with the publication of this paper. When the estimate for a slope adjustment was zero, the random effect was dropped from the model, along with any associated higher-order effects. Sum contrasts were defined for the experimental factors word order and case marking and entered into the models as fixed effects. For word order, the OVS conditions were coded as 1 and the SVO conditions as -1, respectively. For case marking, the ambiguous conditions were coded as 1 and the unambiguous conditions as -1. Since processing spillover is a known concern in self-paced reading, the reading time for the immediately preceding

region was also entered into all models after being appropriately transformed (see below) and subsequently centered. The addition of this parameter improved model fit for all regions of interest,[5] but the method is by no means guaranteed to eliminate spillover entirely, for instance if subjects postpone processing and keep 'tapping' the button at fixed time intervals (Witzel et al., 2012).

An underlying assumption in linear modeling is that the residuals are approximately normally distributed. As this was not the case when raw reading times were used as the dependent variable, we applied the Box-Cox procedure (Box & Cox, 1964; Venables & Ripley, 2002), which suggested a reciprocal transformation (1/RT). Reciprocal reading times were multiplied by -1000 to make the parameters easier to interpret. Additionally, all data points corresponding to reading times below 150 ms were removed, which resulted in a loss of less than one per cent of data in all cases. Effects were judged as significant if the associated t-value was greater than two. Model output is shown in Table 2.

## 3.2 Comprehension accuracy

Participants' overall comprehension accuracy was at 90 per cent, though accuracy for experimental items was somewhat lower at 82 per cent. A linear mixed-effects model was fit to question response times using the same procedure described above for reading times. The analysis revealed no significant effects of the experimental manipulation. An analogous model with reciprocal response time as an additional predictor was fit to response accuracies using a logit link function. The fit showed an effect of response time such that accuracy dropped with increased delay ($\hat{\beta}$ = -0.13, se = 0.03, t = -5.18), as well as a significant word order × case marking interaction ($\hat{\beta}$ = -0.18, se = 0.07, t = -2.74), which nested contrasts[6] revealed to be driven by the OVS/ambiguous condition eliciting more incorrect responses than the SVO/ambiguous condition ($\hat{\beta}$ = -0.27, se = 0.13, t = -2.09). Note that as only a subset of questions targeted the ambiguous structure, this result should be treated with caution.

## 3.3 Reading times

Table 1 shows the mean raw reading times for the analyzed regions of interest. Figure 1 shows residual mean reading times for each region of the antecedent. Residualization was carried out by fitting a linear mixed-effects model with region length as a fixed effect and random slopes by subject. Unresidualized reciprocal reading times (see above) were used in the statistical analysis. A main effect of word order appeared at the auxiliary ($\hat{\beta}$ = 0.03, se = 0.01, t = 2.07), such that OVS was processed more slowly than SVO, which is likely due to the additional plural suffix in the OVS conditions. On the second NP, there were main effects of word order ($\hat{\beta}$ = 0.04, se = 0.01, t = 3.02) and case marking ($\hat{\beta}$ = 0.04, se = 0.01, t = 3.3), such that SVO was read faster than OVS and unambiguous sentences were read faster than ambiguous ones. There was also a significant interaction between the factors ($\hat{\beta}$ = 0.02, se = 0.01, t = 2.12), which

[5] Improvement of fit was assessed through likelihood ratio tests comparing models with and without the spillover predictor.

[6] For this analysis, case marking was treated as nested within word order. One sum contrast compared the two ambiguous conditions, one compared the two unambiguous conditions, and a third one the OVS versus SVO conditions.

nested contrasts revealed to be driven by OVS clauses taking longer to read in the presence of ambiguous case marking ($\hat{\beta}$ = 0.07, se = 0.02, t = 3.68). The preverbal adjunct again showed a main effect of word order ($\hat{\beta}$ = -0.02, se = 0.01, t = -2.38); at this position, OVS clauses were read faster than SVO clauses.

Figure 2 shows the mean reading times from the region right before the ellipsis site to three words after the ellipsis site, again in residualized form. No significant effects appeared at the wh-pronoun or in the immediately following region. In the next region (wh+2), there was a main effect of word order ($\hat{\beta}$ = 0.03, se = 0.01, t = 2.02), such that OVS clauses took longer to read than SVO clauses. For this position, closer inspection of the model revealed one very short reading time (177 ms) to be highly influential in the fit, and removing this value resulted in the effect merely approaching significance ($\hat{\beta}$ = 0.02, se = 0.01, t = 1.89). In the third region after the wh-pronoun (wh+3), a word order × case marking interaction reached significance ($\hat{\beta}$ = -0.03, se = 0.01, t = -2.02), due to the OVS/ambiguous condition being read faster than the OVS/unambiguous condition, with no single condition driving the interaction. During data analysis we noticed that five experimental sentences featured gender-marked pronouns at position wh+2, which presents a possible confound. Adding the presence versus absence of a pronoun as a sum-coded predictor did, however, not change the results found at regions wh+2 and wh+3.

## 3.4 Discussion

The expected garden-path effect for the antecedent appeared one region later than predicted, at the second NP, showing that the experimental manipulation was successful. While no effects were found at the ellipsis site itself, OVS antecedents led to longer reading times two regions downstream from the wh-pronoun. Furthermore, an interaction between the experimental factors appeared at position wh+3, albeit in a surprising form: sentences in the OVS/ambiguous condition were read faster than those in the OVS/unambiguous condition, with the two SVO conditions lying in between. We assume that the observed pattern reflects delayed processing of the ellipsis, either as the consequence of a 'tapping' strategy or as spillover that was not factored out by the statistical model. As the OVS/ambiguous condition was responsible for the garden-path effect within the antecedent clause, the processing advantage is unexpected with regard to the reconstruction hypothesis, which had predicted the same pattern to reappear at the ellipsis site. The result is also not straightforwardly explained by a pointer-based approach, which would have predicted no differences between the conditions.

