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How focus particles and accents affect attachment

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This project shows that focus and information structure, as indicated by the focus particle "only" and pitch accents, influence syntactic attachment, in contrast to the well-known effects of prosodic boundaries on attachment. One written questionnaire, one completion study, and several auditory questionnaires show that the position of "only" strongly affects attachment preferences in ambiguous sentences, while contrastive pitch accents have smaller effects. The two types of focus marking do not interact but independently impact attachment. These results support a modified version of the Focus Attraction Hypothesis, with ambiguous material drawn to attach to the most important information in a sentence. This research shows that information structure can affect sentence structure as well as discourse coherence.

1 Introduction

Sentence processing involves the combination and use of many different types of information, including prosodic and semantic information. One central question for the field is which types of information affect which parts of processing. This work shows novel evidence that the focus particle *only* can influence the attachment of phrases into an evolving syntactic structure, a core part of the sentence processing endeavor.

Numerous works have shown that prosodic boundaries affect the attachment of phrases in a sentence (e.g., Lehiste 1973; Price et al. 1991; Pynte & Prieur 1996; Schafer 1997; Carlson et al. 2001; Snedeker & Trueswell 2003; Kraljic & Brennan 2005; Watson & Gibson 2005; among others). For example, when a phrase could attach higher or lower within a sentence, like the temporal Prepositional Phrase *on Monday* in (1), a prosodic boundary (at #) between the ambiguously-attached phrase and the low attachment site favors high attachment into the Verb Phrase (VP) headed by *claimed*:

(1)   Sandy claimed that Bill had arrived # on Monday.

This result illustrates a natural mapping between prosodic and syntactic structure. The listener needs to decide whether or not to close a syntactic phrase, the VP headed by *arrived*. A prosodic boundary tells them that a prosodic phrase ends at that position, while the lack of a prosodic boundary means the prosodic phrase continues. And although prosodic and syntactic phrase edges do not always coincide, having their final boundaries at the same place in a string of words is favored (Nespor & Vogel 1986; Speer, Kjelgaard & Dobroth 1996; Selkirk 2000). It is intuitively plausible that the two levels of grouping of words, syntactic and prosodic, should be related.

The question of whether information structure, as cued by the presence and position of focus, can affect attachment has been less well studied, with only a handful of papers addressing it (Schafer et al. 1996; Carlson et al. 2009; Lee & Watson 2011; Lee & Garnsey 2012; Carlson & Tyler 2018; Carlson & Potter in press). Most of this research has found that accented heads of attachment sites do attract a later modifier. For example, people hearing (1) with a contrastively accented first verb, *claimed*, are more likely to interpret the modifier as attaching high than those hearing a contrastively accented second verb, *arrived* (Carlson & Tyler 2018). Carlson & Potter (in press) showed that preceding wh-questions, which also indicate focus position within a sentence, can affect attachment similarly, increasing attachments to the constituent focused by the wh-question. These effects all support the Focus Attraction Hypothesis in (2), first formulated in Schafer et al. (1996: 149). The underlying motivation for the hypothesis is that perceivers prefer for ambiguously attached material to modify more important information in the sentence rather than less important information.

(2)   *Focus Attraction Hypothesis:* A phrase that is neither a complement nor syntactically obligatory is preferentially taken to modify a focused phrase unless this violates linguistic (grammatical or pragmatic) constraints.

But questions remain about how focus influences attachment. We will explore in this project whether and how focus particles like *only* can influence attachment. Because the position of *only* affects a sentence's information structure, we suspect that it should affect the attachment of an ambiguous modifier. But there is some doubt about what predictions the Focus Attraction Hypothesis in (2) makes about the impact of *only* on attachment. The hypothesis specifically concerns focused attachment sites drawing modifier attachment. However, *only* does not, itself, cue focus or bear focus. The semantics of the focus particle, its structural position, and the position of a focused element with which it associates all impact the final truth conditions and information-structural interpretation (Rooth 1992; Beaver & Clark 2008). Thus, a sentence containing *only* has multiple information-structural cues which conspire to yield the final information-structural parse.

The central question we address is how these cues impact attachment. Will *only* draw attachment to the syntactic domain it c-commands, its scope? Or will the position of a focused element below *only* be where attachment is drawn—which the current Focus Attraction Hypothesis would seem to predict?

We find that the scope of *only* draws attachment, as does a focused element below it, independently. We therefore will present a revision of the Focus Attraction Hypothesis, generalized to cover the effects of other information-structural cues beyond foci. Ultimately, this research aids in clarifying how different aspects of information structure affect sentence processing generally, including what levels of representation they influence.

1.1 Pitch accent effects on attachment

Schafer et al. (1996) found that relative clauses which could attach to one of two nouns (*propeller* or *plane* in (3)) were more likely to attach to whichever noun was contrastively pitch accented.

(3)   … the propeller of the plane [which the mechanic was so carefully examining]$_{RC}$

They explained these results with the Focus Attraction Hypothesis, on which the focus that accents indicated led to the modifier being attracted to a particular attachment site.

Carlson et al. (2009) found a similar result in a different ambiguity. In sentences like *Jimmy comforted the girl that he had insulted [at the end of the party]*, the final bracketed modifier could attach to the first verb (*comforted*) or the second verb (*insulted*). The sentences were produced with both verbs bearing H* accents, and then either the first or second accent was replaced

with an F0 contour linearly interpolated between surrounding points. The modifier was drawn to whichever verb retained an accent, though this effect was smaller than effects of prosodic boundaries after the first or second verb. Carlson et al. (2009) also attributed their results to the Focus Attraction Hypothesis.

