Abstract

Probabilistic expectations and memory limitations are central factors governing the real-time comprehension of natural language, but how the two factors interact remains poorly understood. One respect in which the two factors have come into theoretical conflict is the documentation of both locality effects, in which more dependents preceding a governing verb increase processing difficulty at the verb, and anti-locality effects, in which more preceding dependents facilitate processing at the verb. However, no controlled study has previously demonstrated both locality and anti-locality effects in the same type of dependency relation within the same language. Also, many previous demonstrations of anti-locality effects have been potentially confounded with lexical identity, plausibility, and sentence position. Here, we provide the first evidence of both locality and anti-locality effects in the same type of dependency relation in a single language—verb-final constructions in German—while controlling for lexical identity, plausibility, and sentence position. In main clauses, we find clear anti-locality effects, with the presence of a preceding dative argument facilitating processing at the final verb; in subject-extracted relative clauses with identical linear ordering of verbal dependents, we find both anti-locality and locality effects, with processing facilitated when the verb is preceded by a dative argument alone, but hindered when the verb is preceded by both the dative argument and an adjunct. These results indicate that both expectations and memory limitations need to be accounted for in any complete theory of online syntactic comprehension.

Keywords: Sentence Comprehension; Memory limitations in language comprehension; Parsing; Prediction

Introduction

A large body of experimental evidence in psycholinguistics indicates that the human sentence processor is able to build up expectations about upcoming linguistic material based on the input it has received so far, and that these expectations can influence both real-time comprehension behavior and the neural correlates of language comprehension (Ehrlich & Rayner, 1981; Kutas & Hillyard, 1980, 1984; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995; Altmann & Kamide, 1999). Although earlier work documenting these effects focused primarily on expectations at the lexical level, more recent work has provided evidence for expectations at the level of syntactic constituency on the basis of grammatical analysis of prior linguistic content (Lau, Stroud, Plesch & Phillips, 2006; Staub & Clifton, 2006; Staub, Clifton & Frazier, 2006; Jaeger, Fedorenko & Gibson, 2009).

A particularly clear example of how online processing can be sharply modulated by fine-grained differences in the grammatical structure of preceding context is provided by Konieczny & Döring (2003), who investigated verb-final structures in German such as (1) below:
The preceding contexts in (1a) and (1b) differ by only a change in a single character—s versus m—but this difference dramatically changes the grammatical structure of the sentence: in (1a), des Kunden is a genitive postmodifier of the noun Freund, whereas in (1b), dem Kunden is a dative dependent of the subordinate verb verkaufte. Intuitively, encountering a preverbal dative constrains the argument structure of the yet-to-be-seen subordinate verb, which sharpens expectations about both when the verb will appear and what it will turn out to be when it appears (Konieczny, 1996; Levy, 2008a). Konieczny & Döring (2003) found evidence supportive of this intuition in a free-reading eye-tracking experiment: regression-path durations (the time elapsed between first fixation on a word and the first fixation beyond it) were shorter for the subordinate verb in the verbal-dependent condition (1b) than in the nominal-dependent condition (1a). However, it was not simply the presence of more preverbal dependents that triggered this expectation-based facilitation: Konieczny & Döring also manipulated the type of PP immediately preceding the subordinate verb, comparing a PP post-modifying the preceding NP, such as aus Plastik, with a preverbal-dependent PP, such as aus Freude. This manipulation did not have a significant effect on reading behavior. Konieczny & Döring’s 2003 study therefore provides evidence for expectation-based facilitation, but only derived from complements of the verb, not for modifiers such as PP adjuncts which intuitively place much less constraint on the governing verb than complements do.

Such effects are sometimes referred to as anti-locality effects, because they run contrary to standard assumptions regarding the processing cost incurred when the sentence processor has to complete dependency relations between previous input and the word currently processed—in the case of (1), the dependencies between the verb verkaufte and its subject der Freund and object das Auto, plus the indirect object dem Kunden and/or the adjunct aus Freude in the appropriate conditions. The theories most closely associated with these notions of dependency-completion processing cost are Dependency Locality Theory (DLT, Gibson 2000; Grodner & Gibson 2005; also known as Syntactic Prediction Locality Theory, Gibson 1998) and Similarity-based Interference (SBI, Gordon, Hendrick & Johnson 2001, 2004; Gordon, Hendrick, Johnson & Lee 2006; Lewis & Vasishth 2005; Lewis, Vasishth & Van Dyke 2006; Van Dyke & Lewis 2003). In DLT, dependency completion involves an integration cost determined by the number and distance of the dependents that precede the current word. In SBI, retrieval of preceding dependents is a precondition for dependency completion, and this retrieval process is subject to interference from similar constituents elsewhere in previous input. To go into slightly greater detail regarding these dependency completion cost theories: in standard DLT theory, the integration cost for each preceding dependent is equal to the number of discourse referents (effectively, the number of NPs) intervening between the dependent and the current word; and total
integration cost is the sum of integration costs across all previous dependents.\(^1\) In (1b), for example, the integration cost at *verkaufte* would be 2 units greater than in (1a), since *dem Kunden* is a preverbal dependent only in (1b), and two discourse referents intervene between it and the clause-final verb. Both theories thus predict locality effects for examples like (1): adding the dative NP should make processing more difficult, rather than easier, given that an additional dependent has to be integrated at the subordinate verb.

Substantial evidence has been adduced for locality effects in English (see Gibson 1998, for an overview), and more recent evidence has suggested the presence of strong locality effects in the processing of Chinese relative clauses (Hsiao & Gibson, 2003) and Russian relative clauses (Levy, Fedorenko & Gibson, 2007). However, locality effects have been elusive in many other languages, including German, Japanese, and Hindi, where *anti-locality* effects of the type found by Konieczny & Döring have been reported (Konieczny, 2000; Nakatani & Gibson, 2008; Vasishth & Lewis, 2006): adding a preverbal dependent facilitates rather than hinders processing at the clause-final verb. A locality-based interpretation of the Konieczny & Döring results might be that the traditional method of quantifying integration cost is wrong. For example, perhaps the total integration cost at a final verb should be taken to be the maximum of the integration costs of each preceding dependent, rather than the sum—a measure that would be natural if integration of preceding dependents were assumed to occur in parallel rather than serially. On this view, the total integration costs in (1a) and (1b) should be identical, since *der Freund* has the highest integration cost of any preverbal dependent, and is separated from its governing verb by the same number of discourse referents. However, the data of Konieczny (2000) speak against this possibility. Among other conditions, Konieczny had participants read sentences of the following form:

(2) a. Er hat die Rose hingelegt, und . . .  
    He has the rose laid down, and . . .
    “He put down the rose, and . . .”

    b. Er hat die Rose auf den Tisch gelegt, und . . .  
    He has the rose on the table laid, and . . .
    “He put the rose on the table, and . . .”

Here, *die Rose* (or *Er*, if it is considered dependent on the participle *(hin)gelegt* rather than on the auxiliary *hat*) is the most distant dependent from the final participial verb *(hin)gelegt*, and is separated from the governing verb by more discourse referents in (2b) than in (2a). Hence both maximum and total integration costs are higher in (2b) than in (2a). Contra to the predictions of DLT and SBI, however, Konieczny found shorter reading times on the final participial verb in (2b) than in (2a). However, there are several crucial confounds in this earlier study: the participial verb’s position within the sentence and the identity of the immediately preceding word—both of which are believed to affect reading times (Mitchell, 1984; Ferreira & Henderson, 1993)—vary across conditions, and in many items, such as the one in (2), the participial verb itself varied across condition as well. Furthermore, neither the Konieczny (2000) nor the Konieczny & Döring (2003) studies controlled for sentence plausibility, which also are known to affect reading times under some circumstances (Traxler & Pickering, 1996; Ni, Crain & Shankweiler, 1996; Garnsey, Perlmutter, Meyers & Lotocky, 1997; Rayner, Warren, Juhasz & Liversedge, 2004).

A conclusive account of the presence or absence of locality effects in German is thus still lacking, but would be of considerable interest given the combination of locality and anti-locality results across multiple

\(^1\)The predictions of SBI would be qualitatively similar in the cases examined in this paper, but precise quantification is more complex due to its dependence on the similarity-space representations of all constituents involved. For simplicity, we therefore use DLT integration costs to exemplify predictions that we would expect to hold of both theories.
experiments in a variety of language. There have been some recent signs that even within a single language, an adequate sentence-processing mechanism must be able to account for both locality and anti-locality effects in verbal processing: Jaeger et al. (2009) demonstrate anti-locality effects at verbs in English, and Demberg & Keller (2008a) found evidence for both locality and expectation effects in an eye-tracking corpus of English newspaper text. However, it has not been previously demonstrated in controlled experiments that both locality and anti-locality effects can arise in a single syntactic dependency configuration in a single language. Such a finding would provide even stronger evidence that a complete model of human sentence processing must be able to account for both types of effects. We report such a finding in this paper, showing that both locality and expectation effects can be found in clause-final verbs in German. The key difference between our results and previous work on German verbal processing is that we find that locality effects are only detectable at much higher level of memory load than have previously been studied. In this situation, both locality and anti-locality effects can manifest themselves simultaneously.

**Experiment 1**

The design of our first experiment is qualitatively similar to that of Konieczny (2000) and Konieczny & Döring (2003)—investigating the effects of adding preverbal dependents varying in predictive value to a verb-final clause—but eliminates several confounds present in previous work, including identity of the critical verb and the words immediately preceding it, position of the critical verb within the sentence, and plausibility. Furthermore, we constructed our materials so that memory loads would be much higher than has been used in previous experiments on verb-final processing in any language, intuitively maximizing the opportunity of finding locality effects. The materials of Konieczny & Döring (2003), for example (see (1)), did not include a strong memory load manipulation: by the DLT metric (Gibson, 2000), the dative NP *dem Kunden* incurs an integration cost of two at the main verb, as there are two discourse referents intervening between the dative NP and the verb (*das Auto* and *aus Freude* or *aus Plastik*). Furthermore, the integration of the verb-modifying adjunct *aus Freude* incurs an integration cost of zero, as it is directly adjacent to the verb it needs to be integrated with, resulting in a distance of zero. It follows that the dative and the adjunct NP in (1) only trigger a relatively small change in integration cost (two additional units); this could be the reason for the absence of locality effects in Konieczny & Döring’s 2003 study. It seems possible that locality effects might become visible in an experiment that increased the number of intervening discourse referents more drastically.