It might be argued that the interaction found at position wh+3 stemmed from occasional processing breakdowns in the OVS/ambiguous sentences. We assume that these would be due to failures in processing the antecedent, which would leave the parser without an adequate retrieval target for the ellipsis. To test this hypothesis, we added the reading time for the second NP, which is expected to reflect the difficulty of the garden path, to the reading time model for position wh+3 on the same trial. While this measure turned out to be a highly significant predictor ($\hat{\beta}$ = 0.13, se = 0.02, t = 5.51), the word order × case marking interaction also stayed significant and indeed became stronger ($\hat{\beta}$ = -0.03, se = 0.01, t = -2.21). This suggests that while the time spent processing

the garden-path influences retrieval difficulty, there are factors above and beyond this measure which determine processing effort at the ellipsis site. In a further test, we added reading times for both the second NP and position wh+3 to the response accuracy model reported above. The reasoning behind this was that processing failure at either position could lead to incorrect responses. Adding these parameters did, however, not change the result. We also compared the median reading time in the OVS/ambiguous condition for position wh+3 with the overall median reading time for the experimental items. The difference lay within reasonable bounds (439 ms, se 18 ms vs. 473 ms, se 2 ms), indicating that very short RTs from processing failures were not pushing down the median. Congruently with this, a visual inspection of a density plot of RTs at position wh+3 did not indicate a mode or tail of fast reading times, nor did Hartigan's Dip Test (Hartigan & Hartigan, 1985) yield any evidence for bimodality. Finally, we removed all trials with incorrect responses to the comprehension test, which amounted to 18 per cent of the data for position wh+3, and refit our model.[7] The word order × case marking interaction stayed near the significance threshold ($\hat{\beta}$ = -0.02, se = 0.01, t = -1.62) and became marginally significant when antecedent reading time was added as a predictor ($\hat{\beta}$ = -0.03, se = 0.01, t = -1.86). To our minds, these results indicate that processing failure was not a factor in decreasing reading times for the OVS/ambiguous condition.

We suggest that what we are observing at positions wh+2 and wh+3 is the interaction of two factors: antecedent-ellipsis mismatch and memory trace reactivation through reanalysis. In German, subordinate clauses are verb-final while main clauses have the finite verb in second position. OVS order in main clauses can be derived through topicalization, with the object occupying the so-called *Vorfeld* ('prefield', e.g. Müller, 2005).[8] As this strategy is not available in subordinate clauses, non-canonical word orders must be derived via *scrambling*, which moves constituents within the so-called *Mittelfeld* ('middle field', e.g. Hinterhölzl, 2006). As the sluicing structures in the present study appeared in subordinate clauses, all antecedent clauses would have had to be verb-final to be compatible with the gap, which however was not the case. Given that sluicing is still perfectly acceptable in all of our stimuli, we seem to be seeing a case of 'acceptable ungrammaticality' (Frazier, 2008). Both SVO and OVS antecedents were, to use the terminology of Arregui et al. (2006), 'flawed', but possibly not in the same way. The slightly simplified examples in (6) illustrate what happens in a non-elided clause when the finite verb appears at the end of the clause, but the order of subject and object stays the same as in the corresponding main clause. SOV order in (6a) is unproblematic, but OSV in (6b) is, at the very least, highly marked. In order to make the sentence acceptable, the *rebels* NP needs to appear to the left of the *sympathizer* NP, as in (6c).

(6) Die Regierung konnte nicht nachweisen, ...
the government could not substantiate

[7] Note that an incorrect answer does not necessarily mean that parsing failed; misinterpretations could, for instance, arise from fragments of discarded analyses in memory (Slattery et al. (2013)). Nevertheless, the results of the comprehension test are the only pertinent measure available to us.

[8] The so-called *Feldertheorie* of German sentence structure was first developed by Drach (1937), and is also known as the *Topological Model*.

a. . . . wie ein Sympathisant der Opposition die Rebellen
how a sympathizer.nom of the opposition the rebels
unterstützt hatte.
supported had.sg

b. ?? . . . wie einen Sympathisanten der Opposition die Rebellen
how a sympathizer.acc of the opposition the rebels
unterstützt hatten.
supported had.pl

c. . . . wie die Rebellen einen Sympathisanten der Opposition
how the rebels a sympathizer.acc of the opposition
unterstützt hatten.
supported had.pl

The Recycling Hypothesis proposed by Arregui et al. (2006) predicts that ellipses are more difficult to process the more the antecedent mismatches the ellipsis site. Arregui et al. assume 'repair' operations as the source of the difficulty, which in this case would need to transform (6b) into (6c). We will offer an alternative explanation below. In any case, the increased reading times for sentences with object-initial antecedents observed at position wh+2 would be expected under the assumption that the mismatch between an OVS antecedent and an SOV sluice is greater than that between an SVO antecedent and an SOV sluice, presumably because the linear order of subject and object is not easily compatible with the local verb-final configuration.

What the Recycling Hypothesis does not explain is why the OVS/unambiguous condition would require more processing effort than the OVS/ambiguous condition at position wh+3. We suggest to analyze this difference in terms of a reactivation of the antecedent's memory trace that outweighs the mismatch penalty. The cue-based retrieval parser of Lewis & Vasishth (2005) incorporates the assumption that syntactic phrases are stored in working memory as chunks. If a chunk is retrieved in order to make an attachment, its activation level increases, which makes subsequent retrievals easier. While this is not explicitly spelled out in the model, a reanalysis such as the one required for sentences in the OVS/ambiguous condition should reactivate the antecedent's memory chunk as its structure needs to be changed. Later, at the ellipsis site, it should thus be retrieved faster than the other types of antecedents, to which reanalysis has not applied.[9] The mismatch effect explained above can also be accounted for through an extension of the Lewis & Vasishth (2005) model: If the wh-pronoun set retrieval cues for a verb-final antecedent in order to match the local clausal configuration, there will be no matching chunk in memory. In order to be able to complete the retrieval, the processor may then attempt to retrieve chunks which do not match the cues perfectly, such as the main clauses in the current study. If a clausal chunk with SVO order resonates more strongly with the cues than one with OVS word order, it will have a lower retrieval latency, thereby predicting the observed OVS disadvantage. The reactivation/mismatch approach is thus able to account for the observed pattern of results, but due its status as a *post-hoc* argument is in need of further empirical validation.