By contrast, Lee & Watson (2011), studying ambiguously-attached relative clauses, argued that salience is the primary factor explaining effects of L + H* accents on attachment. They found that longer relative clauses showed larger changes in attachment rates due to accent than shorter ones. They reasoned that the salience of an accented attachment site aided perceivers more under conditions of greater processing load such as with longer relative clauses; oddly, though, the complexity of relative clauses did not modulate accent effects. In their final experiment, where some questions probed aspects of the sentence meaning besides relative clause attachment, participants preferred to provide the accented noun as an answer, even when it was an irrelevant and wrong answer to the question. Lee and Watson thus argued for a version of their Salience Hypothesis based on post-sentence selection mechanisms: perceivers prefer to provide accented words as answers to any question, about attachment or otherwise, because of their salience. Their results are nevertheless broadly consistent with the Focus Attraction Hypothesis.

Carlson & Tyler (2018) examined the generality of accent effects on attachment in three different attachment ambiguities (4).

(4)   a.   Sammy heard that Bill had called after the meeting.
       b.   Jimmy comforted the girl that he had insulted at the end of the party.
       c.   Paula phoned a friend from Alabama.

All three structures showed effects of L + H* accent placement on attachment, and these effects were independent of prosodic boundaries, though boundaries usually affected attachment more. Further, they showed that the post-sentence selection version of Lee & Watson's Salience Hypothesis did not explain all accent attachment effects, by having participants choose between two answers which both contained all of the potentially accented words. Participants still chose the answers indicating attachment to the actually accented word more often, although the post-sentence selection hypothesis predicted equal rates of choosing the answers. This research showed that accents affect not only relative clause attachment but also attachment of Prepositional Phrase (PP) modifiers to verbs in different clauses (4a–b) or to verbs vs. nouns (4c), suggesting that focus attraction is a general process in syntactic parsing. The results supported the Focus Attraction Hypothesis.

Finally, Carlson & Potter (in press) explored whether focus marked in ways besides contrastive accents could affect attachment preferences. Sentences like (4c) were presented with a neutral prosodic contour after wh-questions that put the VP or the object noun in focus (*What did Paula do?* vs. *Who did Paula phone?*). The final modifier (*from Alabama*) was drawn to attach to the

focused phrase. They argue that these results also favour the Focus Attraction Hypothesis, as focus is the property which unites answers to wh-questions and accented words. It is not clear how a Salience Hypothesis would explain effects of wh-questions on interpretation and pitch accent effects without recapitulating the theory of focus.

These results taken together show evidence that focus impacts attachment. In the current project, we examine whether the Focus Attraction Hypothesis predicts the effects of *only* on attachment, both alone and with pitch accents.

1.2 Focus markers: accents and *only*

Pitch accents in English cue focus, marking the discourse status of an accented element (Pierrehumbert & Hirschberg 1990; Rooth 1992; Schwarzschild 1999). Information structure can also be marked through the interaction of focus and focus-sensitive constructions, such as question-answer pairs, the operator *only,* negation, and modals, among others (Rooth 1985; 1992; 1996; Hajičová, Partee, & Sgall 1998). In focus-sensitive constructions, the presence and location of focus materially affects the truth-conditional meaning and/or contextual felicity of that utterance. Here, we concentrate on the focus particle *only*.

Only is sensitive to focused elements within its scope, which is roughly the syntactic material c-commanded by the particle The meaning of an utterance with *only* depends on the location of focus within its scope, and on the exhaustivity conveyed by the operator (Rooth 1992; 2016; Beaver & Clark 2002; 2003; 2008; Beck 2016). Consider (5a–b), from Rooth (1985), against the context in (5). Answers (5a–b) only differ in the location of focus (indicated by capitalization), yet vary in their truth value: (5a) is false in this context, as Mary also introduced Tom to Sue, while (5b) is true, since the only person Mary introduced Bill to was Sue.

(5)   Context: Mary introduced Bill and Tom to Sue, and there were no other introductions.
   a.   Mary only introduced BILL to Sue.
   b.   Mary only introduced Bill to SUE.

The meaning of an utterance with *only* also depends on its position, which indicates where alternatives to the focused element are calculated. In (6a) and (7a), the embedded verb *hired* is focused, but they differ in whether *only* is in the matrix or embedded clause. Thus, the alternatives calculated in the two examples differ, as in (6b) and (7b).

(6)   a.   Sammy only heard that Bill had HIRED Mary.
   b.   The only thing that Sammy heard that Bill had done with Mary was hire her.

(7)   a.   Sammy heard that Bill had only HIRED Mary.
   b.   Sammy heard that the only thing that Bill had done with Mary was hire her.

When *only* precedes the matrix verb (6a), alternatives to *hire* are calculated at the matrix level: Sammy didn't hear that Bill had done anything but hire Mary. When *only* precedes the embedded verb (7a), alternatives are calculated at the embedded level: Sammy heard that Bill hadn't done anything but hire Mary. (These intuitional claims are supported by the results of Experiment 1c.)

In contrast, accent position relates to the focus structure of a sentence ambiguously. For example, an accent on an embedded intransitive verb might indicate narrow focus on that verb (8a).

(8)　　James said that Mary CALLED.
　　　a.　James said that Mary [$_{focus}$ CALLED].
　　　b.　James said that [$_{focus}$ Mary CALLED].
　　　c.　James [$_{focus}$ said that Mary CALLED].