Our design picks up on this idea, and can be illustrated using the simplified examples in (3). We manipulated two factors: the presence of a dative NP such as *dem Sohn* (“the.DAT son”) in the subordinate clause, and the presence of a PP adjunct modifying the verb such as *zur Ahndung* (“as payback”). The resulting sentence contains neither the dative nor the adjunct as in (3a), or just the adjunct or just the dative as in (3b) and (3c), or both as in (3d).

(3) a. Hans hat den Fußball versteckt.  
   Hans has the.ACC football hidden.  
   “Hans hid the football.”

b. Hans hat zur Ahndung den Fußball versteckt.  
   Hans has as payback the.ACC football hidden.  
   “Hans hid the football as payback.”

c. Hans hat dem Sohn den Fußball versteckt.  
   Hans has the.DAT son the.ACC football hidden.  
   “Hans hid the football from the son.”
d. Hans hat zur Abndung dem Sohn den Fußball versteckt.
   Hans has as payback the.DAT son the.ACC football hidden.
   “Hans hid the football from the son as payback.”

Critical to the design of this and previous experiments on German verbal processing is that most clauses are verb-final: relatively early in the reading of the sentence, the comprehender obtains sufficient information to infer that the clause will end with a verb (possibly participial, depending on the preceding syntactic context). In the case of the sentences in (3), the key piece of information is the use of the second-position auxiliary verb hat, which is a strong sign that the clause is in the present perfect tense, which requires a verb-final participle.\(^2\)

As it stands in (3) above, there is a potential confound in this design: the four versions of the sentence vary in the length of the material preceding the participial verb (we expect locality or expectation effects to appear on this verb). Previous results have indicated that the reading time of a word may be correlated with its position in the sentence (Ferreira & Henderson, 1993; Demberg & Keller, 2008a), which would confound any findings that adding material can speed processing a subsequent verb (and which might indeed confound previous reports of anti-locality effects such as Konieczny, 2000).\(^3\) We address this confound by including additional material preceding the main clause: a subordinate clause with a dative-taking optionally ditransitive verb. This allows us simply to move the dative complement and/or the PP adjunct from the main clause to the subordinate clause to achieve the appropriate configuration for each condition.

The qualitative predictions for this experiment are illustrated in Figure 1. The left panel of this figure graphs the schematic pattern of results that we expect to observe under the expectation-only hypothesis. As we add more phrases to the main clause, processing becomes easier, as the main clause verb becomes more and more expected. Hence (3a) (neither dative nor adjunct in the main clause) should be hardest to process, while (3d) should be easiest (both dative and adjunct in the main clause). (3b) and (3c) should be in between (one phrase in the main clause). To the extent that dative NPs and PP adjuncts turn out to have different predictive strength for the clause-final verbs in our materials, however, adding each may have a facilitative main effect of different strength.

The right panel of Figure 1 illustrates the schematic pattern of results expected under a locality-only hypothesis: processing becomes more difficult as we add more phrases to the main clause, because these phrases have to be integrated at the main-clause verb. We would therefore expect (3a) to be least difficult, (3d) to be most difficult, and (3b) and (3c) to be of intermediate difficulty. To the extent that locality effects from multiple preverbal dependencies are super-additive, the precise predictions regarding reading time in the hardest main/main condition may differ from the schematic depiction of Figure 1.

The results of Konieczny (2000) and Konieczny & Döring (2003) provide some support for the expectation-only hypothesis, as no locality effects were found in their experiment. However, at the beginning of this section, we conjectured that they may have failed to find locality effects because their stimuli did not involve a large enough memory load. If we assume that large memory load is required to override expectation effects, then locality effects would be likely to kick in only in the last condition, in which the dative and the adjunct phrase are both in the main clause and have to be integrated. In this case, the experiment should

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\(^2\)In the simplified example (3a), there is a temporary ambiguity such that previous to reading versteckt, the auxiliary verb hat could be misinterpreted as being a simple-present possessive verb, giving the sentence the meaning “Hans has the football.” In our actual experimental materials, however, the contents of the sentence-initial subordinate clause rule out this interpretation; see (4) for a full example item.

\(^3\)We note in passing that this relationship between sentence position and reading time is not universally agreed upon; see, e.g., Vasishth (2003).
show an interaction of expectation and locality effects, leading to the pattern of results schematically depicted in Figure 2. On this pattern, reading time should decrease if only one of the dative or adjunct appears in the main clause, but should stay the same or increase if both of them are in the main clause.

**Corpus Analysis**

In order to verify that probabilistic expectations should indeed predict the patterns described above, we conducted a corpus analysis of German main clauses to determine the effects of preverbal dative and adjunct dependents on expectations about the final verb. These expectations can usefully be divided into expectations about (i) whether the verb will appear next at any point in online comprehension, and (ii) if the final verb is the next word, what verb it may be. In the language of probability theory, these expectations can be described as

(i) $P(w_i = \text{participial verb}|w_{1...i-1})$

(ii) $P(w_i|w_{1...i-1}, w_i = \text{participial verb})$

The type of corpus data most useful for estimating these probabilities is hand-parsed data such as the NEGRA and TIGER treebanks of German newspaper text (Brants, Skut & Uszkoreit, 1999; Brants, Dipper, Hansen, Lezius & Smith, 2002). Unfortunately, insufficient data are available to easily estimate wordspecific probabilities (ii) above for the range of experimental materials we used (our choice of participial verbs was heavily constrained by the requirement that they be optionally ditransitive). Intuitively, however, it
seems fairly clear that adding a dative to the main clause should sharpen online expectations in the direction of the participial verbs appearing in our experiment: without the dative, the argument-structure constraints placed on the final verb by its preceding dependents simply limit it to the relatively large set of transitive verbs, whereas adding the preverbal dative NP restricts the final verb to the considerably narrower set of ditransitive verbs. Likewise, it seems fairly clear that adding a PP adjunct should not place as strong a constraint as a dative NP on verb identity, since any verb (subject to the relatively general semantic constraints imposed by the adjuncts we use) can take an adjunct.

We can, however, use corpus data to estimate the probability that the next word in a sentence will be a verb, using the syntactic annotation from hand-parsed data. Focusing on the constituency structure of the main clausal constituents, we conducted tree searches in the combined NEGRA and TIGER corpora for syntactic configurations in which a second-position finite auxiliary is followed (not necessarily immediately) in its clause by an accusative NP, with a PP adjunct and/or dative NP possibly preceding the accusative NP in that order; and for extensions of these syntactic configurations in which the accusative NP is immediately followed by a participial verb. These searches (explained in fuller detail in Appendix A) were used to compute relative frequency estimates of probability (i); the results are given in Table 1. Fisher’s exact test indicates that conditional verb probability is significantly higher in the dative+accusative-preceding condition than in the accusative-preceding and PP+accusative-preceding conditions ($p < 0.001$ in both cases); few examples were found in the PP+dative+accusative-preceding condition, but the limited data that are available suggest that its behavior is similar to the dative+accusative-preceding condition. These results provide corroboratory evidence for the qualitative nature of the expectation-based predictions given in the previous section.

### Table 1: Conditional probabilities $P(w_i = \text{participial verb} | w_{1...i-1})$ for Experiment 1 syntactic configurations, as estimated from tree searches in the combined NEGRA and TIGER corpora.

<table>
<thead>
<tr>
<th></th>
<th>NP.ACC</th>
<th>NP.DAT</th>
<th>NP.ACC</th>
<th>PP NP.ACC</th>
<th>PP NP.DAT</th>
<th>NP.ACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support</td>
<td>1915</td>
<td>78</td>
<td>603</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P(w_i = \text{participial verb}</td>
<td>w_{1...i-1})$</td>
<td>0.546</td>
<td>0.756</td>
<td>0.504</td>
<td>0.727</td>
<td></td>
</tr>
</tbody>
</table>

Method

Participants. Twenty-eight native speakers of German resident in Edinburgh were paid to participate in the experiment.

Stimuli. Thirty-two experimental items were constructed. Each contained a subordinate clause followed by a main clause, both of which were headed by dative-selecting optionally ditransitive verbs. In the subordinate clause, the verb was in simple past tense; in the main clause, the verb was in the present perfect form hat...participle, so that it was clear after reading of the first few words of the main clause that it would end with an obligatory participle. For simplicity, we refer to this final participle as the “clause-final verb” or just the “final verb”. We manipulated two factors: the position of a dative NP (subordinate or main clause) and the position of a PP adjunct (subordinate or main clause), and designed each sentence so that all four positionings of the two phrases would result in as natural a sentence as possible. The final verb was followed by a comma (obligatory in German prescriptive grammar) and then by a conjoined participial verb phrase, the beginning of which served as a spillover region (see Data Analysis).

In order to ensure high memory load and thus maximize the chances of observing any underlying locality effect at the clause-final verb, we used long dative NPs and long PP adjuncts, each of which introduced two discourse referents. A set of example stimuli is given in (4):
(4) a. Nachdem der Lehrer zur zusätzlichen Ahndung des mehrfachen Fehlverhaltens dem ungezogenen Sohn des fleißigen Hausmeisters den Strafunterricht  
   determination classes imposed, has Hans Gerstner den Fußball versteckt, und damit die Sache bereinigt.  
   “After the teacher imposed detention classes on the naughty son of the industrious janitor, Hans Gerstner hid the football, and thus corrected the affair.”

b. Nachdem der Lehrer dem ungezogenen Sohn des fleißigen Hausmeisters den Strafunterricht verhängte, hat Hans Gerstner zur zusätzlichen Ahndung des the.ACC football hidden, and thus the affair corrected.  
   “After the teacher imposed detention classes on the naughty son of the industrious janitor as additional payback for the multiple wrongdoings, Hans Gerstner hid the football, and thus corrected the affair.”

c. Nachdem der Lehrer zur zusätzlichen Ahndung des mehrfachen Fehlverhaltens den Strafunterricht  
   determination classes imposed, has Hans Gerstner the.DAT naughty son the.GEN industrious janitor  
   the.ACC football hidden, and thus the affair corrected.  
   “After the teacher imposed detention classes on the naughty son of the industrious janitor, Hans Gerstner hid the football from the naughty son of the industrious janitor, and thus corrected the affair.”

d. Nachdem der Lehrer den Strafunterricht verhängte, hat Hans Gerstner zur zusätzlichen Ahndung des mehrfachen Fehlverhaltens den ungezogenen Sohn des fleißigen Hausmeisters den Strafunterricht  
   determination classes imposed, has Hans Gerstner as additional payback for multiple wrongdoings the.DAT naughty son the.GEN industrious janitor  
   the.ACC football hidden, and thus the affair corrected.  
   “After the teacher imposed detention classes as additional payback for the multiple wrongdoings, Hans Gerstner hid the football from the naughty son of the industrious janitor, and thus corrected the affair.”

