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The Matrix Verb as a Source of Comprehension Difficulty in Object Relative Sentences

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Abstract

Two experiments used eyetracking during reading to examine the processing of the matrix verb following object and subject relative clauses. The experiments show that the processing of the matrix verb following an object relative is indeed slowed compared to the processing of the same verb following a subject relative. However, this difficulty is entirely eliminated if additional material intervenes between the object gap and the matrix verb. An explanation in terms of spillover processing is ruled out, suggesting that it is the gap-matrix verb sequence that is itself responsible for the difficulty. We consider two accounts of this difficulty, one emphasizing the potential difficulty of rapidly switching between the sentential subject's thematic or syntactic role in the embedded clause and its role in the matrix clause, and one emphasizing the potential difficulty of performing two demanding memory retrievals in rapid succession. The present experiments also closely replicate the previous findings from eyetracking that the noun phrase and the verb within an object relative are both loci of processing difficulty, but that the former induces substantially greater difficulty.

Keywords: Sentence processing; Eye movements; Relative clauses

1. Introduction

A very large body of experimental evidence supports the conclusion that in English and many other languages, sentences containing object relative clauses (ORCs; 1a) are more difficult to comprehend than sentences containing subject relative clauses (SRCs; 1b).

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1	(a) The reporter that the senator attacked admitted the error.
	(b) The reporter that attacked the senator admitted the error.

Various caveats to this broad conclusion are necessary; for example, the difficulty associated with ORCs can be reduced by manipulating the types of noun phrases in the sentences, and the similarity or semantic relationship between them (Gennari & MacDonald, 2008, 2009; Gordon, Hendrick, & Johnson, 2001, 2004; Gordon, Hendrick, Johnson, & Lee, 2006). Similarly, ORCs may not be more difficult to process than SRCs in languages like Mandarin Chinese which have prenominal relative clauses (see Jäger, Chen, Li, Lin, & Vasishth, 2015; Lin, 2014 for reviews), or in languages like Russian which have freer word order and richer case marking on dependents (Levy, Fedorenko, & Gibson, 2013). Cross-linguistic differences notwithstanding, the difficulty difference is remarkably robust overall and is notable, given that there is not an obvious syntactic ambiguity at work in ORCs, and that the two structures contain identical lexical items.

There is less agreement, however, about the underlying cause of the difficulty in comprehending ORCs in English. One strategy in arbitrating between competing accounts has been to examine precisely where, in the course of incremental processing of sentences like (1a–b), the difficulty with ORCs is manifested. As discussed by Staub (2010; see also Gordon & Lowder, 2012; Jäger et al., 2015; Levy & Gibson, 2013), theories emphasizing the relative rarity of ORCs, which may lead readers to expect an SRC after encountering the word *that* in (1a–b), predict difficulty to appear on the noun phrase (*the senator*) within an ORC. It is at this point that the reader's initial expectation of an SRC may be disconfirmed (Hale, 2001). On the other hand, theories emphasizing the difficulty of memory-related operations that may be involved in processing an ORC predict that the locus of difficulty should be on the relative clause verb (*attacked*), as it is here that the comprehender must engage in a long-distance retrieval of the head of the relative clause (*the senator*), which will receive a thematic role as the theme or patient of this verb (e.g., Gibson, 1998; Lewis & Vasishth, 2005; Lewis, Vasishth, & Van Dyke, 2006).

In two experiments using eyetracking during reading, Staub (2010) obtained a pattern that offered some confirmation of both predictions. In one experiment, sentences like 1a-b were compared, whereas in the other, sentences like 1a were compared to sentences in which the lexical material in the ORC was inserted in a verbal complement clause (*The reporter said that the senator attacked*. . ..). The noun phrase within an ORC induced a very large overall cost, compared to the same words in an SRC or in a complement clause, due to a large number of regressive eye movements initiated from this material and a resulting increase in go-past reading time (i.e., the time from when the eyes first fixate in a region to when the eyes leave the region to the right). However, there was also a reading time penalty on the verb within an ORC, though a smaller one, due to inflated first pass reading time rather than to an increase in regression probability. On the surface, then, these results suggest that the difficulty in comprehending ORCs may be due both to violation of expectations and to memory retrieval difficulty, with the former playing a larger role.

Staub (2010) noted, however, that other experimental paradigms have not generally obtained both of these effects. In self-paced reading (Gordon et al., 2001; Grodner & Gibson, 2005; cf. Gennari & MacDonald, 2008, 2009), in which each word or phrase is revealed by a button press, difficulty in the form of inflated response times has generally been evident only at the ORC verb. In the "maze" task, on the other hand (Forster, Guerrera, & Elliot, 2009), there appears to be difficulty only at the ORC noun phrase. Hatfield and Artos (2016) recently also found difficulty only at the ORC noun phrase, using a "self-guided reading" paradigm in which text is revealed by sliding a finger on the screen. In sum, self-paced reading appears to be the anomaly among these paradigms, as recent experiments using the other paradigms have found that either all (maze, self-guided reading) or most (eyetracking) of the difficulty in ORCs occurs at the noun phrase.

Another discrepancy regarding the locus of difficulty emerges even within paradigms. Staub (2010) pointed out that among eye movement studies, there is no consistent answer to the question of whether there is difficulty on the matrix verb following an ORC (*admitted* in 1a, compared to 1b). While some previous experiments reported an effect of clause type on this verb, with longer reading times on the matrix verb following an ORC (Gordon et al., 2006, Experiment 1; Traxler, Morris, & Seely, 2002, Experiments 1 and 3; Traxler, Williams, Blozis, & Morris, 2005, Experiments 1 and 3), others found only a trend (Traxler et al., 2002, Experiment 2; Traxler et al., 2005, Experiment 2). Staub (2010) found essentially no hint of such an effect. In self-paced reading, there is also a mixed picture. King and Just (1991), Gennari and MacDonald (2008, 2009) and Gordon et al. (2001) all obtained substantial effects at the matrix verb. However, Grodner and Gibson (2005) argued that these effects could be due simply to spillover from processing of the ORC itself and inserted a prepositional phrase between the verbs. They failed to find any effect of clause type on the matrix verb. A few researchers have assumed that there is indeed difficulty at the matrix verb and have tried to simulate this difficulty. Just and Carpenter's (1992) CC Reader model simulated self-paced reading data from King and Just (1991) in which difficulty did appear at the matrix verb, but it did so by assuming that this is indeed a kind of spillover effect, resulting from a diminished pool of resources available for processing the matrix verb after an ORC. MacDonald and Christiansen (2002) trained simple recurrent networks (SRNs) to predict the next word of a sentence and also simulated the King and Just (1991) patterns.

If there is processing difficulty on the matrix verb following an ORC, and this is not simply attributable to spillover difficulty from the ORC itself, why might this difficulty arise? In fact, expectation-based accounts (e.g., Hale, 2001) do not predict difficulty there, as the matrix verb is no more expected after *the senator* in 1b than after *attacked* in 1a. In addition, some memory-based accounts do not predict differential difficulty there (e.g., Gibson, 1998). Grodner and Gibson (2005) noted that on the Gibson (1998) model, the matrix verb is a point of substantial integration difficulty after either an SRC or an ORC, as in both cases this verb must be integrated with a subject that is separated by the introduction of new discourse referents, but this difficulty does not differ by clause type.

Other memory-based accounts, however, do have the ability to account for increased difficulty on the matrix verb following an ORC. Van Dyke and Lewis (2003; Van Dyke,

2007) adopt a model on which each word in a sentence triggers retrieval of elements to which that word is related by a syntactic dependency (Lewis & Vasishth, 2005). They propose that when a verb is encountered, one of the retrieval cues used to identify the subject is nominative case. On this view, the matrix verb after an ORC could be difficult because the presence of the ORC subject (*the senator* in 1a) results in interference in the attempt to retrieve the matrix subject (*the reporter*), whereas there is no competing noun phrase with nominative case in 1b. More broadly, it may be assumed that the ORC subject interferes with retrieval of the matrix subject because both are syntactic subjects. We refer to this as the *retrieval interference* account of the matrix verb cost.