[9]This presupposes that trace decay has not reduced the activation of the antecedent to zero in any case by the time the ellipsis is processed. The model of Lewis & Vasishth (2005) assumes that the activation of chunks than have been reaccessed is higher even after complete decay.

One might think of yet another explanation for the result, namely that reconstruction *is* taking place and that syntactic priming is responsible for the advantage in the OVS/ambiguous condition. However, such an approach would not fit with the fact that the antecedent's structure is, strictly speaking, incompatible with the word order required at the gap: As the derivations of SOV and OVS structures involve different steps, it is not obvious what exactly would be primed. One would have to make a very specific set of assumptions: First, the parser would need to blindly reconstruct the syntax of the antecedent at the ellipsis site *before* checking for possible mismatches. Secondly, garden-path sentences would need to prime their final structure more strongly than unambiguous controls, which to our knowledge has not been demonstrated. Ambiguous/OVS antecedents would then initially gain an advantage through increased priming while both kinds of OVS antecedents would be disadvantaged during the mismatch checking phase.

In this context, we believe that one additional result is worth mentioning, even though it was only arrived at *post hoc*. It fits with the suggestion by Yoshida et al. (2013) that predictive processing may be involved in the interpretation of sluicing structures. Yoshida et al. tested sentences such as (7), which does not contain a sluice.

(7) 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 so very impressed (with).

Their self-paced reading experiment used a $2 \times 2$ design in which the position of the word *with* and the gender of the second NP (*grandfather/-mother*) were manipulated. Results showed that one word after the reflexive *himself*, reading times for *grandmother* sentences were higher than those for *grandfather* sentences, but only when *with* appeared at the end of the sentence as opposed to before the NP *which story*. The authors explain this interaction through the availability of a sluicing structure at *himself* in the "late *with*" but not in the "early *with*" condition (** . . . but we couldn't remember with which story about himself ~~Jane's grandfather told~~*). Yoshida et al. conclude that as soon as the wh-phrase is encountered, the parser starts building a sluicing structure, presumably because a sluicing continuation is preferred over other possible structures. The pre-constructed sluice contains a matching binder for *himself* only in the *grandfather* condition, thus explaining the observed interaction.

We took the implication of predictive processing as an incentive to analyze reading times for the region directly *preceding* the wh-pronoun in our own experiment: If sluicing is the preferred continuation after a wh-pronoun has been encountered, it is not unlikely that it will also rank fairly highly before that point. This is especially likely given that subordinate clauses in German require a comma, which was thus present in the pre-wh region in all of our stimuli, excluding a vast range of alternative continuations that would have been likely in Yoshida et al.'s materials.

The fitting of a linear mixed-effects model (see above) at position wh-1 revealed a significant interaction between word order and case marking ($\hat{\beta}$ = -0.03, se = 0.01, t = -2.3) which had the same sign as the one observed at position wh+3.[10] Table 3 shows the model output. However, unlike at the later position,

[10] As a sanity check, we also analyzed reading times at position wh-2, finding no significant

nested contrasts showed that the interaction was driven by the OVS/unambiguous condition being read more slowly than the SVO/unambiguous condition ($\hat{\beta}$ = 0.04, se = 0.02, t = 2.24), even though the numerical pattern in raw reading times was the same as for position wh+3. We have no ready explanation for this finding. Speculatively, it might be due to an additional mechanism: There might not be a retrieval at position wh-1, but a heuristic may be used to estimate the fit between the sluice and the antecedent, possibly based on surface strings. Such a heuristic might work better when case is overtly marked as opposed to reassigned via reanalysis, and might operate more quickly when word order is canonical. In our opinion this kind of predictive strategy makes it unlikely that processing proceeds according to the priming-based account described above, in which local constraints do not influence the initial structure assignment for the ellipsis.

To further investigate the notion that a sluicing continuation was the favored and therefore expected structure in our materials, we ran a sentence completion study with thirty-five new participants. The stimuli consisted of the thirty-two sentences used in the current study, along with thirty-two sentences from a different experiment and ninety-six fillers. Sentences were presented using a modified version of Linger's masked auto-paced reading (otherwise known as rapid serial visual presentation or RSVP). The stimuli from the current study were cut off right before the ellipsis site and participants were asked to complete the sentences using the first continuation that came to their minds. Due to the nature of the presentation, participants could not reread the sentences while they were typing their continuation. Results showed a total of only five per cent sluicing continuations. Another fifty-four per cent of continuations were non-sluiced wh-clauses, followed by *if*-clauses at seventeen per cent and *that*-clauses at seven per cent. Assuming that this pattern is not due to idiosyncrasies of the production system, the observed outcome casts some doubt on the assumption that a sluicing continuation was, in fact, highly expected in our stimuli. It is, however, entirely possible that sluicing is only one of several possible continuations which are pre-activated during reading, which might be enough to explain the findings of Yoshida et al. (2013) and the early effect we observed in the self-paced reading study.

# 4 General Discussion

The current experiment investigated the processing of a sluicing construction in cases where the antecedent is a garden-path structure, in this instance a clause with a subject/object ambiguity. We observed reduced reading times for sentences with garden-path antecedents three regions downstream from the ellipsis as well as directly before the ellipsis. Furthermore, there was an overall pattern of elevated reading times in the spillover region for antecedents that mismatched the canonical word order of the ellipsis site. Our results are best compatible with accounts of ellipsis resolution that can be implemented in the form of a memory pointer mechanism (Frazier & Clifton 2001, 2005; Martin & McElree, 2008), which would need to be augmented to account for reactivation assumed by the cue-based retrieval parser of Lewis & Vasishth (2005). The evidence for

effects.

a mismatch effect is in line with the predictions of the Recycling Hypothesis proposed by Arregui et al. (2006). However, given that we have observed no evidence for reconstruction in our experiment, we do not subscribe to Arregui et al.'s assumption that 'flawed' antecedents are 'repaired' in a way that is similar to syntactic reanalysis (p. 242). The mismatch effect may be better approached along the lines of the wh-pronoun setting a retrieval cue for an antecedent that matches the word order requirements of the local clause, opting for the closest candidate upon failure. Alternatively, one could follow the proposal of Kim et al. (2011), in which ellipses with non-canonical antecedents violate parsing heuristics that are based on construction frequency and expectation. Under an approach without reconstruction, we would claim that it is not a parsing heuristic that is violated, but a local expectation as to what the antecedent should look like. If the expectation were global, no mismatch effect would be expected, given that the antecedent has already been encountered in the input. The local expectation account fits with the pattern observed by Yoshida et al. (2013) as well as with the early effect found in the current study.