The critical region used for analysis was the verb of the main clause (versteckt in this example). Note that the memory load at this point is now quite considerable: in DLT terms, for example, in the most extreme condition (example (4d)) there is an integration cost of four for the PP adjunct (as there are four intervening discourse referents) and two for the dative object, resulting in a total additional cost (beyond that in (4a)) of six, as opposed to the additional cost of two in (1) from Konieczny & Döring (2003). Additionally, this design rules out a number of confounds that have been present in previous work, ensuring that the sentences are of the same length across all conditions; that exactly the same words precede the critical region (though in different orders) across conditions, so that position in the sentence is identical across conditions; and that
Table 2: Mean plausibility ratings per condition for the pretest for Experiment 1; reduced data set with 24 items. The factors are: dative position (dat) and adjunct position (adj), each with the two levels main clause and subordinate clause.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>dat = sub, adj = sub</td>
<td>4.54</td>
</tr>
<tr>
<td>dat = main, adj = sub</td>
<td>4.56</td>
</tr>
<tr>
<td>dat = sub, adj = main</td>
<td>4.73</td>
</tr>
<tr>
<td>dat = main, adj = main</td>
<td>4.70</td>
</tr>
</tbody>
</table>

the critical region and immediately preceding words are the same across conditions.

Pretest. It is possible that adding and removing dative complements and PP adjuncts changes the plausibility of the sentences constructed for this experiment. Prior to conducting our reading study, we therefore normed our materials for plausibility, both to minimize the discrepancy in plausibility across conditions and to use plausibility ratings as a predictor in trial-level data analysis. The norming procedure was as follows. As we were primarily interested in reading behavior at the critical verb (*versteckt* in (4) above), we presented versions of our sentences ending in a period immediately after the critical verb, discarding the final *und damit* . . . phrase but leaving the rest of the sentence untouched. Fifty-nine native German speakers rated the plausibility of our experimental items in this form on a scale of 1 (least plausible) to 7 (most plausible). The 128 experimental materials (32 items in four conditions each) were divided into four lists, such that each list contained exactly one condition of each item, and in any given list, each condition occurred the same number of times (Latin square design). Each list was combined with the same 21 fillers; a separate randomization was generated for each participant. We constructed seven of the fillers to be uncontroversially plausible sentences, seven to involve a highly implausible relationship between a sentence-initial subordinate clause and the main clause, and seven to involve violations of the main verb’s argument structure. The pretest was administered over the web using WebExp (Keller, Gunasekharan, Mayo & Corley, 2009).

The mean rating of the plausible fillers was 6.23; of the implausible clause-relationship fillers, 1.96; and of the argument structure violations, 1.67. This wide range indicates that participants made robust distinctions of plausibility for uncontroversially good and bad stimuli. We then used the plausibility ratings for the experimental materials to select the sentences to be used in the subsequent eye-tracking study. An analysis of the mean judgments per item indicated that one item had an untypically low mean rating of 2.39, compared to the global item mean of 4.52. We discarded this item, together with the seven items exhibiting the greatest dative penalty (defined as the difference between the mean scores in the main-clause dative and subordinate-clause dative conditions). This yielded a final set of 24 items with the mean ratings per condition listed in Table 2.

An analysis of variance on this set showed no significant effect of adjunct position and no interaction of adjunct and dative position. There was, however, a significant effect of dative position by participants ($F_1(1,58) = 14.31, p < .001$), but not by items ($F_2(1,23) = 3.14, p > .05$). This effect was small, with a mean dative penalty of .16. We did not expect that reading times would be affected by such a small difference in plausibility—an expectation that was borne out, as will be seen in the Results section—and therefore included all 24 of these final items in the eye-tracking study (see Appendix B for the full item set).

Procedure. The remaining 96 experimental materials (24 items in four conditions each) were divided into four lists, such that each list contained exactly one condition of each item, and in any given list, each condition occurred the same number of times (Latin square design). Each list was combined with the same 44 fillers; a separate randomization was generated for each participant. Line breaks were inserted into the items such that the critical region was always in the middle of the third or fourth line, and was always both preceded and followed by at least three words on the same line.
The experiment was run using an Eyelink II head-mounted eye-tracking system, with a sampling rate of 500 Hz. An eye-dominance test was administered for each participant before the experiment began, and only the dominant eye was tracked. A calibration procedure was carried out, and if the calibration was successful, the experiment began. Stimuli were presented with the aid of Eyetrack software developed at the University of Massachusetts at Amherst. Each trial began with a gaze trigger, in the form of a black square that was displayed at the left edge of the screen in a vertically central position. This square occupied the position of the start of the stimulus text, and when the participant fixated the square, it was automatically replaced by the stimulus text. When the participant had finished reading the text, he/she pressed a button on a game pad. Following half of the items, a yes/no question was then displayed on the screen. The participant answered the questions by pressing one of two pre-specified buttons on the game pad. If the automatic gaze contingent stimulus presentation failed on any given trial, the calibration procedure was repeated, and the trial was initiated again. The experimental trials were preceded by four practice trials. The total duration of the experiment was around 35 minutes.

Data Analysis. Vertical drift in the positions of fixations was corrected, using custom software developed at UMass (see footnote 4). An automatic procedure then pooled short contiguous fixations. The procedure incorporated fixations of less than 80 ms into larger fixations within one character, and then deleted any remaining fixations of less than 40 ms. Readers do not extract much information during such short fixations (Rayner & Pollatsek, 1989).

The experimental sentences were divided into four regions. The first region consisted of all words from the start of the sentence up to (but excluding) the main verb. The second, critical, region was the main verb. The third, spill-over, region consisted of the two words following the main verb. The final region comprised the rest of the sentence. The region boundaries for an example sentence are given below:


We report data for the following eye-movement measures in the critical and spill-over regions. First fixation duration is the duration of the first fixation in a region, provided that there was no earlier fixation on material beyond the region (in which case first fixation duration is zero). First pass time (often called gaze duration for single-word regions) consists of the sum of fixation durations beginning with this first fixation in the region until the first saccade out of the region, either to the left or to the right. Regression path time is computed as the sum of fixation durations beginning with the first fixation in the region until the first saccade out of the region to the right. Note that this may include fixations to the left of the region if there is a regression before the reader moves on to the next region. Total time consists of the sum of all fixation durations in the region, regardless of when these fixations occur. Second pass time consists of the sum of all fixation durations following the first exit of the region (either to right or left). In addition to these reading time measures, we also report the first pass regressions measure, which indicates the proportion of trials in which initial first-pass reading is immediately followed by a regressive saccade exiting the region to the left.

For all eye-movement measures except second pass time, if on any given trial the region received no fixations, then the data for that trial was not included in the analysis. Moreover, for first pass time, regression path time and first pass regressions, no trial in which the region is skipped on first-pass reading (i.e., when first-fixation duration is zero) was included in the analysis. We present separate analyses on skipping rate.

4Downloadable from http://www.psych.umass.edu/eyelab/software/.
a measure which indicates the proportion of trials in which the region was skipped completely on first-pass reading.

Data for the reading time measures were analyzed using Linear Mixed Effects Regression (LMER) analysis (Baayen, 2008; Baayen, Davidson & Bates, 2008). LMER has the advantage of allowing the simultaneous consideration of participants and items as random factors in a single analysis, thus avoiding the need for separate $F_1$ and $F_2$ and Min $F'$ analyses. Moreover, LMER is robust in the face of missing data, a situation that is common in eye-tracking research. Furthermore, LMER models make it possible to include random slopes in the analysis, i.e., to account for the fact that the effect of a given factor may vary across participants.

First-pass regression and skipping rate data were analyzed using mixed-effects logistic regression (Jaeger, 2008). This is necessary because the trial-by-trial data for these measures corresponds to a binary response variable, for which standard LMER—which assumes that the response variable is normally distributed around the predicted mean—would be inappropriate (see Baayen 2008, p. 215).

For random-effects structure, we follow Baayen (2008) in including the possibility of random slopes into our models, noting that failing to include random slopes in models when analyzing data with considerable underlying idiosyncratic by-participants or by-items differences can lead to anti-conservative inferences on fixed effects (see, e.g., Roland, 2009 for discussion). We use forward model selection to determine the appropriate random-effects structure, fitting a series of three nested models for each analysis:

1. **Random intercepts**: This model includes only the main effects of our two fixed factors (dative NP position and PP adjunct position) and their interaction, as well as random intercepts of participants and items. The formal lme4 specification is: $rt \sim dat \times adj + (1|part) + (1|item)$.

2. **Random slopes**: This model includes random intercepts as well as random slopes for the main effects of the two fixed factors. The formal lme4 specification is: $rt \sim dat \times adj + (dat + adj|part) + (dat + adj|item)$.

3. **Random interaction**: This model also adds random slopes for the interaction of the fixed factors. The formal lme4 specification is: $rt \sim dat \times adj + (dat \times adj|part) + (dat \times adj|item)$.

Each successive pair of models—fit using restricted maximum likelihood (REML; Pinheiro & Bates, 2000) for linear models, Laplace-approximated maximum likelihood for logit models—is compared using a likelihood ratio test, and significance is evaluated against the $\chi^2$ distribution, taking as the degrees of freedom the difference in number of parameters between the two successive models (see Baayen 2008, p. 276). The best fitting model is taken to be the most complex model with significantly better fit ($p < 0.05$ criterion) over all simpler models. For example, if random slopes for main effects yield a better fit than random intercepts alone, but random interactions do not lead to any further improvement, then we select the random-slopes model. Given that model evaluation takes into account the number of parameters of each model, this strategy selects the model that gives the most economical and accurate account of the empirical data.