Several other explanations are also possible. One of these also builds on existing theoretical commitments of memory-based models (Gibson, 1998; Lewis & Vasishth, 2005) but generates a matrix verb cost in a different way from the retrieval interference account. The critical point, on this view, is that processing the ORC verb and then the matrix verb requires the processor to engage in two potentially difficult memory retrievals in rapid succession. It is possible that these memory retrievals must occur serially, so that the retrieval initiated at the matrix verb cannot begin until the retrieval at the ORC verb is complete. Indeed, serial execution of memory retrievals during sentence processing is the logical consequence of the view that memory retrieval makes an item available for active processing by restoring it into a focus of attention that is highly limited in capacity, containing only one item (McElree, 2006; McElree, Foraker, & Dyer, 2003). We may assume, then, that a matrix verb cost would arise if the retrieval, or subsequent processing, of the matrix subject as object of the ORC verb is sometimes still ongoing when the matrix subject must (again) be retrieved upon encountering the matrix verb. If this occurs, this would delay the start of this second retrieval, and thereby prolong processing of the matrix verb. We refer to this as the *retrieval bottleneck* account.

Arguably, the retrieval bottleneck account does attribute the difficulty on the matrix verb to a kind of spillover from processing of the ORC verb, or from processing of the ORC gap site. However, it is important to note that on this account the difficulty arises only because of the interaction between the processing demands of the ORC verb or gap site, and the processing demands of the matrix verb. No detectable "spillover" cost would be expected on an element following the ORC verb if this element did not, itself, initiate a difficult retrieval.

Yet a third possible account of difficulty on the matrix verb following an ORC is related to early accounts of ORC difficulty that emphasized the shifts of syntactic and thematic roles that processing a sentence like 1a requires (e.g., MacWhinney & Pléh, 1988; Sheldon, 1974). These accounts propose that one reason it is difficult to process a sentence containing a subject-modifying ORC is that such a sentence requires two such shifts. The initial noun phrase *The reporter* in 1a is initially identified as the syntactic subject, and it may also be assigned an agent role in the event that the sentence describes. But then, reading the relative clause *that the senator attacks* requires the comprehender to assign *the reporter* a role as object, and theme, of the relative clause verb. Finally, encountering the matrix verb *admitted* requires the comprehender to once again assign

the reporter a role as subject and agent. In contrast, no such switches are required in 1b, where *the reporter* is subject and agent throughout.

This account suggests that the matrix verb may induce processing difficulty after an ORC because this is the precise location where the second of these two shifts is required. Notably, when the matrix verb immediately follows the ORC verb, as in 1a, this shift is particularly salient, as it occurs immediately after the location at which the relative clause head has just been assigned a role as object and theme of the relative clause verb. Thus, this is a point at which the comprehender must assign the very same noun phrase two syntactic/thematic roles in very rapid succession. The core of this idea is that such role assignment takes time, and that when the sentence processor does not have sufficient time to complete one assignment before attempting another, sentence processing may be slowed. We refer to this as the *thematic bottleneck* hypothesis, intending this as a cover term for theories emphasizing the role switching that the matrix verb requires, whether the critical aspect of this role switching is actually syntactic or thematic in nature.

This study investigates, by means of two eyetracking experiments, the question of whether there is indeed processing difficulty on the matrix verb following an ORC, and whether any such cost is due to spillover processing from the ORC verb. To anticipate the results, the experiments show that there is indeed a cost, and that it is not due to spillover. However, the experiments also show that the cost is eliminated when the matrix verb is separated from the ORC verb by intervening material, confirming a prediction of the bottleneck accounts and arguing against the retrieval interference account.

2. Experiment 1

This experiment was designed to determine if there is a reading time penalty on the matrix verb following an ORC, compared to the same verb following an SRC. The experiment also assessed whether this is due to spillover from the ORC itself, and whether this penalty emerges only when the matrix verb immediately follows the ORC gap site. We compared the processing of ORCs and SRCs, as in 1a-b. The length of the relative clause was also manipulated, including a final prepositional phrase in two of the four conditions. This resulted in a 2 × 2 design exemplified in (2):

2 (a) The chef that the waiter distracted poured the flour onto the counter. (ORC, short)
(b) The chef that the waiter distracted in the kitchen poured the flour onto the counter. (ORC, long)
(c) The chef that distracted the waiter poured the flour onto the counter. (SRC, short)
(d) The chef that distracted the waiter in the kitchen poured the flour onto the counter. (SRC, long)

The matrix subject and the relative clause NP were always animate. The main goal of this experiment was to assess processing difficulty on the matrix verb. Given the inconsistent results in the previous literature, we reasoned that any effects on this verb were likely to be relatively small, and we planned the experiment to have considerable power,

with more subjects than is typical for an eye movement experiment. For comparison, Experiment 1 of Staub (2010) included only 28 subjects.

2.1. Method

2.1.1. Subjects

Participants were 74 students at UMass Amherst who participated in exchange for course credit. All were speakers of English as a first language, and none reported any history of reading or language disorder. Nine of the 74 subjects were excluded based on a preestablished criterion of losing more than 20% of experimental trials to track loss or blink on the critical region, leaving 65 subjects in the analysis.

2.1.2. Materials

Thirty-six items like (2) were constructed for this experiment, each with four conditions. The items are presented in the Appendix. Many items were adapted from the items used in Staub (2010), with the addition of a prepositional phrase in the long conditions. These items were arranged into four experimental lists, so that each subject read nine items in each of the four experimental conditions, and each item was read in each of its four conditions by an approximately equal number of subjects. These 36 items were randomly intermixed with 120 other sentences, of which 80 were from an unrelated experiment on subject-verb agreement. None of the filler sentences involved relative clauses. The 156 sentences were preceded by eight practice sentences. A total of 44 items were followed by a two-choice comprehension question.

2.1.3. Procedure

Subjects were tested individually. Eye movements were recorded using an EyeLink 1000 (SR Research, Toronto, ON, Canada) eyetracker, interfaced with a PC computer. The sampling rate was 1000 Hz. Subjects were seated 55 cm from a CRT monitor on which the sentences were displayed. At this distance the resolution of the eyetracker was substantially less than one character. Only the movement of the right eye was recorded.

All sentences were displayed on a single line in 11-point Monaco font. Before the experiment began, each subject was instructed to read for comprehension. It was noted that some sentences might be "a little weird" and that subjects should try to understand them as well as possible. A three-point calibration procedure was performed at the start of the experiment and as needed between trials. The subject triggered each sentence by fixating a box at the left edge of the monitor. The experiment lasted approximately 40 minutes. The experiment was implemented with the EyeTrack software, and initial stages of data analysis were carried out with Robodoc and EyeDry (http://blogs.umass.edu/eyelab/software/).

No subject was excluded based on poor performance on the comprehension questions, as all achieved at least 75% correct. Trials were excluded if there was a blink or track loss during first pass reading of the matrix verb. As noted above, nine of the 74 subjects lost more than 20% of trials on this basis, and these subjects were excluded from

subsequent analysis. For the remaining 65 subjects, blinks, track loss, or other error resulted in deletion of 6.1% of trials, leaving 2,197 trials for inclusion in the analysis. Individual eye fixations less than 80 ms in duration and within one character of a previous or subsequent fixation were incorporated into this neighboring fixation. No other data trimming was carried out.