Still, why did we observe a pattern in which the experimental manipulation seemed to have an effect before and after, but not *at* the ellipsis site? We assume that this is due to either insufficient statistical power, to our subjects' reading strategies, or both. Power is always an issue when effect sizes are as small as in the current study: the mean reading time difference between the unambiguous/OVS and the ambiguous/OVS conditions at position wh+3 was only 30 ms. Given this value and the associated standard errors, the post-hoc power to detect a real effect was at 45 per cent, which is comparable to Frazier & Clifton's 2000 study, where the computation yields 43 per cent post-hoc power.[11] The bottom line is that sample size needs to be significantly increased in order to convincingly argue that there really is *no* effect of the manipulation, even though this might be construed as trying to 'force significance'.

The concern related to reading strategies comes from the fact that while non-cumulative self-paced reading more closely resembles data from natural reading than the cumulative variant does (Just et al., 1982), it is by no means certain that subjects will not adopt a 'wait and see' strategy at least on some trials, meaning that they will press the button at a fixed rate and only then start processing. Witzel et al. (2012), suspecting such rhythmic 'tapping' in their data, tried to remove its influence by calculating the standard deviation of the response time by subject and excluding the participants with the smallest variability, which did, however, not change their statistical result. The authors conclude that either 'tapping' was not a factor in their data or their method was not suitable to account for it, leaving the issue for future research. We will do the same here.

There is also a slightly different explanation for the delay we observed, namely that subjects *did* process the words the words as they were revealed, but postponed the processing of the ellipsis until they had more information. Such a strategy might make sense considering that an embedded question usually imparts no relevant information apart from the fact that some piece of information is missing (*. . . , but the government could not substantiate how, . . .*). As the contents of the spillover region put this information in context (*. . . , because/so*

[11] Note that this is not the *true* power of the experiments, which depends on the unknown true effect size.

*that/even though/until ...*), the relevance may have become apparent, causing the observed processing pattern.

A final objection to our study would be that there was no control condition without ellipsis. This is also true for other studies on ellipsis processing (e.g. Frazier & Clifton, 2000, 2005 [except Experiments 2 and 3], Poirier et al., 2010), leaving open the possibility that any observed effects do not actually stem from the antecedent being recovered due to a perceived gap in the sentence but from some other mechanism. While this criticism can be met by pointing to the localization of the effects, as well as to the unavailability of a plausible alternative explanation, it would be desirable to include controls in future studies to strengthen the conclusions drawn from the data.

# Disclosure/Conflict-of-Interest Statement

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

# Acknowledgments

To author wishes to thank Shravan Vasishth, Lena A. Jäger, Barbara Hemforth, the Vasishth Lab team and the audience at CUNY 2015 for helpful comments and suggestions, as well as Johanna Thieke for assistance with data collection.

# References

Arai, M., Nakamura, C., & Mazuka, R. (2014). Predicting the unbeaten path through syntactic priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*(2), 482–500. Retrieved from `http://psycnet.apa.org/psycinfo/2014-55691-001/` doi: 10.1037/a0038389

Arregui, A., Clifton, C., Jr., Frazier, L., & Moulton, K. (2006). Processing elided verb phrases with flawed antecedents: The recycling hypothesis. *Journal of Memory and Language*, *55*(2), 232–246. Retrieved from `http://www.sciencedirect.com/science/article/pii/S0749596X06000192` doi: 10.1016/j.jml.2006.02.005

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). lme4: Linear mixed-effects models using eigen and s4 [Computer software manual]. Retrieved from `http://CRAN.R-project.org/package=lme4` (R package version 1.1-7)

Box, G. E., & Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society. Series B (Methodological)*, 211–252. Retrieved from `http://www.jstor.org/stable/2984418`

Branigan, H. P., Pickering, M. J., & McLean, J. F. (2005). Priming prepositional-phrase attachment during comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(3), 468–481. Retrieved from `http://psycnet.apa.org/journals/xlm/31/3/468/` doi: 10.1037/0278-7393.31.3.468

Cai, Z. G., Pickering, M. J., & Sturt, P. (2013). Processing verb-phrase ellipsis in Mandarin Chinese: Evidence against the syntactic account. *Language and Cognitive Processes*, *28*(6), 810–828. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/01690965.2012.665932 doi: 10.1080/01690965.2012.665932

Chung, S., Ladusaw, W. A., & McCloskey, J. (1995). Sluicing and logical form. *Natural language semantics*, *3*(3), 239–282. Retrieved from http://link.springer.com/article/10.1007/BF01248819 doi: 10.1007/BF01248819

Dickey, M. W., & Bunger, A. C. (2011). Comprehension of elided structure: Evidence from sluicing. *Language and Cognitive Processes*, *26*(1), 63–78. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/01690961003691074 doi: 10.1080/01690961003691074

Drach, E. (1937). *Grundgedanken der deutschen satzlehre*. Frankfurt/Main: Diesterweg.

Dubey, A., Keller, F., & Sturt, P. (2008). A probabilistic corpus-based model of syntactic parallelism. *Cognition*, *109*(3), 326–344. Retrieved from http://www.sciencedirect.com/science/article/pii/S001002770800214X doi: 10.1016/j.cognition.2008.09.006

Frazier, L. (2008). Processing ellipsis: A processing solution to the undergeneration problem. In C. B. Chang & H. J. Haynie (Eds.), *Proceedings of the 26th west coast conference on formal linguistics* (pp. 21–32). Somerville, MA.