We report the significance of model coefficients based on highest posterior density confidence intervals computed using Markov chain Monte Carlo (MCMC) sampling (see Baayen 2008, p. 270) with 10,000 iterations. However, MCMC sampling is not available for models with random slopes or for mixed logit models. Therefore, for random-slope mixed linear models we instead report $p$-values based on the $t$-statistic conventionally used in linear regression analysis, and for mixed logit models we report $p$-values based on the Wald $Z$ statistic conventionally used in logistic regression analysis. Note that maximum likelihood rather than REML is used for inference on random-slope and random-interaction linear mixed model coefficients, following Baayen (2008). In all analyses, we center all fixed effects around their means, which minimizes collinearity in analyses of balanced datasets such as ours.
Table 3: Empirical means for the eye-movement measures in critical and spill-over regions in Experiment 1 in milliseconds. The factors are: dative position (dat) and adjunct position (adj), each with the two levels main clause and subordinate clause.

<table>
<thead>
<tr>
<th></th>
<th>dat = sub</th>
<th>dat = main</th>
<th>adj = sub</th>
<th>adj = main</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical region</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First fixation</td>
<td>254</td>
<td>277</td>
<td>249</td>
<td>259</td>
</tr>
<tr>
<td>First pass</td>
<td>338</td>
<td>354</td>
<td>321</td>
<td>312</td>
</tr>
<tr>
<td>Regression path</td>
<td>595</td>
<td>667</td>
<td>649</td>
<td>518</td>
</tr>
<tr>
<td>Total time</td>
<td>694</td>
<td>728</td>
<td>637</td>
<td>576</td>
</tr>
<tr>
<td>Second pass</td>
<td>318</td>
<td>300</td>
<td>256</td>
<td>216</td>
</tr>
<tr>
<td>Regressions</td>
<td>.238</td>
<td>.214</td>
<td>.238</td>
<td>.250</td>
</tr>
<tr>
<td>Skipping</td>
<td>.048</td>
<td>.024</td>
<td>.048</td>
<td>.042</td>
</tr>
<tr>
<td>Spill-over region</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First fixation</td>
<td>218</td>
<td>211</td>
<td>214</td>
<td>214</td>
</tr>
<tr>
<td>First pass</td>
<td>293</td>
<td>313</td>
<td>296</td>
<td>296</td>
</tr>
<tr>
<td>Regression path</td>
<td>411</td>
<td>383</td>
<td>369</td>
<td>435</td>
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<tr>
<td>Total time</td>
<td>631</td>
<td>562</td>
<td>538</td>
<td>522</td>
</tr>
<tr>
<td>Second pass</td>
<td>293</td>
<td>235</td>
<td>220</td>
<td>202</td>
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<tr>
<td>Regressions</td>
<td>.101</td>
<td>.077</td>
<td>.053</td>
<td>.077</td>
</tr>
<tr>
<td>Skipping</td>
<td>.149</td>
<td>.060</td>
<td>.089</td>
<td>.149</td>
</tr>
</tbody>
</table>

Results

Question-answering accuracy

We also analyzed the answers participants provided to the comprehension questions. Per-participant accuracy ranged from 67.6% to 89.2%, with a mean of 79.4%. Accuracy did not differ significantly across lists.

Eye movement measures

Table 3 shows the empirical means for the critical and spill-over regions, in the seven eye-movement measures. Table 4 lists the results of the LMER analysis; model coefficients need to be interpreted in the context of our factor coding. Centering of our fixed effects resulted in a value of approximately $-0.5$ for main-clause positioning of datives and adjuncts, and approximately 0.5 for subordinate-clause positioning. For main effects, positive coefficients thus mean longer reading times or propensity toward regression/skipping when the constituent in question is in the main clause; negative coefficients mean the reverse. Likewise, a positive interaction coefficient indicates that reading time or propensity toward regression/skipping is greater when both the dative and the adjunct phrases are in the same clause.

Table 4 thus indicates that dative position is a significant factor in first pass, total time, and second pass in the critical region, with shorter reading times when the dative NP is in the main clause. The same effect is present in the spillover region in total and second-pass times. The effect is illustrated by Figure 3, which depicts the model’s predicted mean total time in each condition; patterns in the other measures and in the spillover region are similar.

5In practice the values of the factors will deviate slightly from $-0.5$ and 0.5 due to slight imbalance from trials with missing data.
Adjunct positioning was a significant factor only in critical-region first-fixation times, which were longer when the adjunct was in the main clause.

In none of the measures did the interaction of dative and adjunct position reach significance, with the exception of skipping rate in the spill-over region. Here, we find a highly significant interaction of dative and adjunct phrase position, with a negative coefficient, indicating that there is significantly less skipping if the dative and adjunct phrases are in the same clause. This result merits further discussion, since it does not pattern with any of the other significant results in this experiment. In many of our experimental stimuli, the critical and spillover regions did not lie on the final line of text; close inspection of our stimuli revealed that the number of characters following the spillover region on the same line of text varied considerably across conditions, and patterned similarly with skipping rates: 19.6 characters on average followed the spillover region on the same line in the condition where the dative & adjunct phrases were both in the main clause (the “main/main”) condition; 10.2 characters on average in the main/sub condition; 9.6 characters in the sub/main condition, and 16.5 characters in the sub/sub condition. It is possible that readers planned their eye movements on the line of text containing critical and spillover regions such that the final fixation or fixations lay several characters from the end of the text. This would predict that when the number of characters following the spillover region on the same line was small, the skip rate should be lower than otherwise, since the spillover region would fall in an area attracting the last fixations on the line. We tested this hypothesis by entering the number of characters following spillover into a mixed logit regression analysis of skip rate, with random by-subject and by-item intercepts. Number of characters following spillover had a highly significant effect in the predicted direction (β = −0.048, p < 0.01) on skip rate. We also entered this covariate together with main effects and interaction of (centered) dative and adjunct position; in this model, no factors turned out to be significant (p = 0.103 for number of characters following spillover, and p = 0.102 for the
adjunct/dative interaction). We thus conclude that the dative/adjunct interaction on spillover-region skip rate seen in Table 4 is most likely the product of a confound with the physical positioning of our stimuli on the screen.

To ensure that the other results of this experiment are not being driven by this confound, we also entered number of characters following the spillover region into mixed regression analyses of all models giving significant results reported in Table 4. Including this covariate had no effect on the qualitative patterns observed; all the results shown as significant in Table 4 stayed significant. Number of characters following the spillover region did show up in these analyses as a significant or marginally significant predictor of total reading times at the critical region, and total and second-pass at the spillover region, with shorter reading times in all cases when more characters followed ($\beta = -4.6, -5.4, -3.8; p = 0.07, 0.02, 0.051$ respectively), confirming that the physical positioning of our stimuli on the screen did have some effects on eye movements. Finally, the analysis of spillover-region total reading time including characters following the spillover region revealed a dative/adjunct interaction just passing the threshold for significance ($p = 0.042$), with RTs higher when both phrases appeared in the same clause ($\beta = 136$). This could be weak support for our interactive hypothesis, and issue that will be revisited in Experiment 2 and in the General Discussion.

The final remaining possible confound we address is the small plausibility differential in our items as a function of dative-phrase positioning. Our pretest revealed that structures with a dative NP in the main clause received significantly higher plausibility ratings than structures with a dative in the subordinate clause, even after selecting a more balanced subset (see Table 2). If we assume that processing is easier when the sentence being read is more plausible, then this could explain why we obtained shorter reading times when the dative was positioned in the main clause. We investigated this possibility by fitting a linear mixed effects model that included the factors dative and adjunct position, as well as plausibility, where plausibility was defined as the mean plausibility judgment an item had received in the pretest. The mixed model for total time (formal specification: $rt \sim dat \times adj \times plaus + (1|part) + (1|item)$) yielded a signif-

Figure 3: Per-condition means predicted by the mixed model for total time in the critical region for Experiment 1. Error bars show the 95% confidence interval for the coefficient of the factor dat.
ncient effect of dative position ($\beta = 91.17, p < .01$), as well as a significant interaction of dative position and plausibility ($\beta = -92.61, p < .05$). All other factors and interactions failed to reach significance. We also compared this model to a model without the factor plausibility (formal specification: $rt \sim dat \ast adj + (1|part) + (1|item)$), and failed to find a significant difference in model fit using the log-likelihood criterion ($\chi^2(4) = 3.53, p > .1$). On the other hand, if we start with a model that only includes plausibility and adjunct position (formal specification: $rt \sim plaus \ast adj + (1|part) + (1|item)$), then we find that adding dative position to this model does result in an improved model fit ($\chi^2(4) = 18.960, p < .001$). This indicates that dative position provides a better explanation than plausibility for the reading time effect we observe. We can therefore safely rule out plausibility as an alternative explanation.

Discussion

We found that the presence of a dative NP in the main clause leads to a decrease in reading time at the main verb. This result, which was observed in first pass time, total time, and second pass time, supports the expectation hypothesis: the presence of additional preverbal material makes it possible to generate expectations about the verb, which is then easier to process. The expectation hypothesis is illustrated by Figure 1 (left panel); the results for total time depicted in Figure 3 show the same pattern (though less pronounced, as we found a significant prediction benefit for dative, but not for adjunct phrases).

This result broadly confirms the findings of Konieczny & Döring (2003), even though their study differed from ours in a number of ways: they found an effect in regression path duration (the only measure they report), and their experiment compared the presence of a dative NP with the presence of a genitive NP in the main clause (see (1)), while our study contrasted the presence of the dative NPs with its absence. Unlike the results of Konieczny (2000), our results cannot be attributed to the number of words in the sentence preceding the critical region—which were the same across conditions—or even to the number of words in the same clause preceding the critical region, since the dative and adjunct phrases were of the same length but only introduction of the dative phrase facilitated critical-region reading. Our results showed only two weak signs of locality effects: a main effect of adjunct position on critical-region first-fixation times, which were longer when the adjunct was in the main clause; and an interaction between dative and adjunct positioning on spillover-region total reading time such that times were longest when both phrases were in the same clause, which emerged only when number of characters following the spillover region was controlled for.