Or it could indicate a wider focus, like the embedded clause (8b) or the higher VP (8c), as per Selkirk (1984)'s focus projection rules. The focus alternatives generated in each of these cases are of different syntactic sizes. With *only* present, though, its position would delineate the largest syntactic domain within which alternatives could be constructed.

The particle *only* has been shown to have various effects on sentence congruence with pictures (Paterson et al. 2003), recognition of reduced relative clauses (Sedivy 2002; Filik, Paterson, & Liversedge 2005), and memory for alternatives to NPs (Spalek, Gotzner & Wartenburger 2014). It also affects the resolution of ambiguous ellipsis structures like gapping and bare argument ellipsis (Stolterfoht et al. 2007; Carlson 2001; 2013; Sauermann, Filik, & Paterson 2013) by focusing a potentially contrastive NP. But these results do not guarantee that *only* would also affect the attachment of an ambiguous modifier. One reason for this research, then, is to discover whether focus particles do indeed affect attachment, and if so, how.

In the following experiments, we explore effects of the focus particle *only* on attachment, alone or along with pitch accents. The studies primarily use ambiguous sentences in which a final time-based adverbial phrase could attach into either the VP in a complement clause (in *Susie heard that Bill had called on Monday*, the one headed by *called*) or into the higher VP (headed by *heard*). Experiment 1a is a written questionnaire varying the position of *only* before either verb in order to establish whether this affects attachment. Experiments 1b–c then explore the likely focus structures entertained in the presence of *only* and contrastive accents, first through a written completion study and then an auditory questionnaire. In Experiments 2a–b, we use auditory questionnaires to study effects of *only* on attachment, with and without contrastively accented verbs; Experiment 2a tests these factors with a prosodic boundary before the adverbial, and Experiment 2b tests them without the prosodic boundary. Finally, in Experiment 3, we explore the effects of contrastive accents on multiple verbs as well as *only* before the first verb.

The overall pattern of results suggests that *only* does affect attachment, that it indeed has stronger effects than contrastive accents on attachment, and that it draws attachment into the highest syntactic domain under the particle. We propose revising the Focus Attraction Hypothesis in order to account for these results.

2 Experiments 1a–c

2.1 Experiment 1a

This written questionnaire tested whether the presence and position of the focus particle *only* would affect attachment. The Focus Attraction Hypothesis predicts that *only* before a VP should draw attachment of the ambiguous modifier to that VP, leading to more high attachments with *only* before Verb1, but only if people take the particle to specifically focus the nearest verb. If focus occurs elsewhere within the scope of *only*, then it is not clear what the Focus Attraction Hypothesis predicts. If focus is taken to be on the lowest non-adjunct constituent in the sentence, consistent with the default focus pattern for English (Selkirk 1984; Cinque 1993), then it will be on the lower verb, which should favor low attachment regardless of the position of *only*.

2.1.1 Method

2.1.1.1 Materials

The experimental items were 20 sentences as in (9), with matrix verbs taking a complement clause followed by an ambiguously attached final PP. We placed *only* before either the matrix or the embedded verb.

(9)   a.   Sammy only heard that Bill had called during Monday's emergency meeting.
        b.   Sammy heard that Bill had only called during Monday's emergency meeting.

These sentences were adapted from Carlson and Tyler (2018), with the final time phrases lengthened to an average of 10.4 syllables to encourage high attachment (see Appendix A). We expect that the long final phrases will be read with implicit prosody placing them in their own prosodic phrase (Fodor 1998; Hirose 2003; Breen 2014), and their consequent prosodic separation from the nearest attachment site will increase high attachments (Carlson et al. 2001; Clifton et al. 2002; 2006).

Each experimental sentence was followed by a two-choice comprehension question as in (10).

(10)   question: What happened during Monday's emergency meeting?
        a.   Sammy heard something.   (high attachment)
        b.   Bill called.   (low attachment)

Most of the questions had the adverbial phrase included in the question, rather than the answers. A subset of items (6 out of 20) were followed by the shorter question *What happened?* and the answer choices each included the adverbial. This difference did not significantly affect the results.

Besides the experimental items, participants also saw 24 ambiguous comparative ellipsis sentences, 20 sentences with ambiguous coordination, 15 filler sentences with ambiguous pronouns, and 37 unambiguous filler sentences (some containing comparatives, coordination, or time adverbials).

2.1.1.2 Participants

Forty-eight American English-speaking subjects participated in the experiment on Qualtrics after recruitment through Amazon Mechanical Turk (AMT) and were paid $3.00. Seven participants' data was eliminated on the basis of attention checks, i.e. accuracy of less than 90% on comprehension questions after unambiguous filler sentences; the data from 41 participants was analyzed. This experiment and all other experiments in this project were approved by the Morehead State University Institutional Review Board (IRB) under protocol 16-04-82.

2.1.1.3 Procedure

The 20 experimental sentences, 52 fillers and 44 unrelated experimental items were combined in a latin square design to create 6 lists of 116 items. The lists were pseudo-randomized so that items from the same experiment or condition never appeared consecutively.

Participants from AMT clicked on a link to a Qualtrics survey. In Qualtrics, they read a short introduction explaining the experiment, answered the survey, and answered some demographic questions. Most participants completed the experiment within 30 minutes. They were provided with a code to enter into AMT to qualify for payment.