Frazier, L., & Clifton, C., Jr. (2000). On bound variable interpretations: The LF-only hypothesis. *Journal of Psycholinguistic Research*, *29*(2), 125–140. Retrieved from http://link.springer.com/article/10.1023/A:1005136826534 doi: 10.1023/A:1005136826534

Frazier, L., & Clifton, C., Jr. (2001). Parsing coordinates and ellipsis: Copy $\alpha$. *Syntax*, *4*(1), 1–22. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/1467-9612.00034/abstract doi: 10.1111/1467-9612.00034

Frazier, L., & Clifton, C., Jr. (2005). The syntax-discourse divide: Processing ellipsis. *Syntax*, *8*(2), 121–174. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1467-9612.2005.00077.x/abstract doi: 10.1111/j.1467-9612.2005.00077.x

Grinder, J., & Postal, P. M. (1971). Missing antecedents. *Linguistic Inquiry*, 269–312. Retrieved from http://www.jstor.org/stable/4177639

Hardt, D. (1993). *Verb phrase ellipis: Form, meaning, and processing* (Unpublished doctoral dissertation). University of Pennsylvania, Philadelphia.

Hartigan, J. A., & Hartigan, P. (1985). The dip test of unimodality. *The Annals of Statistics*, 70–84. Retrieved from http://www.jstor.org/stable/2241144

Hemforth, B. (1993). *Kognitives parsing: Repräsentation und verarbeitung sprachlichen wissens*. Sankt Augustin: Infix.

Hinterhölzl, R. (2006). *Scrambling, remnant movement, and restructuring in West Germanic: Oxford studies in comparative syntax*. Oxford: Oxford University Press.

Just, M. A., Carpenter, P. A., & Woolley, J. D. (1982). Paradigms and processes in reading comprehension. *Journal of experimental psychology: General*, *111*(2), 228–238. Retrieved from http://psycnet.apa.org/psycinfo/1982-29564-001 doi: 10.1037/0096-3445.111.2.228

Kehler, A. (2000). Coherence and the resolution of ellipsis. *Linguistics and Philosophy*, *23*(6), 533–575. Retrieved from http://link.springer.com/article/10.1023/A:1005677819813 doi: 10.1023/A:1005677819813

Kertz, L. (2000). *Ellipsis reconsidered* (Unpublished doctoral dissertation). University of San Diego.

Kim, C. S., Kobele, G. M., Runner, J. T., & Hale, J. T. (2011). The acceptability cline in VP ellipsis. *Syntax*, *14*(4), 318–354. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1467-9612.2011.00160.x/full doi: 10.1111/j.1467-9612.2011.00160.x

Lewis, R. L., & Vasishth, S. (2005). An activation-based model of sentence processing as skilled memory retrieval. *Cognitive Science*, *29*(3), 375–419. Retrieved from http://onlinelibrary.wiley.com/doi/10.1207/s15516709cog0000_25/abstract doi: 10.1207/s15516709cog0000_25

Martin, A. E., & McElree, B. (2008). A content-addressable pointer mechanism underlies comprehension of verb-phrase ellipsis. *Journal of Memory and Language*, *58*(3), 879–906. Retrieved from http://www.sciencedirect.com/science/article/pii/S0749596X07000800 doi: 10.1016/j.jml.2007.06.010

Meng, M., & Bader, M. (2000). Mode of disambiguation and garden-path strength: An investigation of subject-object ambiguities in German. *Language and Speech*, *43*(1), 43–74. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/016909600750040580 doi: 10.1080/016909600750040580

Merchant, J. (2001). *The syntax of silence: Sluicing, islands, and the theory of ellipsis*. Oxford: Oxford University Press.

Merchant, J. (2013). Voice and ellipsis. *Linguistic Inquiry*, *44*(1), 77–108.

Merchant, J. (to appear). Ellipsis: A survey of analytical approaches. In J. van Craenenbroeck & T. Temmerma (Eds.), *The oxford handbook of ellipsis.*

Müller, S. (2005). Zur Analyse der deutschen Satzstruktur. *Linguistische Berichte*, *201*, 3–39.

Murguia, E. (2004). *Syntactic identity and locality restrictions on verbal ellipsis* (Unpublished doctoral dissertation). University of Maryland.

Murphy, G. L. (1985). Processes of understanding anaphora. *Journal of Memory and Language*, *24*(3), 290–303. Retrieved from http://www.sciencedirect.com/science/article/pii/0749596X85900294 doi: 10.1016/0749-596X(85)90029-4

Phillips, C., & Parker, D. (2014). The psycholinguistics of ellipsis. *Lingua*, *151*, 78–95. Retrieved from http://www.sciencedirect.com/science/article/pii/S0024384113002209 doi: 10.1016/j.lingua.2013.10.003

Poirier, J., Wolfinger, K., Spellman, L., & Shapiro, L. P. (2010). The real-time processing of sluiced sentences. *Journal of psycholinguistic research*, *39*(5), 411–427. Retrieved from http://link.springer.com/article/10.1007/s10936-010-9148-9 doi: 10.1007/s10936-010-9148-9

Potsdam, E. (2007). Malagasy sluicing and its consequences for the identity requirement on ellipsis. *Natural Language & Linguistic Theory*, *25*(3), 577–613. Retrieved from http://link.springer.com/article/10.1007/s11049-006-9015-4 doi: 10.1007/s11049-006-9015-4

R Core Team. (2015). R: A language and environment for statistical computing [Computer software manual]. Vienna, Austria. Retrieved from http://www.R-project.org/

Rohde, D. (2003). *Linger, version 2.94.* Retrieved from http://tedlab.mit.edu/~dr/Linger/

Ross, J. R. (1967). *Constraints on variables in syntax* (Unpublished doctoral dissertation). Massachusetts Institute of Technology.

Ross, J. R. (1969). Guess who? In R. Binnick, A. Davison, G. Green, & J. Morgan (Eds.), *Papers from the 5th regional meeting of the chicago linguistic society* (pp. 252–286). Chicago, IL: Chicago Linguistic Society.