This experiment thus provides strong support for the expectation hypothesis and little evidence for the locality hypothesis. However, there are some weak signs of what may be locality effects, and it is possible that our manipulation of memory load may still not have been sufficient to induce appreciable memory-retrieval-based processing difficulty at the final verb, especially considering the ubiquity of verb-final structures in German. Therefore our second experiment introduces an additional factor that might be expected to add to memory load and retrieval difficulty: relativization.

Experiment 2

In Experiment 2, we increased integration cost further by embedding the main clause from the stimuli used in Experiment 1 into a relative clause. This can be illustrated with the following simplified set of materials:

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6The results for the other measures are consistent with the results for total time. For first fixation and first pass, we find that adding plausibility does not improve model fit. For second pass, we find that adding plausibility improves model fit significantly, resulting in a model in which the only significant factors are dative position ($\beta = 62.18, p < .05$) and plausibility ($\beta = -62.61, p < .01$). This indicates that plausibility and dative position have independent effects on reading time.
Here, the clause that contains the dative or the adjunct NP is a subject relative clause that modifies the head noun Mitschüler; the critical region is the verbal complex in the relative clause, versteckt hat.

There are several reasons why this use of relativization may increase memory load beyond that in Experiment 1. First, the main-clause structure in Experiment 1 involved a second-position auxiliary verb, whereas the auxiliary verb is final in the relative-clause structure here. If a dependency relation is established between the auxiliary and the subject, having established this relation earlier—as in the main-clause structure—might facilitate subsequent retrieval of the subject when the participle is encountered (e.g., in an interference-based theory such as Lewis et al., 2006, this dependency may have assigned features to the subject that help distinguish it from the other preverbal NPs encountered). Second, relativization induces an unbounded dependency, and it is possible that memory retrieval in unbounded dependency construction is especially costly, and/or that the processor devotes more resources to storing an incomplete unbounded dependency than to an incomplete clause-bounded dependency; there would be some logic to such a deployment of working memory resources, since there are fewer guarantees on when an unbounded dependency will be completed.7 Third, as will be seen in corpus analysis, the most complex syntactic configurations in our experiments we use are less common in relative clauses than in main clauses, and one might expect that storing representations of syntactic configurations imposes lower load on memory when the representations are more frequent.

We thus hypothesize that introducing relativization might increase memory load sufficiently to trigger locality effects, at least in the most extreme condition (6), where the processor now has two additional phrases to integrate (dative and adjunct) on top of dealing with the unbounded dependency of the RC’s head noun. If this is the case, then the present experiment should show an interaction of locality and expectation effects on critical-region eye-movement measures, leading to a pattern as in Figure 2.

Corpus Analysis

As with the previous experiment, we conducted a corpus analysis to estimate the probability that the next word in a sentence will be a verb, using tree searches on the syntactic annotation from the combined hand-parsed NEGRA and TIGER corpora (full tree-search details given in Appendix A). The results are shown in Table 5. In all cases, the conditional probabilities are much lower than was found in Experiment 1.

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7One possible interpretation of the results of ERP studies on unbounded dependencies (e.g., Kluender & Kutas, 1993; King & Kutas, 1995; Kaan, Harris, Gibson & Holcomb, 2000; Phillips, Kazarina & Abada, 2005) is that it can be very costly to hold an unbounded dependency in memory for a long time.
because previous context does not indicate whether the tense of the relative clause is present perfect. Nevertheless, many of the same tendencies emerge as in Experiment 1: adding a dative NP seems to increase the conditional probability of seeing a participle immediately after the accusative NP (though statistical test results are insignificant due to low support in the dative-present conditions). The main difference is that there is some evidence of facilitation from adding a preceding PP to the accusative-only case ($p < 0.01$ by Fisher’s exact test), which was not the case in the main clause covered in Experiment 1.

As for the probability of participle identity, we make the same prediction that a preceding dative NP will sharpen expectations more than a preceding PP adjunct, since the argument-structure constraints imposed by the dative NP narrow the space of available verbs more dramatically.

**Method**

**Participants.** Twenty-eight participants from the same population as Experiment 2 were recruited for this experiment. None had participated in Experiment 1.

**Stimuli.** Twenty-four experimental items were constructed (see Appendix B for a full list). These were obtained by modifying the sentences used for Experiment 1 in the following way: the proper name subject of the main clause was replaced by a definite NP modified by a subject relative clause derived from the main clause in Experiment 1. The spill-over region in Experiment 1 was replaced by a short transitive VP which had as its subject the NP modified by the relative clause. As explained in the introduction to Experiment 2, this manipulation was intended to increase memory load before reaching the final verb, which we hypothesized would make locality effects easier to detect.

As in Experiment 1, the design manipulated two factors: the position of the dative NP (subordinate or relative clause) and the position of a PP modifier (subordinate or relative clause). The presence of the additional material in the relative clause should facilitate the processing of the head verb according to surprisal theory, but make it more difficult according to Dependency Locality Theory. A set of example stimuli is given in (7):

(7)  
\[ a. \text{Nachdem der Lehrer zur zusätzlichen Ahndung des mehrfachen Fehlverhaltens dem ungezogenen Sohn des fleißigen Hausmeisters den Strafunterricht } \text{verhängte, hat der Mitschüler, der den Fußball versteckt hat, die Sache bereinigt.} \]

\[ \text{After the teacher as additional payback for multiple wrongdoings the.DAT ungezogenen Sohn des fleißigen Hausmeisters den Strafunterricht verhängte, hat der Mitschüler, der den Fußball versteckt hat, die Sache bereinigt.} \]

\[ \text{“After the teacher imposed detention classes on the naughty son of the industrious janitor as additional payback for the multiple wrongdoings, the classmate who hid the football corrected the affair.”} \]

---

8Definite NPs were used in place of proper nouns in this experiment because several subjects in Experiment 1 noted that they occasionally wondered whether the proper-name NP was coreferent with one of the other definite NPs in the sentence.

After the teacher imposed detention classes, the naughty son of the industrious janitor hid the football as additional payback for the multiple wrongdoings, the affair corrected.

As with Experiment 1, this design ensures that the sentences are of the same length across all conditions, ruling out the potential position effects. Due to the effect observed in Experiment 1 of the variable number of characters following the spillover region on the same line, in this experiment we planned line breaks so as to ensure that the critical region and spillover regions (versteckt hat, die Sache in the example sentence) occurred on the last line, so that the same number of characters followed these regions in all conditions.

Procedure. The experimental procedure was identical to that used in Experiment 1.

Data Analysis. The experimental sentences were divided into four regions. The first region consisted of all words from the start of the sentence up to (but excluding) the head verb of the relative clause. The second, critical, region was the head participial verb of the relative clause, and the auxiliary that followed it; following this auxiliary there was always a comma marking the end of the relative clause (obligatory in prescriptive German grammar). The third, spill-over, region consisted of the two words following the critical region verb. The final region comprised the rest of the sentence. The region boundaries for an example sentence are given below:

(8) Nachdem der Lehrer den Strafunterricht verhängte, hat der Mitschüler, der zur zusätzlichen Ahndung des mehrfachen Fehlverhaltens dem ungezogenen Sohn des fleißigen Hausmeisters den Fußball versteckt hat, die Sache bereinigt.
Table 6: Empirical means for the eye-movement measures in critical and spill-over regions in Experiment 2 in milliseconds. The factors are: dative position (dat) and adjunct position (adj), each with the two levels relative clause and subordinate clause.

<table>
<thead>
<tr>
<th></th>
<th>dat = sub</th>
<th>dat = rel</th>
<th>adj = sub</th>
<th>adj = rel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Critical region</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First fixation</td>
<td>232.19</td>
<td>241.92</td>
<td>254.29</td>
<td>237.96</td>
</tr>
<tr>
<td>First pass</td>
<td>386.78</td>
<td>385.99</td>
<td>377.17</td>
<td>383.02</td>
</tr>
<tr>
<td>Regression path</td>
<td>565.17</td>
<td>685.51</td>
<td>571.77</td>
<td>642.47</td>
</tr>
<tr>
<td>Total time</td>
<td>793.08</td>
<td>749.76</td>
<td>648.55</td>
<td>742.47</td>
</tr>
<tr>
<td>Second pass</td>
<td>346.87</td>
<td>268.17</td>
<td>224.95</td>
<td>311.79</td>
</tr>
<tr>
<td>Regressions</td>
<td>.143</td>
<td>.244</td>
<td>.170</td>
<td>.161</td>
</tr>
<tr>
<td>Skipping</td>
<td>.030</td>
<td>.012</td>
<td>.042</td>
<td>.042</td>
</tr>
<tr>
<td><strong>Spill-over region</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First fixation</td>
<td>215.29</td>
<td>219.60</td>
<td>208.70</td>
<td>214.55</td>
</tr>
<tr>
<td>First pass</td>
<td>361.24</td>
<td>355.68</td>
<td>362.68</td>
<td>346.38</td>
</tr>
<tr>
<td>Regression path</td>
<td>720.75</td>
<td>537.76</td>
<td>709.64</td>
<td>778.45</td>
</tr>
<tr>
<td>Total time</td>
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<td>702.58</td>
<td>747.59</td>
<td>846.37</td>
</tr>
<tr>
<td>Second pass</td>
<td>419.19</td>
<td>342.24</td>
<td>352.51</td>
<td>458.63</td>
</tr>
<tr>
<td>Regressions</td>
<td>.101</td>
<td>.071</td>
<td>.065</td>
<td>.071</td>
</tr>
<tr>
<td>Skipping</td>
<td>.071</td>
<td>.054</td>
<td>.024</td>
<td>.054</td>
</tr>
</tbody>
</table>

The remainder of the data analysis was the same as in Experiment 1. The same eye-movement measures were computed and analyzed using linear mixed effects models as described earlier.

**Results**

We analyzed the answers participants provided to the comprehension questions. Per-participant accuracy ranged from 62.5% to 96.0%, with a mean of 80.0%. Accuracy did not differ significantly across lists.

Table 6 shows the empirical means for the critical and spill-over regions, in the seven eye-movement measures. Table 7 lists the results of the LMER analysis.