2.1.2 Results and Discussion

The data was analyzed using a linear mixed-effects model with a binomial link function (Bates et al. 2015). The dependent variable was the participant response disambiguating the stimuli as high or low attachment (1 = high attachment; 0 = low attachment). The independent variable was contrast coded, with the Verb1 *only* condition as = 0.5, and the Verb2 *only* condition coded as = –0.5, and was introduced into the model as a fixed effect. The model included the maximal random effects structure justified by the design that would converge (Barr et al. 2013): random intercepts for frame and for participant, and random slopes for participant by position of *only*.[1] The model results are shown in **Table 1**.

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[1] The specific R syntax was (dataModelExp1a = glmer(Response~ OnlyPositionContrastCoding + (1 + OnlyPosition-ContrastCoding|participant) + (1|frame), data = dataSet, family = "binomial")).

	Estimate	Std. Error	z value	Pr(>|z|)
(intercept)	–0.38	0.29	–1.29	0.20
Only Position Contrast	2.16	0.31	6.87	6.55e-12

Table 1: Statistical analysis of the results of Experiment 1a.

There were significantly more high attachment responses in the Verb1 *only* condition (61.5%) than in the Verb2 *only* condition (26.6%; β = 2.16 ± 0.31, z = 6.87, p ≤ 0.001).[2]

Indeed, in this written questionnaire, the position of *only* strongly affected the attachment of the final adverbial. *Only* before the first verb led to an increase of more than 30 percentage points in high attachment answers, vs. the condition with *only* before Verb2. One possible explanation is that the focus particle was taken to indicate focus on the nearest verb, which drew the attachment of the modifier to the relevant VP. On this explanation, these conditions would be analogous to those of Carlson and Tyler (2018), in which contrastive accents on the first or second verb drew attachment into the VP headed by the accented verb. These results would also follow neatly from the Focus Attraction Hypothesis.

But is it likely that participants took the verb following *only* to be focused? The particle *only* obligatorily associates with focused elements somewhere within its scope (Beaver & Clark 2002; 2003; 2008; Rooth 1992; 2016; Beck 2016). However, in these experimental items, focus position is not explicitly cued, so there are many potential elements that *only* could associate with.

In (11a–b) we show the focus position (in brackets) and an alternative in parentheses, if participants interpret *only* as associating with the nearest verb. But when *only* precedes the matrix verb, it could associate with other focused elements, like the complement clause or the entire matrix VP (11c–d).

(11) a. Sammy only [$_{focus}$ heard] that Bill had called…(Sammy didn't repeat it.)
      b. Sammy heard that Bill had only [$_{focus}$ called]… (Bill didn't text as well.)
      c. Sammy only heard [$_{focus}$ that Bill had called]… (Sammy didn't hear anything else.)
      d. Sammy only [$_{focus}$ heard that Bill had called]… (Sammy didn't do anything else.)

Given the range of potential foci that *only* could associate with, it is unclear whether participants actually interpreted the nearest verb as being focused. In addition, English default focus is on the rightmost element of a clause (Cinque 1993; Selkirk 1995; Arregi 2016). Experiments with focus-sensitive ellipsis sentences have found that perceivers rely on expectations about this final focus position despite conflicting prosodic information (Stolterfoht et al. 2007; Carlson, Dickey

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[2] High attachment rates by item ranged between 22 and 68%; items 10 and 12 were relatively low, and items 6, 9, and 18 were relatively high. High attachment rates by subjects ranged from only 5% to 100%.

et al. 2009; Harris & Carlson 2018). These facts suggest that narrow focus on the verb following *only* is unlikely to have been the first choice of perceivers for sentences like (9). To explore which element participants would actually take to be focused under *only,* we conducted a completion experiment.

2.2 Experiment 1b

This experiment explored what focus structure readers would apply to sentences with complement clauses in the presence of *only*. We asked participants to complete complex sentences that contained *only* before either verb, with a negated clause showing a contrast set. We expected that participants would offer completions showing what they understood to be focused in the preceding material.

2.2.1 Method

2.2.1.1 Materials

The materials were adapted from the 20 sentences in Experiment 1a without the final adverbials. The focus particle *only* appeared before the first or second verb, as in (12).[3]

(12)   a.   Kathie only claimed that Alex had lied, she didn't _____.
        b.   Kathie claimed that Alex had only lied, he didn't _____.

The sentences were followed by a contradicting clause starting with the pronoun *he* or *she*. The original sentences were standardized so that first- and second-clause subjects were of different genders within each item (see Appendix B). The pronouns disambiguated the intended level of the continuation as the clause containing *only*. The contradiction paradigm was chosen because the exhaustivity of *only* rules out alternatives to the stated event (Rooth 1992; Kiss 1998; Umbach 2004), and was modeled on the procedure in Hurley & Bishop (2016). What part of the original sentence participants contradicted would indicate where within the scope of *only* they interpreted focus.

In addition to the 20 experimental items, participants also saw 80 filler items. Twenty-eight of the fillers were ambiguous (with ambiguities related to causal relations or ellipsis) and 52 were unambiguous sentences with various structures. Across the experiment, 45 items were completions, with the rest forced-choice or rating items.

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[3] An anonymous reviewer notes that the punctuation of these experimental items makes them comma splices, and so technically ungrammatical. We believe that this did not materially affect the answers.

2.2.1.2 Participants

Twenty-eight self-reported American English-speaking people participated in the experiment on Qualtrics through a link from AMT, and were paid $4.00. The data of 3 participants were discarded for providing four or more ungrammatical or incoherent completions. Any additional ungrammatical answers were also removed from the data.

2.2.1.3 Procedure

The 20 experimental completion items were combined in a latin square design with 80 filler items to create two pseudorandomized lists of 100 items. The lists were presented on Qualtrics after recruitment of participants through AMT as in Experiment 1a. Most participants completed the experiment within 30 minutes.