2.2. Results

We focus our analyses on four regions of the sentences: the noun phrase within the relative clause (*the waiter*), the relative clause verb (*distracted*), the prepositional phrase in the long conditions (*in the kitchen*), and the matrix verb (*poured*). We report four eye movement measures on each region. *First fixation duration* is the duration of the first eye fixation on the critical word or phrase, on the first pass through the sentence. *First pass time* is the sum of the durations of all first pass fixations on the word or phrase, before the eyes first leave the word to either the left or right. If the reader made only a single first pass fixation before leaving the region, first fixation duration and first pass time are identical for that trial. *Go-past time* is the sum of all fixation durations beginning with the first on a word or phrase, and including all fixations until the reader moves past the word to the right; this measure includes the durations of any fixations made after a regressive eye movement to the left. Finally, *regression proportion* is the proportion of trials on which first pass inspection of a word or phrase ended with an eye movement to the left rather than the right. For all of these measures, a trial is excluded if the word or phrase was skipped on first pass reading.

Statistical analysis was carried out by means of linear mixed effects models of reading times and logistic mixed effects models of regression probability, implemented using the lme4 package (version 1.1-7; Bates, Maechler, Bolker, & Walker, 2015) for the R statistical programming environment (version 3.1.2; R Core Team, 2014). In all cases, relative clause type, relative clause length, and their interaction were treated as fixed effects. Both factors were centered, with the SRC and short conditions receiving the value of -0.5, and the ORC and long conditions receiving the value of 0.5. Except as noted below, the maximal random effects structure was used, that is, with random intercepts for subjects and items and random slopes for each fixed effect and their interaction, for both subjects and items. In the linear mixed effects models, t values greater than 2 are treated as significant (Gelman & Hill, 2006).

Condition means, for each measure on each region, are shown in Fig. 1. We begin with the relative clause NP and verb, where we expected to replicate the findings from Staub (2010) regarding effects of clause type. First fixation duration on the relative clause NP was not significantly affected by either manipulation, but first past time was significantly longer in the ORC conditions ($\beta = 28.67$, $SE = 10.67$, $t = 2.69$). The effect of clause type on go-past time was also significant, and much larger ($\beta = 123.10$, $SE = 17.74$, $t = 6.94$). There was also a significant interaction effect on go-past time ($\beta = -65.78$, $SE = 29.77$, $t = -2.21$); as Fig. 1 shows, this reflects a slight reduction in go-past time on the ORC verb in the long condition, and a substantial increase in go-past

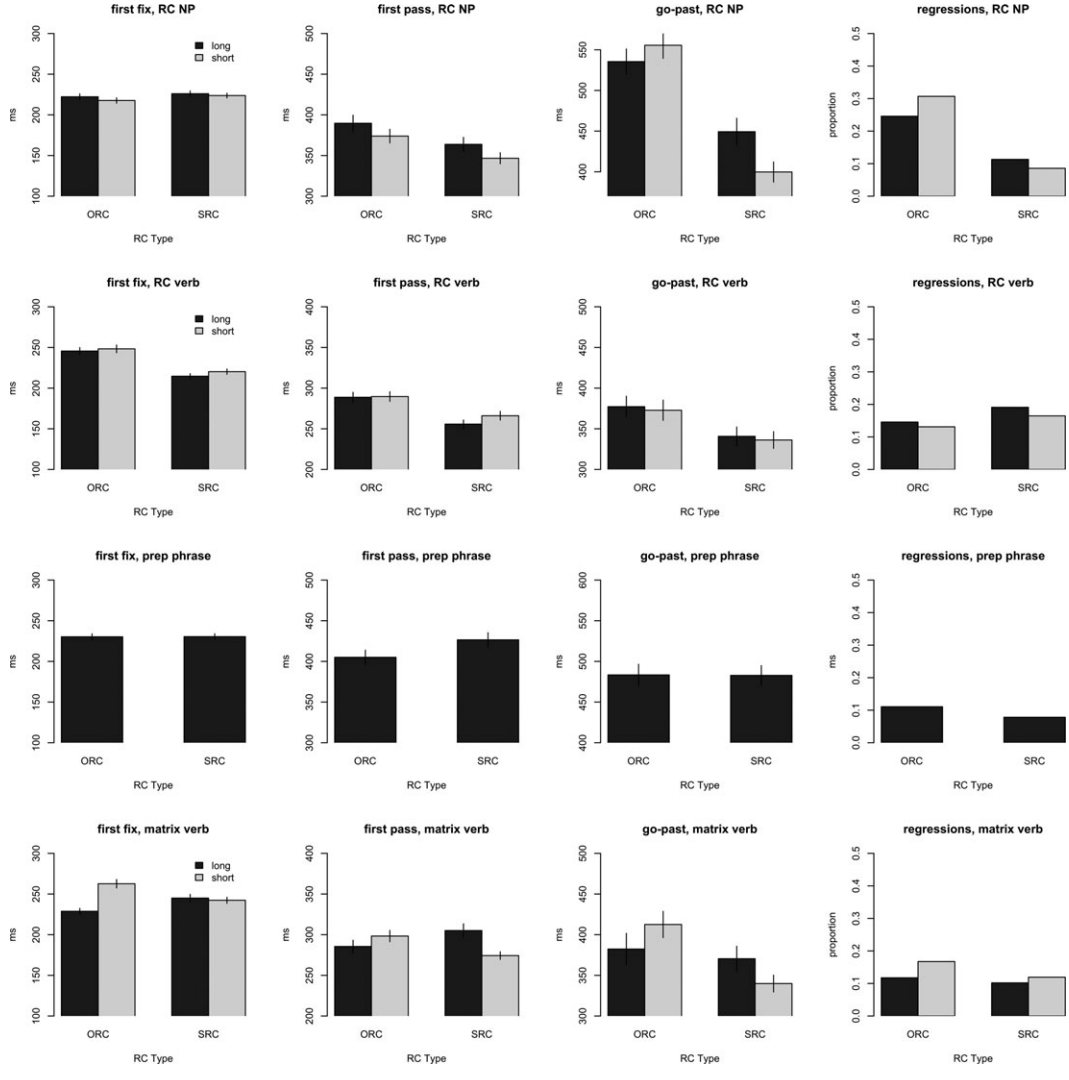

Figure 1. Experiment 1 grand mean and standard error for first fixation duration, first pass time, and go-past time (note adjustment of *y*-axis range for each measure), and regression proportion, for each of the four critical sentence regions, by condition.

time on the SRC verb in the long condition. We discuss this below. The go-past effect of clause type was driven by an increased probability of regressing from the NP in the ORC conditions ($\beta = 1.55$, $SE = 0.22$, $z = 6.97$, $p < .001$). There was also a significant interaction effect on regression probability ($\beta = -0.85$, $SE = 0.40$, $z = -2.14$, $p < .05$). No other effects on this region were significant.

On the relative clause verb, first fixation durations were affected by clause type, with longer fixations on the ORC verb ($\beta = 29.54$, $SE = 5.06$, $t = 5.83$). This difference carried over into first pass time ($\beta = 29.47$, $SE = 7.41$, $t = 3.98$) and go-past time

(β = 35.77, *SE* = 15.52, *t* = 2.31), which necessarily reflect first fixation differences. No other reading time effects on this region were significant, and there were no significant effects on regression probability.

Clause type did not significantly affect any measure on the prepositional phrase that preceded the matrix verb in the long conditions. The trend in first pass time is in the direction of longer reading time in the SRC condition, and for the other measures reading times are almost identical.

The pattern on the matrix verb is more complex. There was a significant effect of length on first fixation duration, with shorter first fixations when the relative clause was long (β = −16.53, *SE* = 4.72, *t* = −3.50), qualified by a significant interaction between length and clause type (β = −32.72, *SE* = 12.10, *t* = −2.70). In first pass time, however, neither main effect approached significance, while again there was a significant interaction (β = −37.35, *SE* = 12.24, *t* = −3.05; we note that to obtain model convergence in this case it was necessary to remove the random slopes for the interactions). In go-past time, neither the main effects nor the interaction approached significance. Note that the qualitative pattern is the same across all three reading time measures: In the short conditions, the matrix verb elicited longer reading times after an ORC than after an SRC, but lengthening the ORC reduced reading times on the matrix verb, whereas lengthening the SRC actually increased reading times on the matrix verb. No effects on the regressions measure neared significance, except a marginal effect of length (β = −0.51, *SE* = 0.29, *z* = −1.77, *p* = .08).