Table 7 indicates that dative position is a significant factor in total time in the critical region. The coefficient of this factor is positive, indicating that shorter reading times occur when the dative NP is located in the relative clause. Furthermore, we find a significant interaction of dative and adjunct position in first fixation time, total time, second pass time, and first-pass regressions. This interaction is also present in total time and second pass in the spillover region. The main effect and the interaction are illustrated in Figure 4, which graphs the predicted means for total time at the critical region. Second pass time shows the same pattern. There is no main effect of adjunct position in any of the measures or regions.

The interaction of dative and adjunct position bears a positive coefficient for total time and second pass. This means that an increased reading time occurs when either both the dative and the adjunct phrase are in the subordinate clause, or when both phrases are in the relative clause (recall from Experiment 1 that the factors are encoded as $-0.5$ for “rel” and $0.5$ for “sub”). On the other hand, reading time is reduced when one of the two phrases is in the subordinate clause, while the other one is in the main clause.

We also find a significant interaction of dative and adjunct position in first fixations, which however bears a negative coefficient. This means that first fixation times are lower when the dative and adjunct phrase are either both in the subordinate clause or both in the relative clause. The same interaction also reached significance for number of regressions.
Table 7: Results of linear mixed effects model analysis for Experiment 2. The table lists the coefficients of the best-fitting model with significance level (computed using either MCMC, t-test, or z-scores, see main text). Note that the factors are centered: “rel” is encoded as \(\approx -0.5\), “sub” as \(\approx 0.5\). The column “Random” indicates whether random intercepts, random slopes, or random interactions are include in the best model.

<table>
<thead>
<tr>
<th>Critical region</th>
<th>Intercept</th>
<th>dat</th>
<th>adj</th>
<th>dat \times adj</th>
<th>Random</th>
</tr>
</thead>
<tbody>
<tr>
<td>First fixation</td>
<td>241.24</td>
<td>-8.51</td>
<td>3.26</td>
<td>-25.28*</td>
<td>Slopes</td>
</tr>
<tr>
<td>First pass</td>
<td>382.97</td>
<td>7.57</td>
<td>-1.86</td>
<td>7.47</td>
<td></td>
</tr>
<tr>
<td>Regression path</td>
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<td>15.96</td>
<td>-93.41</td>
<td>-44.68</td>
<td>Interactions</td>
</tr>
<tr>
<td>Total time</td>
<td>733.10</td>
<td>75.44**</td>
<td>-23.80</td>
<td>132.42*</td>
<td>Interactions</td>
</tr>
<tr>
<td>Second pass</td>
<td>287.94</td>
<td>39.15</td>
<td>-4.07</td>
<td>165.54**</td>
<td>Interactions</td>
</tr>
<tr>
<td>Regressions</td>
<td>-1.73</td>
<td>.15</td>
<td>-0.30</td>
<td>-0.89*</td>
<td>Intercepts</td>
</tr>
<tr>
<td>Skipping</td>
<td>4.402</td>
<td>.87</td>
<td>-0.49</td>
<td>-0.98</td>
<td>Intercepts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spill-over region</th>
<th>Intercept</th>
<th>dat</th>
<th>adj</th>
<th>dat \times adj</th>
<th>Random</th>
</tr>
</thead>
<tbody>
<tr>
<td>First fixation</td>
<td>215.14</td>
<td>6.81</td>
<td>-5.68</td>
<td>-1.35</td>
<td>Intercepts</td>
</tr>
<tr>
<td>First pass</td>
<td>352.11</td>
<td>2.44</td>
<td>12.39</td>
<td>-15.82</td>
<td>Intercepts</td>
</tr>
<tr>
<td>Regression path</td>
<td>676.73</td>
<td>-129.93</td>
<td>67.75</td>
<td>258.37</td>
<td>Interactions</td>
</tr>
<tr>
<td>Total time</td>
<td>771.40</td>
<td>-43.03</td>
<td>-1.67</td>
<td>189.95**</td>
<td>Interactions</td>
</tr>
<tr>
<td>Second pass</td>
<td>393.15</td>
<td>-24.85</td>
<td>-14.59</td>
<td>183.06**</td>
<td>Interactions</td>
</tr>
<tr>
<td>Regressions</td>
<td>-2.90</td>
<td>.30</td>
<td>.16</td>
<td>0.51</td>
<td>Intercepts</td>
</tr>
<tr>
<td>Skipping</td>
<td>5.07</td>
<td>-.70</td>
<td>.32</td>
<td>-1.59</td>
<td>Intercepts</td>
</tr>
</tbody>
</table>

*: p < .05; **: p < .01

For completeness, we also checked the effect of entering number of characters following the spillover region as a covariate in the models for which significant results are reported in Table 7. All critical and spillover region significant effects remained significant in these analyses. On first-pass regression rate in the spillover region, we recovered a marginal effect \((p = 0.091)\) of number of characters following the spillover region, with more characters associated with a lower rate of first-pass regressions \((\beta = 0.22)\). In all other analyses, number of characters following the spillover region was not a significant predictor.

**Discussion**

This experiment confirmed the results of Experiment 1 in that we found a significant effect of dative position in total time: the presence of a dative NP in the relative clause results in reduced reading time at the head verb of the relative clause. At the same time, however, we found a significant interaction of dative and adjunct position, with reading times elevated when both phrases occurred in the same clause. These results can be interpreted as a facilitative prediction effect at the RC verb when the dative NP precedes it as a dependent, but one which is at least partially canceled out when the adjunct phrase also appears as a preverbal dependent in the RC. On this interpretation, the presence of two phrases preverbally entails an integration cost high enough to counteract most or all of the prediction benefit obtained from the dative NP.

Recall that the crucial difference between the present experiment and Experiment 1 was the fact that the critical verb was embedded into a relative clause, which we hypothesized might entail increased memory load that could increase difficulty associated with distance-based integration. Experiment 2 supports this hypothesis, and suggests that the processing costs associated with memory load may be super-additive: moving the adjunct phrase into the RC does not drive up reading times when the dative NP is in a preceding subordinate clause, but it does when the dative NP is a preverbal dependent inside the RC. To illustrate this,
Figure 4: Per-condition means predicted by the mixed model for total time in the critical region for Experiment 2. Error bars show the 95% confidence interval for the coefficient of the factor dat.

compare Figure 2, which schematically depicts this hypothesis, with Figure 4, which graphs the predicted values for total time in Experiment 2. The patterns are qualitatively similar; the key difference is that Figure 2 hypothesized expectation-based facilitation from both the adjunct and dative phrases, whereas in both experiments we found expectation-based facilitation only from the dative phrase.

Recall that we did obtain one main effect of adjunct position in Experiment 1, with increased first-fixation times when an adjunct phrase was present in the main clause. This could be evidence of a locality effect, which however was not present in any other measure in Experiment 1. In the present experiment, we obtained a significant interaction of dative and adjunct position on first-fixation times, but in the opposite direction as found in total-time and second-pass time measures: first-fixation times were shorter when the adjunct and the dative were located in the same clause. This mirror-image interaction is surprising at first glance, but a possible explanation is that first-fixation times in the subordinate/subordinate and RC/RC conditions are balanced by higher first-pass refixation rates in these conditions, which may be a sign of the greater difficulty in these conditions that is clear in second-pass and total time measures. Refixation rates were 53.7% in the dative-subordinate/adjunct-subordinate condition, 51.9% in the dative-subordinate/adjunct-main condition, 48.1% in the dative-RC/adjunct-subordinate condition, and 57.4% in the dative-RC/adjunct-RC condition; a mixed-effects logit model indicated that this interaction was marginally significant ($p = 0.08$). A similar relationship between first-fixation duration and refixation rate has been found previously (Vitu, O’Regan & Mittau, 1990; Rayner, Sereno & Raney, 1996), possibly reflecting a bifurcation between strategies of one long fixation and multiple short fixations in first-pass reading. We see the same mirror-image interaction in rate of first-pass regressions, though the fact that no such interaction was found in regression-path time makes the proper interpretation of the first-pass regression effect unclear.
General Discussion

The results in this paper provide evidence for both expectation and locality effects in the processing of verb final clauses in German. We conducted two experiments which tracked participants’ eye-movements as they read verb final dative constructions and found that the presence of a dative noun phrase led to decreased reading time at the corresponding verb, compared to a condition in which there is no preceding dative noun phrase. This can be explained by assuming that the presence the additional preverbal material allows the processor to predict the upcoming verb, which leads to a facilitation effect. In this respect, our experimental results reaffirm the findings of Konieczny (2000) and Konieczny & Döring (2003), while ruling out a number of possible confounds that were present in these earlier experiments.

However, our experiments also showed that locality effects can occur in the same structure: in Experiment 1, we found that the presence of an prepositional phrase adjunct leads to longer reading time at the verb that it modifies. This effect was only observed in first fixation time, a very early measure of processing in reading. In addition, Experiment 2 showed an interaction of adjunct position and dative position, such that the verb was more difficult to process when both the adjunct and the dative phrase were present. This also indicates the presence of a locality effect, i.e., the additional material that needs to be integrated at the verb, leading to a distance-based cost. This effect was only present in Experiment 2, which tested relative clauses, rather than main clauses as in Experiment 1. This indicates that locality effects can override expectation effects only occur under conditions of high memory load, as we hypothesized would be most likely to occur in a relative clause.

Taken together, our results provide evidence for both expectation effects (processing becomes easier with additional material) and locality effects (processing becomes more difficult with additional material). Locality effects have been observed for a range of different constructions in English (Gibson, 1998), while expectation effects (also known as anti-locality effects) have been reported for German, Japanese, and Hindi (Konieczny, 2000; Konieczny & Döring, 2003; Nakatani & Gibson, 2008; Vasishth & Lewis, 2006), and more recently also for English (Demberg & Keller, 2008a; Jaeger et al., 2009). However, ours is the first demonstration to our knowledge that both expectation and locality effects can occur in the same structure in the same language, and that the two effects interact with each other. More specifically, we found that expectation effects dominate locality effects, to the extent that Experiment 1 did not demonstrate any locality effects (other than the adjunct locality effect in first fixation). Locality is only able to counteract expectation in cases of extremely high memory load, as in the longest relative clauses used in Experiment 2.