Simner, J., & Smyth, R. (1999). Phonological activation in anaphoric lexical access (ALA). *Brain and language*, *68*(1), 40–45. Retrieved from http://www.sciencedirect.com/science/article/pii/S0093934X99921120 doi: 10.1006/brln.1999.2112

Slattery, T. J., Sturt, P., Christianson, K., Yoshida, M., & Ferreira, F. (2013). Lingering misinterpretations of garden path sentences arise from competing syntactic representations. *Journal of Memory and Language*, *69*(2), 104–120.

Tanenhaus, M. K., & Carlson, G. N. (1990). Comprehension of deep and surface verbphrase anaphors. *Language and Cognitive Processes*, *5*(4), 257–280. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/01690969008407064 doi: 10.1080/01690969008407064

Venables, W. N., & Ripley, B. D. (2002). *Modern applied statistics with S.* New York: Springer.

Wasow, T. (1972). *Anaphoric relations in english* (Unpublished doctoral dissertation). Massachusetts Institute of Technology.

Williams, E. S. (1977). Discourse and logical form. *Linguistic Inquiry*, *8*(1), 101–139. Retrieved from http://www.jstor.org/stable/4177974

Witzel, N., Witzel, J., & Forster, K. (2012). Comparisons of online reading paradigms: Eye tracking, moving-window, and maze. *Journal of psycholinguistic research*, *41*(2), 105–128. Retrieved from http://link.springer.com/article/10.1007/s10936-011-9179-x doi: 10.1007/s10936-011-9179-x

Xiang, M., Grove, J., & Merchant, J. (2014). Ellipsis sites induce structural priming effects. *Manuscript, University of Chicago*.

Yoshida, M., Dickey, M. W., & Sturt, P. (2013). Predictive processing of syntactic structure: Sluicing and ellipsis in real-time sentence processing. *Language and Cognitive Processes*, *28*(3), 272–302. Retrieved from `http://www.tandfonline.com/doi/abs/10.1080/01690965.2011.622905` doi: 10.1080/01690965.2011.622905

# Figures and Tables

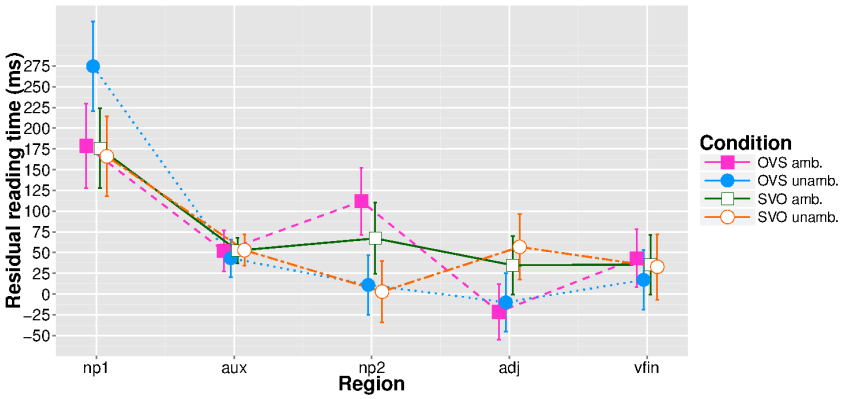


**Figure 1.** Residual reading times for the antecedent regions, extreme values removed. Error bars represent 95% confidence intervals.

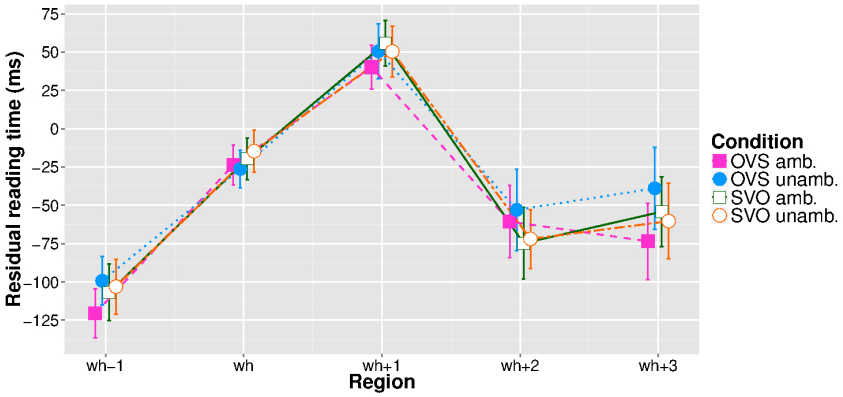


**Figure 2.** Residual reading times for the pre-ellipsis, ellipsis, and spillover regions, extreme values removed. Error bars represent 95% confidence intervals.

**Table 1.** Raw mean reading times in milliseconds by condition for antecedent, ellipsis and spillover regions, standard errors in parantheses.

| | | OVS/amb. | SVO/amb. | OVS/unamb. | SVO/unamb. |
|---|---|---|---|---|---|
| *A sympathizer ...* | np1 | 1793 (48) | 1760 (39) | 1830 (41) | 1651 (39) |
| *had.sg/pl* | aux | 519 (17) | 474 (8) | 499 (12) | 474 (10) |
| *the rebels* | np2 | 1021 (28) | 976 (28) | 913 (23) | 921 (27) |
| *according to ...* | adj | 1041 (26) | 1107 (29) | 1066 (28) | 1135 (31) |
| *decisively supported* | vp | 892 (23) | 887 (24) | 868 (22) | 900 (26) |
| ... | | | | | |
| *substantiate* | wh-1 | 471 (8) | 485 (10) | 493 (9) | 486 (10) |
| *how* | wh | 423 (7) | 427 (7) | 422 (6) | 434 (7) |
| *so greatly* | wh+1 | 437 (7) | 452 (8) | 449 (9) | 449 (8) |
| *itself* | wh+2 | 578 (15) | 564 (15) | 591 (16) | 584 (18) |
| *the ... commission* | wh+3 | 571 (18) | 580 (16) | 604 (17) | 590 (17) |

**Table 2.** Coefficient estimates, standard errors and t values for the linear mixed-effects models fit to reciprocal reading times at the indicated regions of interest.