Because reading times on the matrix verb are of central interest, we constructed additional models to directly test the hypothesis that reading time is inflated in the ORC short condition compared to each of the others, as suggested at least in the case of first fixation duration by the condition means in Fig. 1. In these models the ORC short condition was treated as the reference level, and the other three conditions were directly compared to it. For first fixation duration, this model revealed that reading times in all three of the other conditions were significantly shorter: ORC long (β = −33.30, *SE* = 8.49, *t* = −3.92); SRC short (β = −18.89, *SE* = 8.86, *t* = −2.13); SRC long (β = −19.94, *SE* = 7.88, *t* = −2.44). For first pass time and go-past time, the mean in the SRC short condition was significantly shorter than the mean in ORC short condition (first pass: β = −23.15, *SE* = 11.15, *t* = −2.08; go-past: β = −73.49, *SE* = 28.06, *t* = −2.62), but the other two conditions were not significantly different from the ORC short condition.

2.3. Discussion

For the relative clause itself, this experiment closely replicated the results obtained by Staub (2010). First, the NP within an ORC elicited a large number of regressions compared to the NP within an SRC, and a corresponding increase in go-past reading time. The verb within an ORC also incurred a reading time penalty, but it was smaller overall, and it was due to an increase in first-pass reading time rather than to an increase in regression probability. In the present experiment, almost the entire reading time penalty on the ORC verb occurred during the first fixation on this word. The one puzzling aspect

of the present data is the interaction between RC type and length on the NP region, obtained in both the go-past and regressions measures. We initially regarded this effect as very likely to be spurious, as it would seem to reflect an effect of a length manipulation that the reader has yet to encounter during first pass reading of the NP. We postpone further discussion of this issue until after the results of Experiment 2 have been presented.

The first central question that this experiment addressed is whether there is in fact a reading time penalty on the matrix verb when this verb directly follows the verb in an ORC. The answer is yes: In all three reading time measures, there was a significant reading time penalty in the ORC short condition compared to the SRC short condition. This penalty is not very large, as our statistical models estimated a 19 ms effect on first fixation duration, a 23 ms effect on first pass time, and a 73 ms effect on go-past time. Thus, it is perhaps not too surprising that less powerful previous experiments have occasionally failed to detect it. What is also notable, however, is that this penalty is completely absent when an additional prepositional phrase is inserted prior to the matrix verb. Indeed, for two of the three reading time measures, the numerical trend is in the opposite direction in the long conditions, with longer reading times on the matrix verb following an SRC.

This pattern might suggest, on its surface, that the effect on the matrix verb in the short conditions is due simply to spillover from processing of the ORC itself; if other material intervenes between the difficulty-inducing regions of the ORC (the NP and the verb) and the matrix verb, there is no longer any difficulty on the matrix verb. But this account cannot be correct, because it predicts that in the ORC long condition, there should be some sign of spillover processing difficulty on the prepositional phrase. Not only were there no significant effects of RC type on reading of this phrase, in fact the numerical differences that did exist were in the opposite direction, with longer first pass time on this material when it followed the SRC. It appears, then, that what causes difficulty is encountering the matrix verb immediately after the ORC verb.

It is also notable that the full data pattern on the matrix verb is not compatible with an expectation-based explanation. Expectation-based accounts do predict a general effect of relative clause length, whereby the matrix verb is made easier as the relative clause is lengthened (Levy, 2008). This would be considered an "anti-locality" effect and would be attributed to the comprehender's increasing certainty that the matrix verb is coming up as the relative clause gets longer. However, this is not the pattern in the present data, as lengthening an ORC reduced reading times on the matrix verb, but lengthening an SRC did not. Indeed, to the extent that the additional length made reading times longer on the matrix verb for SRC conditions, an expectation-based anti-locality explanation of reading difficulty on the matrix verb appears to be disconfirmed.

The conclusion that the difficulty is specifically due to encountering the matrix verb immediately after the ORC verb is consistent with both of the "bottleneck" accounts outlined above. On the retrieval bottleneck account, difficulty should arise only when the memory retrieval required at the ORC verb is still ongoing when the matrix verb is encountered. On the thematic bottleneck account, difficulty should arise only when thematic/syntactic assignment of the matrix subject as theme/object of the ORC verb is still ongoing. On the other hand, this conclusion does not support a simple retrieval

interference account. Inserting a prepositional phrase after the ORC verb would not be expected to eliminate retrieval interference from the ORC subject. Indeed, simulations using a web-based implementation of the Lewis and Vasishth (2005) ACT-R parsing model (Engelmann, 2016) suggest that the additional length should *increase* the amount of interference contributed by the ORC subject at the matrix verb, albeit modestly. Thus, the results of the present experiment narrow the range of theoretical alternatives.

One additional possibility, however, is that the parser's difficulty with the matrix verb in this position is due to a relatively superficial property of this structure, namely, that two lexical verbs appear in succession, both inflected for past tense. Undoubtedly this is an unusual sequence in English. Experiment 2 was designed to test whether the cost arises only when two lexical verbs appear in a row, by determining whether there is a processing cost on the matrix verb when the relative clause verb in the critical ORC short condition is replaced by a phrasal verb, so that the matrix verb directly follows a preposition rather than a verb. This comparison is shown in (3a–b):

3 (a) The chef that the waiter distracted poured the flour onto the counter.
(b) The chef that the waiter talked about poured the flour onto the counter.

If the cost on the matrix verb in 3a is due to encountering two lexical verbs in a row, this cost should be absent in 3b. However, if the cost is due to encountering the matrix verb immediately after an object gap, the cost should also be present in 3b.

3. Experiment 2

3.1. Method

3.1.1. Participants

Participants were 60 subjects from the same pool as Experiment 1. Six of the 60 subjects were excluded based on losing more than 20% of experimental trials to track loss or blink on the critical region, leaving 54 subjects in the analysis.

3.1.2. Materials

The 36 items from Experiment 1 were adapted for this experiment. Two new conditions were added to each item, in which the ORC verb was replaced by a phrasal verb; these are referred to as the Phrasal ORC conditions. An example is in (4).

4 (a) The chef that the waiter distracted poured the flour onto the counter. (ORC, short)
(b) The chef that the waiter distracted in the kitchen poured the flour onto the counter. (ORC, long)
(c) The chef that the waiter talked about poured the flour onto the counter. (Phrasal ORC, short)
(d) The chef that the waiter talked about in the kitchen poured the flour onto the counter. (Phrasal ORC, long)
(e) The chef that distracted the waiter poured the flour onto the counter. (SRC, short)
(f) The chef that distracted the waiter in the kitchen poured the flour onto the counter. (SRC, long)

These items were arranged into six experimental lists, so that each subject read six items in each of the six experimental conditions, and each item was read in each of its six conditions by an approximately equal number of subjects. These 36 items were randomly intermixed with 64 other sentences from unrelated experiments. None of the filler sentences involved relative clauses. The 100 sentences were preceded by eight practice sentences. A total of 38 items were followed by two-choice comprehension questions.

3.1.3. Procedure

The procedure was identical to Experiment 1, except as follows. Nine-point calibration was used, as some of the filler sentences were presented over two lines of text, though the experimental sentences were all displayed on a single line. The experiment lasted approximately 30 min. All subjects achieved at least 74% correct on the comprehension questions. As noted above, six of the 60 lost more than 20% of trials on the basis of blinks or track losses on the critical region, and these subjects were excluded from subsequent analysis. For the remaining 54 subjects, blinks, track loss, or other error resulted in deletion of 4.4% of trials, leaving 1,858 trials for inclusion in the analysis.

3.2. Results

We analyzed the same four regions as in Experiment 1. Condition means are displayed in Fig. 2. In the Phrasal ORC conditions, the preposition that followed the relative clause verb was included in the same region for the purpose of Fig. 2. However, we leave these conditions out of the statistical analysis of that region because of uncontrolled differences in length and lexical content.