None of the classical theories of online syntactic processing complexity is straightforwardly compatible with our results. The existence of expectation effects is inconsistent with Gibson’s 1998 Dependency Locality Theory, which predicts that additional material that needs to integrated with a head increases processing effort at the head, which is the opposite of what we found in the case of dative phrases in our experiments. Surprisal theory (Hale, 2001) does predict the expectation effects we found, as demonstrated by Levy (2008a)’s surprisal-based model of the closely related findings of Konieczny (2000) and Konieczny & Döring (2003). However, surprisal alone is not sufficient to explain why under some circumstances what seem to be locality effects can partially override expectation-based facilitation in the same structure, as we saw in Experiment 2. These results call for the development of new models of processing difficulty in online sentence comprehension which integrate the insights of surprisal and locality theories. Similar conclusions have been reached by other researchers, including Grodner & Gibson (2005), who noted the apparent conflict between locality-based reading-time patterns they observed in English relative clauses and expectation-based patterns found by Konieczny (2000), Vasishth (2002), and Nakatani & Gibson (2003; now published as Nakatani & Gibson, 2010); by Vasishth & Lewis (2006), who explicitly investigated the differences in reading-time patterns in English versus Hindi relative clauses; by (Demberg & Keller, 2008a),
who show that both integration cost and surprisal effects can be found in an eye-tracking corpus; by Patil, Vaisishth & Kliegl (2009) who find both memory retrieval cost and surprisal effects, again in an eye-tracking corpus. The present experiments make an important additional contribution to this literature, however, as the first simultaneous demonstration of locality and anti-locality effects in controlled experiments using a single grammatical construction in a single language—verb-final clauses in German—achieved by varying both expectations and memory load through the number and type of preverbal dependents and the presence of relativization.

We close with brief speculation on the prospects for developing precise, implemented models that can account for both locality and anti-locality effects of the sorts found here. It is useful here to briefly consider a distinction made in much of cognitive science (Marr, 1982; Anderson, 1990) between models developed at the algorithmic level—those which focus on input and output representations and the steps taken to convert inputs to outputs—and those developed at the computational level—those which focus on the ultimate goals of computation, constraints on the computing system, and what properties might hold of a well-designed system for achieving the goals subject to the constraints. At the algorithmic level, at least two theories are available which could accommodate our results. The first is Lewis & Vaisishth (2005)’s ACT-R based model of sentence processing as skilled memory retrieval (see also Vaisishth & Lewis, 2006; Lewis et al., 2006). In this model, processing of a clause-final verb requires retrieval and integration of its preceding dependents, a process which is subject to interference from preceding material. Greater amounts and complexity of preceding material yield greater interference effects, which could explain the difficulty seen in the dative-RC/adjunct-RC condition of Experiment 2. At the same time, however, preceding dependents boost the activation of the upcoming verb and thus facilitate its retrieval; under the appropriate conditions, then, the appropriate quantity and type of preceding material can facilitate final-verb processing, as seen in both our experiments.

The second algorithmic theory readily available to account for our findings is the Psycholinguistically Motivated Tree-Adjoining Grammar (PLTAG) model of Demberg & Keller (2008b, 2009), a model of incremental syntactic analysis through tree-fragment combination which also includes an explicit syntactic-prediction component. This component generates predictions of upcoming syntactic material if this material is required to ensure word-by-word incrementality while maintaining a fully connected tree. In PLTAG, predictions can be read directly off the PLTAG tree, and surprisal scores can be computed based on a probability distribution over partial PLTAG trees defined by Demberg & Keller (2009). In addition to surprisal-based expectation effects, however, the PLTAG model includes a verification component, which closely mirrors DLT’s memory cost component. Whenever a prediction is discharged, a penalty is incurred that is based on the distance between the first generation of a prediction and its verification. Demberg & Keller (2009) show that their model can account for locality effects in subject vs. object relative clauses as well as for expectation effects in coordinate structures.

At the computational level, it is possible that an analysis of our findings could be available within the uncertain-input rational comprehension model of Levy (2008b). This model does not contain an explicit memory-retrieval or integration cost for the online processing of verbs (or, for that matter, any other syntactic category). However, both the representations of current sensory input and memory traces from previous sensory input are taken in this model to be noisy and uncertain. When comprehending simple and relatively canonical types of sentences, these representations are corrected and sharpened by prior grammatical and world knowledge. When comprehending complex sentences with infrequent grammatical structures, however, prior knowledge is less effective in reinforcing these representations. In such situations, the representation of preceding context may not be sharp enough to support the expectations about upcoming input that would be computed by an ideal comprehender with perfect perception and memory. We might thus see
a failure to take advantage of what should ideally be accurate expectations in the comprehension of the most complex sentences, as in Experiment 2.

In all three cases, substantial work remains to be done to demonstrate whether these speculative explanations can in fact account for the data reported here within the existing theoretical frameworks. Since the reconciliation of locality and anti-locality effects has become an area of substantial interest for the sentence-processing community, we plan to conduct additional modeling work in these directions, and hope that this work, together with new empirical studies, can qualitatively improve our understanding of the interplay between memory and probabilistic knowledge in language processing.

Acknowledgments

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25


Appendix A. Tree Search Patterns

All searches were conducted using the Tregex tree-search software (Levy & Andrew, 2006), on a version of the combined NEGRA and TIGER corpus transformed automatically to context-free format (Levy, 2005).

Experiment 1: main-clause searches

The term *aux* is used here as a place-holder for the expression /ˆ(hat|haben|hatte|hatten|ist|sind|war|w.ren)$/, which picks out finite third-person forms of the auxiliary verbs haben and sein.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Pattern</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP.ACC</td>
<td>VAFIN-HD &lt; <em>aux</em> .. NP-OA=obj $++ (@VP &lt;- (__ ,, =obj))</td>
<td>1915</td>
</tr>
<tr>
<td>... immediately followed by verb</td>
<td>VAFIN-HD &lt; <em>aux</em> $++ (@VP &lt; ($VVVP , NP-OA))</td>
<td>1046</td>
</tr>
<tr>
<td>NP.DAT preceding NP.ACC</td>
<td>VAFIN-HD &lt; <em>aux</em> .. (NP-DA .. NP-OA=obj) $++ (@VP &lt;- (__ ,, =obj))</td>
<td>78</td>
</tr>
<tr>
<td>... immediately followed by verb</td>
<td>VAFIN-HD &lt; <em>aux</em> .. (NP-DA .. NP-OA=obj) $++ (@VP &lt; ($VVVP , =obj))</td>
<td>59</td>
</tr>
<tr>
<td>PP adjunct preceding NP.ACC</td>
<td>VAFIN-HD &lt; <em>aux</em> .. (PP-MO .. NP-OA=obj) $++ (@VP &lt;- (__ ,, =obj))</td>
<td>603</td>
</tr>
<tr>
<td>... immediately followed by verb</td>
<td>VAFIN-HD &lt; <em>aux</em> .. (PP-MO .. NP-OA=obj) $++ (@VP &lt; ($VVVP , =obj))</td>
<td>304</td>
</tr>
<tr>
<td>PP adjunct preceding NP.DAT preceding NP.ACC</td>
<td>VAFIN-HD &lt; <em>aux</em> .. (PP-MO .. (NP-DA .. NP-OA=obj)) $++ (@VP &lt;- (__ ,, =obj))</td>
<td>11</td>
</tr>
<tr>
<td>... immediately followed by verb</td>
<td>VAFIN-HD &lt; <em>aux</em> .. (PP-MO .. (NP-DA .. NP-OA=obj)) $++ (@VP &lt; ($VVVP , =obj))</td>
<td>8</td>
</tr>
</tbody>
</table>

Experiment 2: subject-extracted relative clause searches

These searches were made slightly more complex by the fact that the finite verb in German relative clauses is itself clause-final, so that preverbal information in the clause does not clearly indicate that there will be a participial verb at all. As a result, the ratio between conditioning counts and verb-outcome counts is much higher in these searches than for the main-clause searches.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Pattern</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP.ACC</td>
<td>S-RC &lt; (PRELS-SB .. NP-OA=obj) &lt; (/\V.FIN/ ,, =obj)</td>
<td>1197</td>
</tr>
<tr>
<td>... immediately followed by verb</td>
<td>S-RC &lt; (PRELS-SB .. NP-OA=obj) &lt; (/\V.FIN/ $- (@VP &lt; ($VVVP , =obj)))</td>
<td>87</td>
</tr>
<tr>
<td>NP.DAT preceding NP.ACC</td>
<td>S-RC &lt; (PRELS-SB .. (NP-DA .. NP-OA=obj)) &lt; (/\V. FIN/ ,, =obj)</td>
<td>48</td>
</tr>
<tr>
<td>... immediately followed by verb</td>
<td>S-RC &lt; (PRELS-SB .. (NP-DA .. NP-OA=obj)) &lt; (/\V. FIN/ $- (@VP &lt; ($VVVP , =obj)))</td>
<td>5</td>
</tr>
<tr>
<td>PP adjunct preceding NP.ACC</td>
<td>S-RC &lt; (PRELS-SB .. (PP-MO.. NP-OA=obj)) &lt; (/\V.FIN /,, =obj)</td>
<td>269</td>
</tr>
<tr>
<td>... immediately followed by verb</td>
<td>S-RC &lt; (PRELS-SB .. (PP-MO.. NP-OA=obj)) &lt; (/\V.FIN / $- (@VP &lt; ($VVVP , =obj)))</td>
<td>35</td>
</tr>
<tr>
<td>PP adjunct preceding NP.DAT preceding NP.ACC</td>
<td>S-RC &lt; (PRELS-SB .. (PP-MO .. (NP-DA .. NP-OA=obj) )) &lt; (/\V.FIN/ ,, =obj)</td>
<td>4</td>
</tr>
<tr>
<td>... immediately followed by verb</td>
<td>S-RC &lt; (PRELS-SB .. (PP-MO .. (NP-DA .. NP-OA=obj) )) &lt; (/\V.FIN/ $- (@VP &lt; ($VVVP , =obj)))</td>
<td>1</td>
</tr>
</tbody>
</table>
Appendix B. Experimental Materials

Experiment 1

We give the experimental stimuli in the condition dat = main, adj = main. The other conditions can be constructed by moving the dative phrase and/or the adjective phrase into the subordinate clause, as illustrated by example (4) in the main text.