| aux | | | |
|---|---|---|---|
| | Estimate | Std. Error | t value |
| (Intercept) | -2.19 | 0.07 | -32.82 |
| gender | 0.01 | 0.01 | 0.51 |
| order | 0.03 | 0.01 | 2.07 |
| prev | -0.08 | 0.04 | -1.75 |
| gender:order | -0.01 | 0.01 | -0.91 |
| **np2** | | | |
| | Estimate | Std. Error | t value |
| (Intercept) | -1.32 | 0.08 | -17.08 |
| gender | 0.04 | 0.01 | 3.30 |
| order | 0.04 | 0.01 | 3.02 |
| prev | 0.15 | 0.02 | 6.48 |
| gender:order | 0.02 | 0.01 | 2.12 |
| **adj** | | | |
| | Estimate | Std. Error | t value |
| (Intercept) | -1.17 | 0.07 | -15.96 |
| gender | 0.00 | 0.01 | 0.26 |
| order | -0.02 | 0.01 | -2.38 |
| prev | -0.01 | 0.02 | -0.83 |
| gender:order | -0.00 | 0.01 | -0.35 |
| **wh+2** | | | |
| | Estimate | Std. Error | t value |
| (Intercept) | -1.98 | 0.10 | -20.65 |
| gender | -0.02 | 0.01 | -1.37 |
| order | 0.03 | 0.01 | 2.02 |
| prev | 0.25 | 0.02 | 10.22 |
| gender:order | 0.01 | 0.01 | 0.89 |
| **wh+3** | | | |
| | Estimate | Std. Error | t value |
| (Intercept) | -2.11 | 0.10 | -21.19 |
| gender | -0.03 | 0.01 | -1.86 |
| order | -0.00 | 0.02 | -0.12 |
| prev | 0.06 | 0.02 | 3.05 |
| gender:order | -0.03 | 0.01 | -2.01 |

**Table 3.** Coefficient estimates, standard errors and t values for the linear mixed-effects model fit to reciprocal reading times at region wh-1.

| | wh-1 | | |
|---|---|---|---|
| | Estimate | Std. Error | t value |
| (Intercept) | -2.10 | 0.06 | -35.17 |
| gender | -0.02 | 0.01 | -1.60 |
| order | 0.01 | 0.01 | 0.93 |
| prev | 0.36 | 0.02 | 15.21 |
| gender:order | -0.03 | 0.01 | -2.30 |

# Appendix - Experimental Materials

Ein/e/n Vertreter/in der Gewerkschaft * hatte/n * die anwesenden Minister * während der Sitzung * scharf attackiert, * aber * der gesprächige Parlamentarier * wusste * selbst * nicht, * warum, * denn * er * war * nicht * dabei gewesen.

Ein/e/n Vertraute/r/n des Bürgermeisters * hatte/n * die Ratsmitglieder * kurz vor der Wahl * auffallend häufig angerufen, * aber * heute * weiß * niemand * mehr, * warum, * wie * eine Zeitung * kürzlich * in einem Kommentar * schrieb.

Ein/e/n Kellner/in des Lokals * hatte/n * die Stammgäste * über das geplante Skatturnier * ausgefragt, * aber * der Wirt * konnte * nicht * sagen, * warum, * da * er * offenbar * an jenem Abend * sehr beschäftigt gewesen war.

Eine Beraterin des Präsidenten * hatte/n * die Ermittler * offensichtlich * mit Erfolg getäuscht, * aber * man * fand * nie * heraus, * wie, * denn * es * galt * nach wie vor * die höchste Geheimhaltungsstufe.

Ein/e/n Sprecher/in des Pharmakonzerns * hatte/n * die Sportler * nach Angaben der Presse * persönlich getroffen, * aber * die Quelle * konnte * nicht * mitteilen, * wo, * sodass * die Geschichte * den meisten Lesern * wahrscheinlich * nicht sehr glaubwürdig erschien.

Ein/e/n Sympathisant/in/en der Opposition * hatte/n * die Rebellen * laut einem Bericht * maßgeblich unterstützt, * aber * die Regierung * konnte * nicht * nachweisen, * wie, * so sehr * sich * die Untersuchungskommission * auch * bemühte.

Ein/e/n Gönner/in des Künstlers * hatte/n * die etwas seltsamen Verwandten * zu Anfang * des Mordes verdächtigt, * aber * aus den Tagebüchern * geht * nicht * hervor, * warum, * zumal * es * sich * relativ eindeutig * um Suizid handelte.

Ein/e/n Schüler/in des Schachmeisters * hatte/n * die Schiedsrichter * während des Turniers * sehr genau beobachtet, * aber * der aufmerksame Zuschauer * fragte * sich * noch immer, * warum, * als * er * am Abend * endlich * nach Hause kam.

Ein/e/n Spieler/in des Vereins * hatte/n * die aufdringlichen Fans * nach dem Auswärtsspiel * grob beleidigt, * aber * der Trainer * konnte * nicht * verstehen, * warum, * sodass * er * nur * enttäuscht * den Kopf schüttelte.

Ein/e/n Geschworene/r/n des Gerichts * hatte/n * die beiden Angeklagten * trotz richterlicher Verwarnung * direkt angesprochen, * aber * niemand im Saal * verstand * wohl * so recht, * weshalb, * bevor * die Verhandlung * überraschend * auf unbestimmte Zeit * vertagt wurde.

Ein/e/n Mitarbeiter/in der maroden Firma * hatte/n * die Geschäftsführer * in das raffinierte Veruntreuungssystem * eingeweiht, * aber * es * herrscht * Uneinigkeit * darüber, * wann, * denn * von den belastenden Dokumenten * trägt * keines * ein Datum.

Ein/e/n Aufseher/in des Gefängnisses * hatte/n * die verdächtigen Häftlinge * durch ein erfundenes Alibi * gedeckt, * aber * keinem der Beteiligten * war * damals * zu entlocken, * wieso, * denn * eine Aussage * hätte * wohl * gegen die Ehre verstoßen.

Ein/e/n Angestellte/r/n des städtischen Verkehrsunternehmens * hatte/n * die Fahrgäste * mit unverschämten äußerungen * belästigt, * aber * das Team von Soziologen * konnte * nicht * erklären, * wieso, * sodass * der Zwischenfall * für die Wissenschaft * bis heute * rätselhaft bleibt.