We computed the same four eyetracking measures as in Experiment 1. In the statistical analysis, the RC type factor was coded using two orthogonal contrasts, one comparing the SRC condition (coded with −0.5) to both the standard ORC condition and the Phrasal ORC condition (coded with 0.5), and the other comparing the standard ORC condition (coded with −0.5) to the Phrasal ORC condition (coded with 0.5). It was necessary to remove random interaction slopes to obtain convergence of the statistical models. Otherwise, all statistical analyses were carried out as in Experiment 1.

On the relative clause NP, there was a small but significant effect of RC type on first fixation duration ($\beta = -16.88$, $SE = 5.50$, $t = -3.07$), with shorter fixation durations on this NP in an ORC than in an SRC. (See Staub, 2010, Experiment 1, for a similar "reversed" effect in first fixation duration on the RC noun.) This effect was not present in first pass time, and there were no other significant effects on either first fixation duration or first pass time. Go-past time was much longer for the NP in ORCs ($\beta = 117.83$, $SE = 17.77$, $t = 6.63$), and there were many more regressions from the NP in ORCs ($\beta = 0.98$, $SE = 0.15$, $z = 6.32$, $p < .001$). For both the first pass and regressions analyses, it was necessary to remove random item slopes to obtain convergence. We note that while the puzzling interaction that was present in go-past time and regressions out in Experiment 1 was not significant in this experiment ($|t|$ and $|z| < 1.3$), the pattern of condition means is the same, with the additional prepositional phrase in the long condition

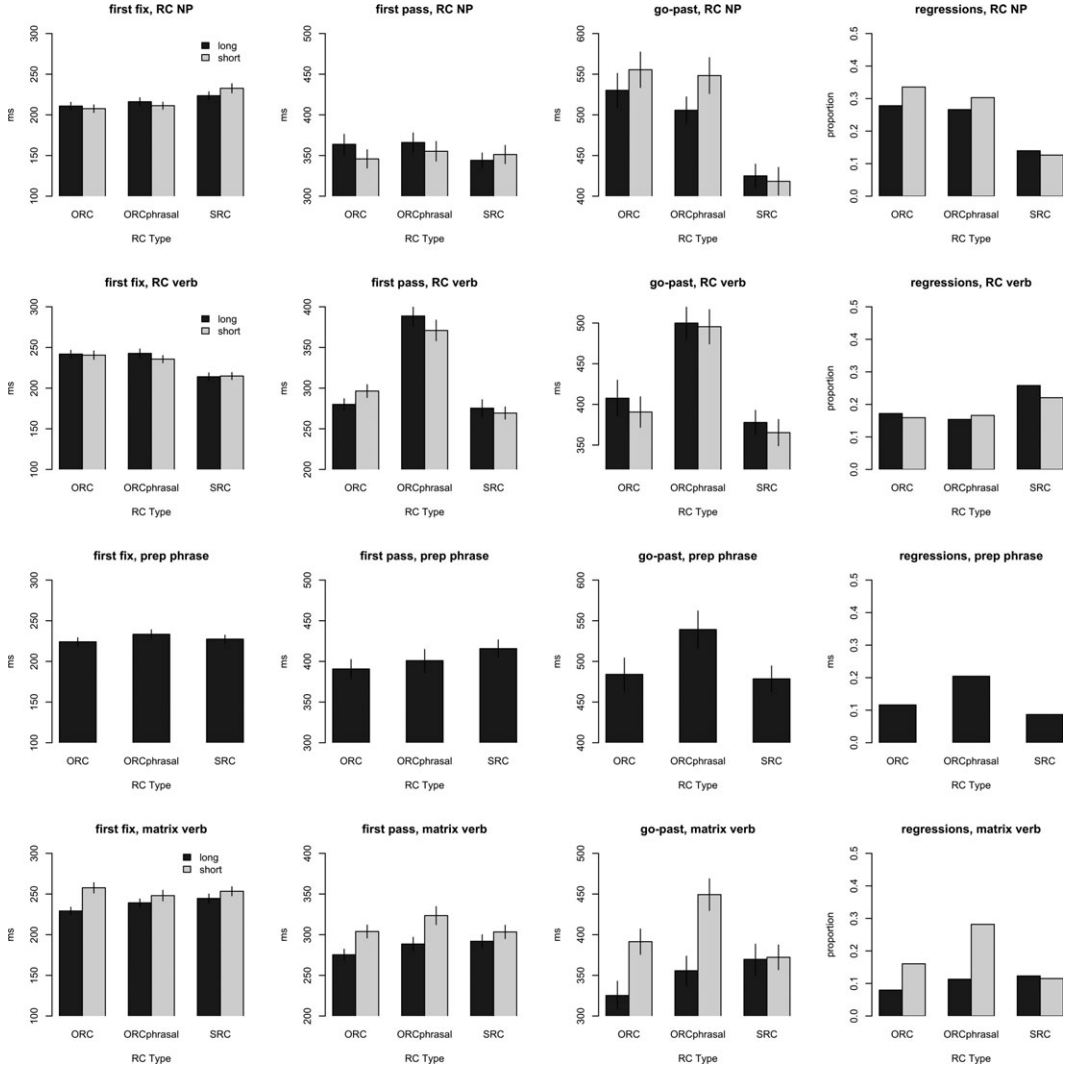

Figure 2. Experiment 2 grand mean and standard error for first fixation duration, first pass time, and go-past time (note adjustment of *y*-axis range for each measure), and regression proportion, for each of the four critical sentence regions, by condition.

reducing the number of regressions from the NP in an ORC, and increasing the number of regressions from the NP in an SRC, and similarly affecting go-past time.

On the relative clause verb region, where we leave the Phrasal ORC conditions out of the analysis, the increase in reading time in the ORC reached full significance only in first fixation duration ($\beta = 29.92$, $SE = 5.46$, $t = 5.11$), not in first pass time ($\beta = 20.70$, $SE = 10.48$, $t = 1.98$) or go-past time ($\beta = 36.03$, $SE = 28.77$, $t = 1.25$). There were marginally fewer regressions from the verb in the ORC than in the SRC ($\beta = -0.38$, $SE = 0.23$, $z = -1.66$, $p = .10$).

On the prepositional phrase in the long conditions, no effect on any measure reached full significance. There was a marginal effect of the SRC versus ORC contrast on the regressions out measure (β = 0.73, *SE* = 0.38, *z* = 1.89, *p* = .06).

Finally, on the matrix verb, the only significant effect on first fixation duration was a main effect of length (β = −13.85, *SE* = 6.06, *t* = −2.29), due to shorter first fixations in the long conditions. The same pattern held for first pass time (β = −21.23, *SE* = 8.20, *t* = −2.59). For go-past time, there was both a significant effect of length (β = −38.52, *SE* = 16.35, *t* = −2.36) and a significant interaction between length and the SRC versus ORC contrast (β = −77.06, *SE* = 28.55, *t* = −2.70). As Fig. 2 shows, this interaction is due to the fact that when the relative clause was short, go-past time on the matrix verb was longer after an ORC than after an SRC (especially in the Phrasal ORC condition), but when the relative clause was long, this effect was eliminated, and indeed was numerically reversed. The same pattern held for regressions, where again there was a significant effect of length (β = −0.50, *SE* = 0.17, *z* = −2.91, *p* < .01) and a significant interaction between length and the ORC versus SRC contrast (β = −1.06, *SE* = 0.32, *z* = −3.31, *p* < .001). There were also significantly more regressions from the matrix verb following the phrasal ORC than following the standard ORC (β = 0.54, *SE* = 0.21, *z* = 2.52, *p* < .05).