(1) Weil der Verkäufer den Mangel verheimlichte, hat Peter Mühlberger ohne langes Bedenken des Because the seller the defect hid has Peter Mühlberger without long consideration of-the problematicen Sachverhalts dem arroganten Händler des vornehmen Autohauses den Höchstpreis offered and thus a loss made geboten, und so einen Verlust gemacht.

(2) Nachdem der Lehrer den Strafunterricht verhängte, hat Hans Gerstner zur zusätzlichen Ahndung des after the teacher the detention-classes imposed has Hand Gerstner as additional payback of-the mehrfachen Fehlverhaltens dem ungezogenen Sohn des fleißigen Hausmeisters den Fußball versteckt, multiple wrongdoings the naughty son of-the industrious janitor the football hidden und damit die Sache bereinigt. and thus the affair corrected

(3) Weil der Kollege den Bestechungsvorwurf machte, hat Fritz Lorzig nach intensiver Diskussion des because the colleague the corruption-allegation made has Fritz Lorzig after intensive discussion of-the brisanten Falls dem fleißigen Mitarbeiter des strengen Chefs den Aktenkoffer entwendet, und damit eine delicate case the industrious worker of-the strict boss the briefcase stolen and thus a Straftat begangen. crime committed

(4) Weil der Stadtrat den Antrag ablehnte, hat Jens Hartmann nach stundenlanger Erörterung des because the councilor the application rejected has Jens Hartmann after many-hour discussion of-the langen Berichts dem schmierigen Politiker des kleinen Ortes den Finanzplan präsentiert, und so long report the sleazy politician of-the small town the financial-plan presented and therefore the crisis defused

(5) Weil der Manager den Vorschlag zurückwies, hat Wolfgang Meier nach sofortiger Angabe des because the manager the proposal rejected has Wolfgang Meier after immediate mention of-a überzeugenden Grund dem senilen Vorstand des unrentablen Unternehmens den Aktienanteil convincing reason the senile executive of-the unprofitable company the share-holding entzogen, und damit die Pleite verursacht. withdrawn and therefore the bankruptcy caused

(6) Obwohl der Komplize den Zeugendienst verweigerte, hat Karl Riester nach stundenlangem Abstreiten although the accessory the witness-service refused has Karl Riester after many-hour denial des fraglichen Sachverhalts dem wütenden Polizisten des kleinen Orts den Mittäter genannt, und of-the contested fact the angry policeman of-the small town the accomplice named, and damit den Fall abgeschlossen. thus the case closed
(7) Nachdem den Vertriebsplan vorstellte, hat Thomas Schmidt nach erfolgreicher Widerlegung des unbegründeten Einwands dem ungeduldigen Vorsitzenden des großen Konzerns den Vertrag gesichert, und so ein Riesengeschäft gemacht. secured and thus a huge-business made

(8) Weil der Einkäufer den Preis erhöhte, hat Frank Sailer nach erneuter Ausweitung des großzügigen Angebots dem kränkelnden Betrieb des alternend Unternehmers den Auftrag versprochen, und damit offer the sickly company of the aging entrepreneur the order promised and therefore den Konkurs abgewendet. the bankruptcy prevented

(9) Nachdem der Beamte den Schadensfall bescheinigte, hat Sabine Berger trotz vereinzelter Bedenken des verwalteten Familienkreises dem effizienten Versorgungsamt des kleinen Kurorts den Rentenantrag gestellt, und dann den Lebensabend genossen submitted, and then the retirement enjoyed

(10) Nachdem der Konzern den Filmvertrags anbot, hat Karin Kowalsky trotz heftigen Protestes des verängerten Produzenten dem berühmten Regisseur des erstklassigen Werks den Schauspieler vorgestellt, annoyed producer the famous director of the first-class work the actor introduced und so die Produktion ermöglicht. and thus the production enabled

(11) Nachdem der Manager den Bonus auszahlte, hat Heike Schneider wegen guter Leistung des nachäherten Mitarbeiters des verdienten Betriebes den Vertrag verlängert, und damit Weitsicht bewiesen. extended and thus forward-planning shown

(12) Nachdem der Koch den Truthahn zubereitete, hat Simone Küfer unter genauer Beachtung des detaillierten Reglements dem treuen Stammgast des französischen Restaurants den Hauptgang serviert, detailed regulations the faithful customer of the French restaurant the main-course served und so den Kritiker beschwichtigt. and thus the critic placated

(13) Nachdem der Trainer den Übungsplan entwickelte, hat Birgit Messner trotz negativer Berichterstattung des dummen Journalisten dem ehrgeizigen Sportler des aufgestiegenen Vereins den Erfolg of the stupid journalist the ambitious sportsman of the promoted club the success vorhergesagt, und damit Recht behalten. predicted and therefore right remained
(14) Weil der Landtag den Zuschuss bewilligte, hat Franz Ritter nach langwierigem Aushandeln des because the parliament the subsidy approved has Franz Ritter after long negotiations-of-the schwierigen Vertrags dem kleinen Betrieb des ehemaligen Zonenrandgebiets den Auftrag eingebracht, difficult contract the small company-of-the former border-area the order earned und damit Arbeitsplätze gesichert.
and thus jobs secured

(15) Weil der Gefängnisdirektor den Hafturlaub genehmigte, hat Stefan Bauer nach vorschriftsmäßigem because the prison-director the prison-holiday approved has Stefan Bauer after rule-compliant Befragen des direkten Vorgesetzten dem harmlosen Häftling des kleinen Gefängnisses den Ausgang consultation-of-the direct superior the harmless inmate-of-the small prison the leave erlaubt, und so den Besuch ermöglicht.
granted and thus the visit enabled

(16) Nachdem der Geizhals den Schuppen abriss, hat David Weinberger ohne große Beachtung des after the scrooge the shed demolished has David Weinberger without much regard to-the kalten Wetters dem frierenden Stadtstreicher des armen Vororts den Sommermantel geschenkt, und damit cold weather the freezing hob of-the poor suburb the summer-coat given and thus Unruhe gestiftet.
unrest caused

(17) Weil der Vater den Ratschlag gab, hat Klaus Berger nach nochmaligem Überdenken des because the father the advice gave has Klaus Berger after repeated contemplation-of-the schwierigen Problems dem reichen Onkel des entfernten Verwandten den Bittbrief geschickt, und difficult problem the rich Uncle of-the distant relative the request-letter sent and damit die Notlage beseitigt.
therefore the distress removed

(18) Nachdem der Junge den Hilfsdienst versprach, hat Martin Kaufmann ohne langes Erwagen des After the boy the help promised has Martin Kaufmann without long deliberation-of-the möglichen Trinkgelds dem alten Rentner des baufälligen Nachbarhauses den Koffer getragen, und possible tip the old pensioner-of-the dilapidated neighbor-house the suitcase carried and so einen guten Eindruck gemacht.
thus a good impression made

(19) Obgleich der Manager den Zweifel anmeldete, hat Lisa Friedländer nach genauer Überprüfung des Even-though the manager the doubt raised has Lisa Friedländer after exact verification-of-the detaillierten Angebots dem dynamischen Vertreter des kleinen Unternehmens den Auftrag vergeben, detailed offer the dynamic representative-of-the small business the order given und so die Firma ruiniert.
and so the company ruined

(20) Nachdem der Polizist den Durchsuchungsbefehl vorlegte, hat Heinz Mischnik trotz sofortigen After the policeman the search-warrant presented has Heinz Mischnik despite immediate Einspruches des gewitzen Anwalts dem beharrlichen Fahnder des örtlichen Finanzamts den objection of-the clever lawyer the insistent investigator-of-the local tax-office the Aktenschrank aufgemacht, und dann die Beweismittel übergeben.
file opened and then the evidence handed-over
(21) Weil der Pächter den Beistand leistete, hat Paul Schnitzer zur sofortigen Behebung des
because the tenant the assistance rendered has Paul Schnitzer for immediate remedy of-the
offensichtlichen Notstands dem frierenden Bewohner des eingestürzten Hochhauses den Schuppen
obvious emergency the freezing occupant of-the collapsed tower-block the shed
aufgeschlossen, und so die Not gelindert.
unlocked and so the distress reduced

(22) Weil der Großvater den Aktienanteil verkaufte, hat Johannes Probst trotz erheblicher Bedenken
because the grandfather the shares sold has Johannes Probst despite serious doubts
des gewissenhaften Steuerberaters dem gierigen Angestellten des großen Finanzhauses den
of-the meticulous tax-accountant of-the greedy employee of-the big financial-company the
Anteilschein vorgelegt, und damit das Vermögen gefährdet.
coupon presented and thus the fortune endangered

(23) Nachdem der Passant den Sachverhalts schilderte, hat Markus Kaiser trotz anfänglichem Bestreiten
after the passer-by the fact described has Markus Kaiser despite initial denial
des peinlichen Vorfalls dem jungen Beamten des herbeigerufenen Streifenwagens
of-the embarrassing event the young officer of-the called police-car the
Ausweis vorgezeigt, und dann eine Blutprobe abgegeben.
identity-card presented and then a blood-sample given

(24) Weil der Manager den Termin vorschrieb, hat Tom Pressberger trotz heftiger Proteste des
because the manger the appointment dictated has Tom Pressberger despite intense protests of-the
aufgebrachten Betriebsrats dem neuen Leiter des kleinen Vertriebsbüros den Urlaub gestrichen, und
enraged workers-council the new leader of-the small sales-office the holiday canceled and
so das Arbeitsklima vergiftet.
thus the work-atmosphere poisoned

Experiment 2

We give one example for an experimental stimulus. As can be seem by comparison with (1), the stimuli
for Experiment 2 can be derived from those of Experiment 1 by replacing the proper name with a definite
NP, and turning the rest of the main clause into a relative clause that modifies this definite NP.
The example in (1) is in the condition dat = rel, adj = main. The other conditions can again be con-
structed by moving the dative phrase and/or the adjective phrase into the subordinate clause, as illustrated
by example (7) in the main text.

(1) Weil der Verkäufer den Mangel verheimlichte, hat der Kunde, der ohne langes Bedenken des
Because the seller the defect hid has the customer who without long consideration of-the
problematischen Sachverhalts dem arroganten Händler des vornehmen Autohauses den Höchstpreis
problematic fact the arrogant dealer of-the posh car-dealership the maximum-price
geboten hat, einen Verlust gemacht.
offered has a loss made