Ein/e/n Dolmetscher/in des Botschafters * hatte/n * die Gastgeber * während der Begrüßungszeremonie * empfindlich gekränkt, * aber * damals * konnte * niemand * nachvollziehen, * womit, * obwohl * die kulturellen Gepflogenheiten * der jeweils anderen Seite * auf jeden Fall * hinreichend bekannt waren.

Ein/e/n Spion/in des Inlandsgeheimdienstes * hatte/n * die Informanten * im Vorfeld der Verhandlungen * enttarnt, * aber * nicht einmal Experten * wussten * letztlich * zu sagen, * wie, * bis * irgendwann * eine Reinigungskraft * im Schutz der Anonymität * den entscheidenden Hinweis gab.

Ein/e/n Redakteur/in der Tageszeitung * hatte/n * die maskierten Aktivisten * zu einer geheimen Videokonferenz * eingeladen, * aber * niemand * konnte * überzeugend * begründen, * wieso, * nachdem * das Vorhaben * unbeabsichtigterweise * der öffentlichkeit * bekannt geworden war.

Ein/e/n Sachverständige/r/n aus Osteuropa * hatte/n * die Investoren * in der Planungsphase * eigenständig hinzugezogen, * aber * im Nachhinein * fragte * sich * so mancher Gutachter, * wieso, * da * das Ergebnis * augenscheinlich * nicht * verbessert wurde.

Ein/e/n Biologe/n/in mit Doktortitel * hatte/n * die Naturschützer * auf einer Fachkonferenz * äußerst heftig kritisiert, * aber * die anderen Teilnehmer * erinnerten * sich * nicht, * wieso, * zumal * die Diskussion * offenbar * abseits des Podiums * stattfand.

Ein/e/n Patient/en/in mit unklaren Symptomen * hatte/n * die Krankenschwestern * dem behandelnden Arzt zufolge * mehrfach angeschrien, * aber * es * war * nicht * zu ergründen, * wieso, * obwohl * seitdem * schon * mehrere Gespräche * geführt wurden.

Ein/e/n Teenager/in ohne Schulabschluss * hatte/n * die Talentsucher * in der Bewerbungsphase * angeschrieben, * aber * der Programmverantwortliche * fragte * sich * ernsthaft, * wozu, * denn * bemerkenswerte Fähigkeiten * wurden * an keiner Stelle * erwähnt.

Ein/e/n Straßenhündin/hund mit schwarzem Fell * hatte/n * die Kinder * bis an den Rand des Dorfes * verfolgt, * aber * niemand * konnte * sich * erklären, * weshalb, * zumal * das Tier * sich * normalerweise * vor Menschen versteckte.

Ein/e/n Violinist/en/in des Nationalorchesters * hatte/n * die Konzertbesucher * während der halbstündigen Pause * heimlich fotografiert, * aber * der Beitrag * verriet * leider * nicht, * weshalb, * sondern * befasste * sich * eher * mit der Bildqualität.

Ein/e/n Korrespondent/en/in des erfolgreichen Nachrichtensenders * hatte/n * die Kollegen * vor laufender Kamera * schlechtgemacht, * aber * in einem Gespräch * konnte * nicht * festgestellt werden, * weshalb, * sodass * der Konflikt * trotz aller Entschuldigungen * ohne Zweifel * weiterhin bestehen blieb.

Ein/e/n Autor/in aus Bolivien * hatte/n * die vier Literaturwissenschaftler * in einem 2500-Seiten-Werk * zitiert, * aber * noch * kann * niemand * sagen, * wo, * da * der Text * bislang * seltsamerweise * verschollen blieb.

Ein/e/n Student/en/in mit außergewöhnlichen Leistungen * hatte/n * die Professoren * laut Stellungnahme des Instituts * tatkräftig unterstützt, * aber * es * war * nicht * zu erfahren, * wobei, * da * der Projektverantwortliche * nicht * für Nachfragen * zu erreichen ist.

Ein/e/n Schwimmer/in mit zwei Beinprothesen * hatte/n * die Komiteemitglieder * bezüglich der geplanten Werbekampagne * kontaktiert, * aber * es * bleibt * äußerst * schleierhaft, * wann, * zumal * das Schriftstück * angeblich * zwischenzeitlich * verloren gegangen ist.

Ein/e/n Mathematiker/in mit Programmierkenntnissen * hatte/n * die Seitenbetreiber * über die Sicherheitslücke * informiert, * aber * der Staatsanwalt * wollte * genau * wissen, * wann, * da * dies * für den Tathergang * womöglich * äußerst entscheidend war.

Ein/e/n Abgeordnete/r/n der Landtagsfraktion * hatte/n * die Finanzbeamten * in einem offenen Brief * gemaßregelt, * aber * fünfzig Jahre später * erscheint * es * unverständlich, * weshalb, * da * aus heutiger Sicht * wohl * kein Fehlverhalten * vorlag.

Ein/e/n Sanitäter/in des Rettungsteams * hatte/n * die Feuerwehrleute * nachdrücklich * um Hilfe gebeten, * aber * man * verstand * später * nicht, * warum, * bis * schließlich * Bildmaterial vom Unglücksort * das Ausmaß der Verwüstung * verständlich machte.

Ein/e/n Befürworter/in der Steuerreform * hatte/n * die Leiter der betroffenen Behörden * wiederholt * verbal angegriffen, * aber * es * bleibt * völlig * im Dunkeln, * weshalb, * da * das Wortgefecht * von beiden Seiten * überaus unsachlich * geführt wurde.

Ein/e/n Gegner/in des umstrittenen Staudammprojekts * hatte/n * die Planer * schließlich * doch noch überzeugt, * aber * es * herrscht * Stillschweigen * darüber, * wie, * weil * niemand * sich * dem Verdacht der Bestechlichkeit * aussetzen will.

Ein/e/n Soldat/en/in der gegnerischen Streitkräfte * hatte/n * die ausgesandten Kundschafter * offenbar * in die Irre geführt, * aber * der Befehlshaber * begriff * einfach * nicht, * wie, * obwohl * ihm * die Finte * mehrmals * erklärt worden war.