It is notable that if the analysis is restricted to just the four conditions from this experiment that were also used in Experiment 1, the conclusions from the statistical analysis are slightly different from that experiment. Comparing each of the other three conditions to the ORC short condition, as in the post hoc analysis of Experiment 1, we find that while reading times on the matrix verb in the ORC long condition are significantly shorter than in the ORC short condition (e.g., for go-past: β = −67.82, *SE* = 22.36, *t* = −3.03), neither of the SRC conditions is significantly different from the ORC short condition. However, additional post hoc analyses of the combined data from both experiments show neither main effects of experiment nor interactions between experiment and condition, on any eye movement measure, suggesting that the differences between experiments are not themselves reliable. In the combined analysis, moreover, the pattern that was obtained in first fixation for Experiment 1, in which all three of the other conditions are read faster than the ORC short condition, is still present (ORC long: β = −30.77, *SE* = 6.50, *t* = −4.73; SRC short: *β* = −13.38, *SE* = 6.53, *t* = −2.02; SRC long: β = −16.51, *SE* = 6.78, *t* = −2.44).

3.3. Discussion

The patterns on the relative clause itself once again replicated the results obtained by Staub (2010). There was a large reading time penalty on the ORC NP, due to an increased probability of regression from this phrase, and a small penalty on the ORC verb, due to increased first fixation duration. An unexpected interaction effect on the relative clause NP had appeared in Experiment 1, with the addition of the prepositional phrase decreasing go-past time and regressions from the ORC NP, and increasing go-past time and regressions from the SRC NP. In Experiment 2 this interaction did not reach

significance in either measure, but the trend was similar. Notably, in Experiment 2 there was essentially no effect of the prepositional phrase on the SRC NP (see the top row, right two panels of Fig. 2); the effect that is consistent across the two experiments is on the ORC NP. This is the effect that is arguably most surprising, as it would seem to suggest an effect of the presence of material substantially to the right of the ORC NP on first pass reading of the ORC NP itself (e.g., reduction in regressions from *the waiter* in 2b due to the presence of *in the kitchen* later in the sentence). We speculate that if this is a real effect, it may be due to readers' awareness of the overall length of the sentence, which is visible in peripheral vision. It is possible that when difficulty is encountered on the ORC NP, readers are more likely to adopt a "wait-and-see" strategy if there is relatively more material to the right. This account is necessarily vague and speculative, and the basic effect should be confirmed more directly before this account is taken too seriously.

As in Experiment 1, relative clause type did not reliably influence reading of the prepositional phrase that ended this clause in the long conditions. While there was a trend toward increased reading time on this material in the Phrasal ORC condition, suggesting a spillover effect, this did not reach statistical significance on any measure. Focusing on just the conditions that were present in Experiment 1, reading times were again essentially identical on all measures except first pass time, where like in Experiment 1 there was a trend toward slower reading in the SRC condition. Though we hesitate to interpret this non-significant effect, it may be due to the ambiguity of the attachment of the prepositional phrase. In SRC conditions (e.g., 4f), *in the kitchen* could modify either the immediately preceding noun, *waiter*, or the verb phrase, *distracted the waiter*; only the latter modification is available in ORC conditions. Although we do not expect ambiguity *per se* to create processing difficulty (Clifton & Staub, 2008), the interpretation of the prepositional phrase may have differed between the ORC and SRC conditions, at least for some of the items. In light of these potential interpretive differences, it is difficult to draw any firm conclusions about differences in reading time on the prepositional phrase itself.

Experiment 2 was focused on the question of whether processing of the matrix verb following an ORC is different when the ORC contains a phrasal verb. Specifically, the experiment addressed the question of whether the reading time penalty when the matrix verb immediately follows the ORC verb is in evidence when processing this sequence does not involve reading two lexical verbs in a row. In fact, the longest go-past times on the matrix verb, and the most regressions from this verb, occurred in the Phrasal ORC short condition. As in Experiment 1, the ORC penalty on the matrix verb was completely eliminated—even numerically reversed—in the long conditions, when an additional prepositional phrase was inserted before the matrix verb. In this experiment the critical interaction effects reached significance in the go-past and regressions measures, whereas in Experiment 1 they appeared in earlier reading time measures. However, the numerical trend is similar across all measures in both experiments. The experiments converge on the conclusion that there is a reading time penalty on the matrix verb after an ORC compared to the same verb after an SRC, and that additional material after the ORC gap eliminates this penalty. The ameliorative effect of additional material after the ORC gap

site is present if the gap follows a lexical verb such as *distracted*, and also if the gap follows a phrasal verb such as *talked about*.

It is worth noting, however, that the phrasal verbs themselves may have had independent effects. Regressions from the material immediately after the phrasal verb were very common, and go-past time was inflated. In the long condition, this material was the prepositional phrase (third row of Fig. 2, third panel from right); in the short condition, it was the matrix verb (bottom row of Fig. 2, third panel from right). In sum, it appears that a phrasal relative clause verb does induce some difficulty. Given the design of the present experiment, it was not possible to assess this cost on the phrasal verb itself, but the cost appears on the subsequent material. A number of factors may be involved in this cost, such as the presence of two prepositions in a row when the phrasal verb is followed by a prepositional phrase, and the potential for the phrasal verb to elicit a form of "filled gap" effect (e.g., Stowe, 1986). For present purposes, what is most important is that whether the verb in an object relative is a lexical verb or a phrasal verb, reading times on the subsequent matrix verb are inflated only when it immediately follows this ORC verb.

4. General discussion

The experiments presented here suggest that there is indeed some processing difficulty on the matrix verb when it immediately follows the ORC verb, which is eliminated when additional material is inserted between the two verbs. There is no sign of difficulty on the intervening material itself. The size of the effect on the matrix verb is modest, and it appears in different measures in the two relatively high-powered experiments. It is not surprising, then, that previous experiments have not always obtained this effect.

The results suggest that the cause of difficulty is the gap-matrix verb sequence itself. In the Introduction, we proposed three explanations for this difficulty. The first, the retrieval interference account, cannot easily account for the elimination of the difficulty when additional material is interposed between the ORC verb and the matrix verb. The second, the retrieval bottleneck account, holds that processing the matrix verb after the relative clause verb is difficult because the memory retrieval required at the matrix verb must await completion of the memory retrieval required at the ORC verb. The third, the thematic bottleneck account, holds that this sequence causes difficulty because it requires the comprehender to engage in a particularly complex act of thematic processing. First, the relative clause head (*the chef* in examples (2) and (4)) must be interpreted as the theme or patient of the relative clause verb, *distracted* or *talked about*. But almost immediately, the very same entity must be interpreted as the agent of the matrix verb, *poured*. Correctly assigning these two distinct thematic roles in rapid succession may be especially difficult, resulting in slowed reading of the matrix verb. On both accounts, when additional material in the form of a prepositional phrase follows the gap, the bottleneck would be averted.

Both of these accounts are still standing, but we think that a principle of parsimony favors the retrieval bottleneck account. As we noted in the Introduction, there is

independent motivation for the notion that the memory retrievals that are carried out in the course of sentence processing must occur in a serial manner. Arguably the most direct evidence for this comes from McElree et al. (2003), who used the speed-accuracy trade-off (SAT) paradigm to investigate structures like (5):

5	(a) This is the album$_i$ that the collector found difficult to spread ___$_i$ open
	(b) This is the album$_i$ that the stamps$_j$ were difficult to mount ___$_j$ in ___$_i$

McElree et al. observed that the rate parameter of the SAT function was significantly lower for double gap constructions like 5b than for single gap constructions like 5a, suggesting that the former are processed more slowly than the latter. This pattern of results is inconsistent with the possibility that the independent retrievals necessary to interpret double gap constructions like 5b could be executed in parallel with no time cost, instead supporting the view that when multiple retrieval events are necessary to parse and interpret a linguistic expression, those retrievals are executed serially.