2.2.2 Results and Discussion

First, we examined the range of verbs provided in the answers. With *only* before Verb1, the most frequent completions included either *say* or *know*, and those verbs appeared in nearly 50% of completions. This makes sense, since the initial verbs were verbs of speech, thought, or discovery taking tensed complement clauses, and *say* and *know* are common verbs of that type. An average of 5.9 different first verbs per item appeared in completions.

With *only* before Verb2, the most frequent verbs varied more, including *take, have, leave,* and *get*. The most frequent verbs appeared in only 30% of the completions, and on average, 8.7 different verbs appeared in completions per item. This reflects the higher variability of the original second verbs, which did not all fit within a semantic or syntactic class and included intransitives, passives, *be*-verbs with adjective complements, and particle verbs like *step down*.

We then examined contrasts between the contradiction clause and the previous sentence: did the completion just contrast with one of the verbs, with the whole VP, or with the complement (if any) of the verb (Complementizer Phrase, CP)? The results of this analysis are in **Table 2**.

With *only* before Verb1, 99% of contrasts were with the first verb, the first VP, or its complement; with *only* before Verb2, 96% of contrasts were with elements of the lower clause. Completions with other contrasts were so rare as to plausibly be mistakes. Thus the initial pronoun and particle position successfully conveyed at what level to complete the contradiction.

The contrasts were coded by both authors, with disagreements resolved by discussion. Examples of contrasts in the condition with high *only* are shown in (13).

	High only	**Low only**
High contrasts:	**99%**	**5%**
Verb1	13%	0%
VP1	36%	3%
Complement of Verb1	51%	2%
Low contrasts:	**<1%**	**96%**
Verb2	0%	6%
VP2	<1%	88%
Complement of Verb2	0%	2%

Table 2: Results of Experiment 1b by level of contrast and type of contrast.

(13)   contrasts with high *only*
    a.   Kathie only claimed that Alex had lied, …
    b.   she didn't [prove] it.   (Verb1 focus)
    c.   she didn't [know that he had cheated also].   (VP1 focus)
    d.   she didn't say [he stole the jewelry].   (Complement of V1 focus)

In (13b), we took claiming and proving to be distinct acts, so this was classified as V1 focus (the relegation of all other material to a pronoun clarified the lack of additional contrasts). In (13c), knowing is different from claiming, and the CPs also contrast in content, so we classified this as having focus on the entire VP1. In (13d), though, claiming and saying are quite similar, both being verbs of speech, with *say* just less specific than *claim*. Therefore we categorized the CP following *say* as what contrasts with the original embedded clause (lying and stealing jewelry being distinct).

As **Table 2** shows, completions contrasting with VP1 and with V1's Complement (the embedded CP) were both frequent, forming 87% of completions in this condition. Contrasts with Verb1 alone were possible, but not particularly common, at 13% of completions.

With *only* before Verb2, there was much less variety in the level of contrast. Contrasts in the second clause were usually with the complete second VP, as in (14c). However, in most items, the second verbs were intransitive or clause-final. We coded these as VP2 focus instead of V2 focus because it was impossible to tell whether a narrower focus was intended.

(14)   contrasts with low *only*
    a.   Linda reported that Thomas was only bribed…
    b.   he didn't actually [take] the money. (V2 contrast, if bribing is just <u>offering</u> money)
    c.   he didn't [murder anyone].   (VP2 contrast)

Overall, Experiment 1b demonstrated that *only* can associate with focus on a variety of phrases in its scope, including the nearest verb, the entire matrix VP, or the clausal complement of the higher verb. Thus the results of Experiment 1a, with attraction toward the highest syntactic domain under *only*, are likely not due to comprehenders interpreting the verb nearest *only* as focused. Indeed, Experiment 1b suggests comprehenders would rarely choose narrow verb focus. However, the attraction effect from *only* in Experiment 1a was robust: the VP preceded by *only* was much more likely to be modified by the adverbial than the other VP. This is interesting; we might have predicted that high *only* would not draw a modifier to VP1 because it was consistent with focus at so many positions. Instead, *only* was apparently even more effective than accents in drawing attachment to a VP (cf. accent effects in Carlson & Tyler (2018) which were in the range of 5%).

2.3 Experiment 1c

Experiment 1b showed that the basic sentences from Experiment 1a, without the final adverbial, have a range of possible focus structures given a particular position of *only*. Experiment 1c explored the interpretive consequences of *only* in different positions with accent position kept constant. We wanted to check that experimental participants would report different interpretations of utterances with the position of *only* varied while the focused element below it was held constant.

In this and following auditory experiments, we primarily vary $L+H^*$ accents.[4] Schafer et al. (1996) found that H^* accents affected relative clause attachment in the same direction as $L+H^*$ accents, but were less effective. Related work by Lee & Watson (2011), Lee & Garnsey (2013), and Carlson & Tyler (2018) studied only $L+H^*$ accents. It remains an open question whether H^* accents would affect attachment in the structures studied by Carlson and Tyler (2018), though the small size of many effects with $L+H^*$ accents is not encouraging.

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[4] There remains controversy about whether English prosody contains two distinct categories of high accent, $L+H^*$ vs. H^*, as proposed in the ToBI transcription system (Beckman & Ayers 1997), or only one category which varies along a continuum (Bartels & Kingston 1996; Ladd & Morton 1997; Krahmer & Swerts 2001; Dainora 2002; Ladd & Schepman 2003; etc.). For readers with the latter view, we used accents with particularly high and steep F0 peaks compared to other H^* accents. These are likely to be used with a contrastive focus meaning.