There is also another aspect of the present data that provides circumstantial support for the notion that retrieval of the matrix subject, upon encountering the matrix verb, plays a role in reading times at that verb. In the measures in which the RC type-by-length interaction reached full significance on the matrix verb (first fixation duration and first pass time in Experiment 1; go-past time and regressions out in Experiment 2), this interaction is actually due to a crossover pattern in which (a) in the short conditions, processing is more difficult on the matrix verb following an ORC, and (b) in the long conditions, processing is slightly *easier* on the matrix verb following an ORC. If this latter difference is in fact meaningful, it receives a plausible explanation in terms of the difficulty of retrieval of the matrix subject. On retrieval-based models (e.g., Lewis & Vasishth, 2005), repeated retrievals of a single item strengthen the representation of that item, facilitating subsequent retrievals. This mechanism has been offered as an explanation for antilocality effects in sentence processing (Lewis et al., 2006; Vasishth & Lewis, 2006). These models make the claim, then, that the additional retrieval operation necessary to parse the long filler-gap dependency in an ORC should have the side effect of strengthening the representation of the head noun. Once the retrieval bottleneck has been eliminated, this strengthening should lead to facilitated retrieval of the head noun of an ORC at the matrix verb, all else being equal. Because the representation of the head noun of an SRC is not strengthened through retrieval in this fashion, it should be harder to retrieve at the matrix verb, consistent with the reading time patterns we observe.

From a larger perspective, the two present experiments, together with the two experiments in Staub (2010), suggest that there may be three independent loci of processing difficulty in the standard subject-modifying ORC sentences like 1a, compared to sentences like 1b. Easily the largest of these effects is on the NP within the ORC, where go-past times are reliably about 100 ms longer than on the corresponding NP within an SRC. A much smaller effect, on the order of 30 ms in all experiments, appears on the ORC verb, always in first pass reading measures. A relatively small effect also appears on the matrix verb when it immediately follows the ORC, varying in whether it appears in first pass

reading (Experiment 1) or only in regression-based measures (Experiment 2). Thus, it appears that the subject-modifying ORC may be a "perfect storm" of processing difficulty, in which several independent sources of difficulty combine to induce a substantial overall penalty. From a theoretical point of view, these results suggest that one-factor accounts of ORC difficulty are unlikely to capture the full complexity of the data.

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Appendix

Items used in Experiments 1 and 2. Experiment 1 did not include the third and fourth version of each item (i.e., the Phrasal ORC conditions).

1.	The bus driver that the kids followed wondered about the location of a hotel.
	The bus driver that the kids followed during the day wondered about the location of a hotel.
	The bus driver that the kids laughed at wondered about the location of a hotel.
	The bus driver that the kids laughed at during the day wondered about the location of a hotel.
	The bus driver that followed the kids wondered about the location of a hotel.
	The bus driver that followed the kids during the day wondered about the location of a hotel.
2.	The chef that the waiter distracted poured the flour onto the counter.
	The chef that the waiter distracted in the kitchen poured the flour onto the counter.
	The chef that the waiter talked about poured the flour onto the counter.
	The chef that the waiter talked about in the kitchen poured the flour onto the counter.
	The chef that distracted the waiter poured the flour onto the counter.
	The chef that distracted the waiter in the kitchen poured the flour onto the counter.
3.	The children that the babysitter ignored bothered her about a trip to the beach.
	The children that the babysitter ignored before breakfast bothered her about a trip to the beach.
	The children that the babysitter yelled at bothered her about a trip to the beach.
	The children that the babysitter yelled at before breakfast bothered her about a trip to the beach.
	The children that ignored the babysitter bothered her about a trip to the beach.
	The children that ignored the babysitter before breakfast bothered her about a trip to the beach.
4.	The students that the teacher threatened skipped the reading for the week.
	The students that the teacher threatened after class skipped the reading for the week.
	The students that the teacher spoke to skipped the reading for the week.
	The students that the teacher spoke to after class skipped the reading for the week.
	The students that threatened the teacher skipped the reading for the week.
	The students that threatened the teacher after class skipped the reading for the week.
5.	The dancer that the audience loved ignored the director's instructions.
	The dancer that the audience loved at the FAC* ignored the director's instructions.
	The dancer that the audience chatted about ignored the director's instructions.
	The dancer that the audience chatted about at the FAC ignored the director's instructions.
	The dancer that loved the audience ignored the director's instructions.
	The dancer that loved the audience at the FAC ignored the director's instructions.
Note: FAC is an acronym for the Fine Arts Center, a performance space at UMass Amherst.	
6.	The employees that the fireman spotted hurried across the open field.
	The employees that the fireman spotted in the building hurried across the open field.
	The employees that the fireman shouted to hurried across the open field.
	The employees that the fireman shouted to in the building hurried across the open field.
	The employees that spotted the fireman hurried across the open field.
	The employees that spotted the fireman in the building hurried across the open field.
7.	The farmer that the customers approached lifted the chickens from their coop.
	The farmer that the customers approached at the market lifted the chickens from their coop.
	The farmer that the customers bargained with lifted the chickens from their coop.
	The farmer that the customers bargained with at the market lifted the chickens from their coop.
	The farmer that approached the customers lifted the chickens from their coop.
	The farmer that approached the customers at the market lifted the chickens from their coop.

8.	The farmer that the rancher hired planted the seeds in long rows.
	The farmer that the rancher hired during the season planted the seeds in long rows.
	The farmer that the rancher worked for planted the seeds in long rows.
	The farmer that the rancher worked for during the season planted the seeds in long rows.
	The farmer that hired the rancher planted the seeds in long rows.
	The farmer that hired the rancher during the season planted the seeds in long rows.
9.	The fireman that the residents signaled sprayed the house with high-powered hoses.
	The fireman that the residents signaled from the street sprayed the house with high-powered hoses.
	The fireman that the residents spoke to sprayed the house with high -powered hoses.
	The fireman that the residents spoke to from the street sprayed the house with high-powered hoses.
	The fireman that signaled the residents sprayed the house with high -powered hoses.
	The fireman that signaled the residents from the street sprayed the house with high-powered hoses.
10.	The actor that the director watched forgot a critical line.
	The actor that the director watched on the set forgot a critical line.
	The actor that the director listened to forgot a critical line.
	The actor that the director listened to on the set forgot a critical line.
	The actor that watched the director forgot a critical line.
	The actor that watched the director on the set forgot a critical line.
11.	The investigator that the agency phoned suspected the new person from accounting.
	The investigator that the agency phoned for the job suspected the new person from accounting.
	The investigator that the agency called up suspected the new person from accounting.
	The investigator that the agency called up for the job suspected the new person from accounting.
	The investigator that phoned the agency suspected the new person from accounting.
	The investigator that phoned the agency for the job suspected the new person from accounting.
12.	The judge that the witnesses addressed noticed the defense attorneys.
	The judge that the witnesses addressed on the stand noticed the defense attorneys.
	The judge that the witnesses waited for noticed the defense attorneys.
	The judge that the witnesses waited for on the stand noticed the defense attorneys.
	The judge that addressed the witnesses noticed the defense attorneys.
	The judge that addressed the witnesses on the stand noticed the defense attorneys.
13.	The manager that the foreman visited remembered some inconvenient facts.
	The manager that the foreman visited in the shop remembered some inconvenient facts.
	The manager that the foreman looked for remembered some inconvenient facts.
	The manager that the foreman looked for in the shop remembered some inconvenient facts.
	The manager that visited the foreman remembered some inconvenient facts.
	The manager that visited the foreman in the shop remembered some inconvenient facts.
14.	The mathematician that the chairman admired created a solution to the well-known problem.
	The mathematician that the chairman admired from afar created a solution to the well-known problem.
	The mathematician that the chairman read about created a solution to the well-known problem.
	The mathematician that the chairman read about from afar created a solution to the well-known problem.
	The mathematician that admired the chairman created a solution to the well-known problem.
	The mathematician that admired the chairman from afar created a solution to the well-known problem.