2.3.1 Method

2.3.1.1 Materials

The 20 sentences from Experiment 1a, without final adverbials, were recorded with contrastive L+H* accents on Verb2. The position of *only* before Verb1 or Verb2 was the sole difference between the conditions (15).

(15)   a.   Sammy only heard that Bill had CALLED.
       b.   Sammy heard that Bill had only CALLED.

Acoustic measurements in **Table 3** show the average F0 and duration properties of the sentences, and **Figure 1** shows a sample prosodic contour. In this and the other auditory experiments reported here, audio files were recorded in .wav format and converted to high bitrate .mp3s (320kbit/s) using ffmpeg[5]. The acoustic measures and pitch tracks show that the two conditions had similar contours, with the final verb (Verb2) always reaching an F0 peak higher than the F0 on the first verb and usually higher than the subject. The final verbs also had fairly long durations. The height of the F0 peak on the initial subject varied, with (a) conditions (V1 *only*) averaging slightly higher subject peaks than (b) conditions (V2 *only*). We do not believe this variation in initial H* accents affected sentence interpretation.

   Each recorded sentence was followed by a two-choice comprehension question as in (16).

(16)   What did the sentence mean?
       a.   The only thing that Sammy heard that Bill had done was call.   (high answer)
       b.   Sammy heard that the only thing that Bill had done was call.   (low answer)

Condition	Subject Peak/Dur.	Verb1 Peak/Dur.	Verb2 Peak/Dur.
F0 averages			
V1 Only	248	207	261
V2 Only	237	215	252
Duration averages			
V1 Only	326	398	559
V2 Only	300	402	550

Table 3: Average F0 and duration measurements for items in Experiment 1c.

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[5] FFmpeg Developers. (2018). ffmpeg tool (Version 4.1.2) [Software]. Available from http://ffmpeg.org/.
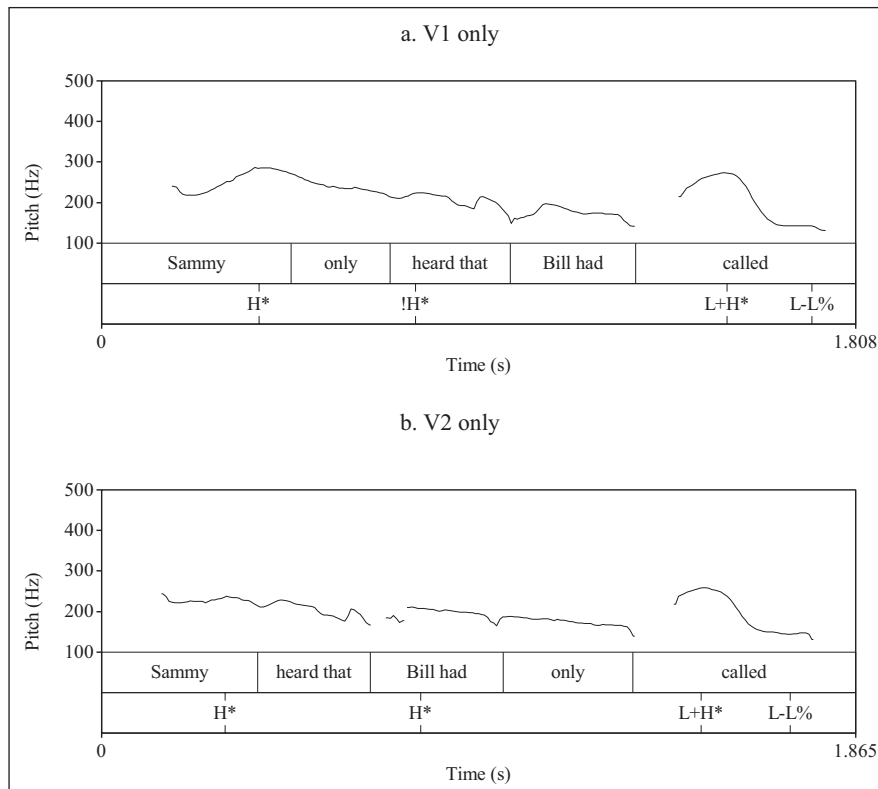
Figure 1: Pitch tracks for example sentence from Experiment 1c.

The answers explicitly labeled which event the exhaustivity of *only* applied to: a hearing event, with the first VP as the particle's domain, or a calling event, with the second VP as the domain. The high answer assumed the widest focus consistent with Verb2 accent: the entire first VP including complements. We expected that condition (a) with *only* high would get more high answers than low answers, with low answers preferred for condition (b). If instead a narrower focus given Verb2 accent was preferred, we would expect low responses to dominate for both conditions.

   Besides the 20 experimental items, participants also heard 94 filler items with a range of structures, including 40 pure fillers, 20 conjoined possessive phrases, 20 ambiguous VP ellipsis sentences, and 24 stripping ellipsis or it-clefts. These fillers involved single-talker and two-talker dialogues, and participants were asked to either rate the naturalness of, or to disambiguate, the utterances.

2.3.1.2 Participants

Forty-five native American English-speaking participants began the experiment. Forty-one of them completed it and were paid $3.50. The data from three participants who achieved less than

90% accuracy on unambiguous attention check items was excluded; data from 38 participants was analyzed.

2.3.1.3 Procedure

The experimental items were combined in a latin square design with filler items into four pseudorandomized lists of 114 items. Participants from AMT clicked on a link to a survey tool developed in the Linguistics department at Northwestern University by Chun Chan. Participants read a short introduction text, completed the survey, and answered some demographic questions. For each item, the question and answers appeared on the screen at the same time as the audio file was played. Participants had unlimited time to answer the questions. Most participants completed the experiment within 30 minutes.

2.3.2 Results and Discussion

The data was analyzed using a linear mixed-effects model with a binomial link function (Bates et al. 2015). The dependent variable was the participant response disambiguating the stimuli as high or low interpretation (1 = high interpretation; 0 = low interpretation). The independent variable was contrast coded, with the V1 *only* condition as = 0.5, and the V2 *only* condition coded as = –0.5, and introduced into the model as a fixed effect. The model included the maximal random effects structure justified by the design that would converge (Barr et al. 2013): random intercepts and random slopes for frame and for participant by position of *only*.[6] The model results are shown in **Table 4**.[7]

There was a clear effect of the position of *only* in these sentences, with 77.5% high answers for the condition with high *only* but 33.2% high with low *only* (33.2%; β = 2.14 ± 0.34, z = 6.31, p ≤ 0.001). This is reassuring, showing that *only*'s position affects the interpretation of an utterance by changing the alternatives considered by the listener.

	Estimate	Std. Error	z value	Pr($>$|z|)
(intercept)	0.21	0.14	1.43	0.15
Only Position Contrast	2.15	0.34	6.31	2.86 e-10

Table 4: Statistical analysis of the results of Experiment 1c.

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[6] The specific R syntax was (dataModelExp1c = glmer(Response~ OnlyPositionContrastCoding + (1 + OnlyPosition-ContrastCoding|participant) + (1+ OnlyPositionContrastCoding|frame), data = dataSet, family = "binomial")).

[7] High answer rates by item ranged from 30% to 68%; items 1 and 11 had relatively low rates of high answers, and items 14 and 20 had high rates. High answer rates by subject ranged from 25% to 90%.

We highlight this result because it was not clear that a questionnaire would be sensitive enough to detect this effect. A pilot experiment used questions concerning the implied vs. new status of a following sentence (17).

(17)   Which follow-up sentence gives you new information, instead of presenting information implied by the sentence you will hear?
    a.   She didn't hear that he had done anything else.
    b.   According to her source, he hadn't done anything else.

In that pilot, we found no significant effect of *only* position. We suspect that the complexity of the question and answers obscured any possible effect. The formulation of the question and answer pairs in Experiment 1c was more straightforward, allowing the observed effect to surface.

Overall, Experiments 1a–c have shown several things. First, the focus particle *only* does affect attachment preferences, with a relatively strong effect in the initial written study, Experiment 1a. We do not yet know how it might interact with accents or whether it works in auditory processing as well. Second, placing *only* before a predicate is compatible with many different focus structures (Experiment 1b), so Experiment 1a's effects were unlikely to be due to readers usually placing narrow focus on the adjacent verb. This makes effects of *only* different in their mechanism from accents on the heads of attachment sites. Third, placing *only* before different predicates while holding accent position constant did affect interpretation (Experiment 1c) through differences in the domain over which alternatives are calculated. These findings provide a background for interpreting the upcoming auditory studies, which vary the presence and position of both *only* and pitch accents.

3 Experiment 2

To learn more about effects of *only* on attachment, we turned to auditory studies allowing us to ask how the focus particle might interact with accents.

3.1 Experiment 2a

This auditory questionnaire experiment tested conditions with *only* placed before the first or second verb, plus the same conditions with the corresponding verb contrastively accented.

The first question was whether the position of the focus particle would draw attachment to each verb, and the second was whether accenting the same verb would intensify this effect. On the original Focus Attraction Hypothesis, we would predict that *only* before a verb should draw attachment of the ambiguous modifier to that verb only if people take the particle to specifically focus the nearest verb. However, *only* can associate with any focused phrase within its scope (as Experiment 1b showed). With contrastive accent on the same verb preceded by *only*, then, we

might predict that attachment to the indicated phrase would be increased: more high attachments with *only* and accenting of Verb1, and more low attachments (fewer high attachments) with *only* and accenting of Verb2. Alternatively, the focus particle position could unambiguously indicate focus within its scope, making accenting of the same position redundant: this would lead to no effect of accent.

3.1.1 Method

3.1.1.1 Materials

Twenty experimental items (18) were adapted from Experiment 1a, but with shorter adverbial phrases (see Appendix C). The conditions varied the position of *only*: before the first verb in conditions (a–b), and before the second verb in (c–d).

(18) a. Sammy only heard that Bill had called [ip] on Monday.
b. Sammy only HEARD that Bill had called [ip] on Monday.
c. Sammy heard that Bill had only called [ip] on Monday.
d. Sammy heard that Bill had only CALLED [ip] on Monday.

The items were recorded by the first author with two different prosodic contours. Conditions (a/c) had neutral contours with the highest H* pitch accent on the first subject and downstepping accents through the rest of the sentence, but no contrastive accents. Conditions (b/d) had contrastive L+H* accents on the verb marked with *only*. All conditions had intermediate phrase (ip) boundaries with L- boundary tones before the adverbial to encourage high attachment, and H* accents within the adverbial. Acoustic measurements to substantiate this description are shown in **Table 5**, and sample pitch tracks in **Figure 2**. The audio files were recorded in .wav format and converted to high bitrate .mp3s (320kbit/s) using ffmpeg.