15.	The monkeys that the zookeepers watched rattled the bars of their cage.
	The monkeys that the zookeepers watched from a distance rattled the bars of their cage.
	The monkeys that the zookeepers spied on rattled the bars of their cage.
	The monkeys that the zookeepers spied on from a distance rattled the bars of their cage.
	The monkeys that watched the zookeepers rattled the bars of their cage.
	The monkeys that watched the zookeepers from a distance rattled the bars of their cage.
16.	The movie star that the philanthropists invited proposed an annual prize.
	The movie star that the philanthropists invited during the festival proposed an annual prize.
	The movie star that the philanthropists asked for proposed an annual prize.
	The movie star that the philanthropists asked for during the festival proposed an annual prize.
	The movie star that invited the philanthropists proposed an annual prize.
	The movie star that invited the philanthropists during the festival proposed an annual prize.
17.	The woman that the couple observed purchased the old Victorian house.
	The woman that the couple observed at the park purchased the old Victorian house.
	The woman that the couple wondered about purchased the old Victorian house.
	The woman that the couple wondered about at the park purchased the old Victorian house.
	The woman that observed the couple purchased the old Victorian house.
	The woman that observed the couple at the park purchased the old Victorian house.
18.	The pilot that the ground crew delayed remained on the runway for a long time.
	The pilot that the ground crew delayed for hours remained on the runway for a long time.
	The pilot that the ground crew talked to remained on the runway for a long time.
	The pilot that the ground crew talked to for hours remained on the runway for a long time.
	The pilot that delayed the ground crew remained on the runway for a long time.
	The pilot that delayed the ground crew for hours remained on the runway for a long time.
19.	The soldiers that the natives helped climbed the big rock that blocked the path.
	The soldiers that the natives helped in the forest climbed the big rock that blocked the path.
	The soldiers that the natives walked behind climbed the big rock that blocked the path.
	The soldiers that the natives walked behind in the forest climbed the big rock that blocked the path.
	The soldiers that helped the natives climbed the big rock that blocked the path.
	The soldiers that helped the natives in the forest climbed the big rock that blocked the path.
20.	The speaker that the economists entertained predicted a good year for the industry.
	The speaker that the economists entertained for days predicted a good year for the industry.
	The speaker that the economists heard about predicted a good year for the industry.
	The speaker that the economists heard about for days predicted a good year for the industry.
	The speaker that entertained the economists predicted a good year for the industry.
	The speaker that entertained the economists for days predicted a good year for the industry.
21.	The executives that the lawyers sued filed a grievance with the judge.
	The executives that the lawyers sued in court filed a grievance with the judge.
	The executives that the lawyers complained about filed a grievance with the judge.
	The executives that the lawyers complained about in court filed a grievance with the judge.
	The executives that sued the lawyers filed a grievance with the judge.
	The executives that sued the lawyers in court filed a grievance with the judge.
22.	The trainer that the jockey called rubbed the horse's back.
	The trainer that the jockey called in the stables rubbed the horse's back.
	The trainer that the jockey stopped near rubbed the horse's back.
	The trainer that the jockey stopped near in the stables rubbed the horse's back.
	The trainer that called the jockey rubbed the horse's back.
	The trainer that called the jockey in the stables rubbed the horse's back.

23.	The tennis player that the coach admired defeated his greatest rival.
	The tennis player that the coach admired for years defeated his greatest rival.
	The tennis player that the coach worked with defeated his greatest rival.
	The tennis player that the coach worked with for years defeated his greatest rival.
	The tennis player that admired the coach defeated his greatest rival.
	The tennis player that admired the coach for years defeated his greatest rival.
24.	The visitor that the student introduced walked across the quad.
	The visitor that the student introduced at the seminar walked across the quad.
	The visitor that the student met with walked across the quad.
	The visitor that the student met with at the seminar walked across the quad.
	The visitor that introduced the student walked across the quad.
	The visitor that introduced the student at the seminar walked across the quad.
25.	The bartender that the drunk fought ate some nachos for dinner.
	The bartender that the drunk fought at the party ate some nachos for dinner.
	The bartender that the drunk ordered from ate some nachos for dinner.
	The bartender that the drunk ordered from at the party ate some nachos for dinner.
	The bartender that fought the drunk ate some nachos.
	The bartender that fought the drunk at the party ate some nachos.
26.	The ballerina that the murderer saved took her final bow.
	The ballerina that the murderer saved on the stage took her final bow.
	The ballerina that the murderer sang with took her final bow.
	The ballerina that the murderer sang with on the stage took her final bow.
	The ballerina that saved the murderer took her final bow.
	The ballerina that saved the murderer on the stage took her final bow.
27.	The witch that the girl killed was resurrected eventually.
	The witch that the girl killed in the castle was resurrected eventually.
	The witch that the girl battled with was resurrected eventually.
	The witch that the girl battled with in the castle was resurrected eventually.
	The witch that killed the girl was resurrected eventually.
	The witch that killed the girl in the castle was resurrected eventually.
28.	The graduate student that the researcher helped wrote a paper about a new study.
	The graduate student that the researcher helped in the summer wrote a paper about a new study.
	The graduate student that the researcher worked with wrote a paper about a new study.
	The graduate student that the researcher worked with in the summer wrote a paper about a new study.
	The graduate student that helped the researcher wrote a paper about a new study.
	The graduate student that helped the researcher in the summer wrote a paper about a new study.
29.	The doctor that the patient saw thought about what was causing the pain.
	The doctor that the patient saw in the lobby thought about what was causing the pain.
	The doctor that the patient met with thought about what was causing the pain.
	The doctor that the patient met with in the lobby thought about what was causing the pain.
	The doctor that saw the patient thought about what was causing the pain.
	The doctor that saw the patient in the lobby thought about what was causing the pain.
30.	The man that the woman kissed left early to go to work.
	The man that the woman kissed in Chicopee left early to go to work.
	The man that the woman lived with left early to go to work.
	The man that the woman lived within Chicopee left early to go to work.
	The man that kissed the woman left early to go to work.
	The man that kissed the woman in Chicopee left early to go to work.

Note: Chicopee is a town near UMass Amherst.

31.	The lady that the photographer filmed walked off the movie set.
	The lady that the photographer filmed after lunch walked off the movie set.
	The lady that the photographer talked with walked off the movie set.
	The lady that the photographer talked with after lunch walked off the movie set.
	The lady that filmed the photographer walked off the movie set.
	The lady that filmed the photographer after lunch walked off the movie set.
32.	The mother that the child stopped asked her if she needed help.
	The mother that the child stopped on the sidewalk asked her if she needed help.
	The mother that the child spoke with asked her if she needed help.
	The mother that the child spoke with on the sidewalk asked her if she needed help.
	The mother that stopped the child asked her if she needed help.
	The mother that stopped the child on the sidewalk asked her if she needed help.
33.	The professor that the students ignored continued with his lecture.
	The professor that the students ignored during the break continued with his lecture.
	The professor that the students talked about continued with his lecture.
	The professor that the students talked about during the break continued with his lecture.
	The professor that ignored the students continued with his lecture.
	The professor that ignored the students during the break continued with his lecture.
34.	The doctor that the patients disliked decided to stop working at the hospital.
	The doctor that the patients disliked for a long time decided to stop working at the hospital.
	The doctor that the patients laughed at decided to stop working at the hospital.
	The doctor that the patients laughed at for a long time decided to stop working at the hospital.
	The doctor that disliked the patients decided to stop working at the hospital.
	The doctor that disliked the patients for a long time decided to stop working at the hospital.
35.	The woman that the children irritated yelled at her husband a lot.
	The woman that the children irritated during dinner yelled at her husband a lot.
	The woman that the children fussed at yelled at her husband a lot.
	The woman that the children fussed at during dinner yelled at her husband a lot.
	The woman that irritated the children yelled at her husband a lot.
	The woman that irritated the children during dinner yelled at her husband a lot.
36.	The celebrity that the waiter harassed called security following the incident.
	The celebrity that the waiter harassed on Friday called security following the incident.
	The celebrity that the waiter complained to called security following the incident.
	The celebrity that the waiter complained to on Friday called security following the incident.
	The celebrity that harassed the waiter called security following the incident.
	The celebrity that harassed the waiter on Friday called security following the incident.