The acoustic measurements and pitch tracks show that each verb, when contrastively accented, had average F0 peaks over 30 Hz higher and average durations at least 30 ms longer than when unaccented. All conditions had a low F0 and a pause of over 150 ms before each final adverbial, consistent with a L- ip boundary. Conditions without contrastive accents showed general declining F0 from the first subject to the boundary. The main additional variation in the prosodies was on the initial subject, which was higher and longer in conditions without contrastively accented verbs. This resulted from a different metrical structure: the most felicitous-sounding contour with the first verb less prominent had the initial subject more prominent. The pitch tracks for conditions (a/c) look as if the initial subjects had contrastive L+H* accents, though we suspect this derives from each sentence starting at a relatively constant F0 range and then moving to a delayed H* peak in subjects with initial stress. (Also, Carlson & Tyler 2018 showed that accenting subjects did not affect attachment preferences for this sentence type.)

Condition	Subject Peak/Dur.	Verb1 Peak/Dur.	Verb2 Peak/Dur.	Boundary L- or Dip	Pause Dur.	Adverbial Peak
F0 averages						
V1 Only	321	238	193	177		230
V1 Only + Accent	238	**288**	176	166		226
V2 Only	309	253	187	173		230
V2 Only + Accent	256	227	**266**	165		221
Duration averages						
V1 Only	345	396	542		176	
V1 Only + Accent	319	**452**	534		217	
V2 Only	320	395	548		227	
V2 Only + Accent	307	379	**584**		172	

Table 5: F0 averages for items in Experiment 2a in Hz and duration averages in ms by condition; accented verb measurements shown in bold.
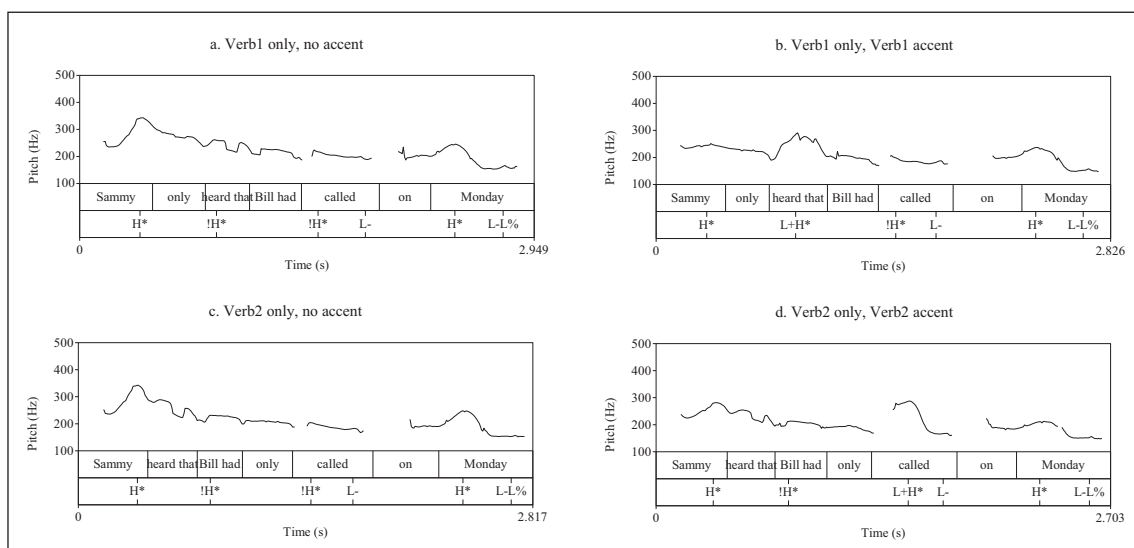

Figure 2: Pitch tracks for example sentence from Experiment 2a.

Each recorded sentence was accompanied by a two-choice comprehension question as in (19).

(19)   What happened?
     a.   Sammy heard something on Monday.   (high attachment)
     b.   Bill called on Monday.   (low attachment)

Participants also heard 79 filler items, including 20 unambiguous filler sentences with a range of structures, followed by forced-choice interpretation questions; 20 ellipsis sentences with two possible completions; 24 sets of conjoined clauses in which participants were asked to pick from two sound files the one which best expressed a certain meaning; and 15 sentences with ambiguous pronouns and two possible completions.

3.1.1.2 Participants

Fifty-nine self-reported native speakers of American English were recruited and paid $3.75 through AMT. The data from 7 participants was excluded due to less than 90% performance on unambiguous attention checks or more than 2 items skipped. This left 52 participants whose data were analyzed.

3.1.1.3 Procedure

The 20 experimental sentences were combined in a latin square design with 79 filler items to create 8 pseudo-randomized lists of 99 items. The experiment was presented using AMT and Qualtrics. The questions and answers (or completions) for each item were visible on screen along with an audio player which participants clicked to hear the sound files. There was no time limit on answers. Most participants completed the experiment within 20 minutes.

3.1.2 Results and Discussion

The data was analyzed using a linear mixed-effects model with a binomial link function (Bates et al. 2015). The dependent variable was the participant response disambiguating the stimuli as high or low attachment (1 = high attachment; 0 = low attachment). The independent variables were presence of the focus operator *only* before the matrix verb (contrast coded as = 0.5) or the embedded verb (coded as = –0.5) and the presence of a contrastive pitch accent on the verb adjacent to *only* (coded as = 0.5) or the absence of a contrastive pitch accent (coded as = –0.5). These variables were each introduced into the model as fixed effects, and the model included the maximal random effects structure justified by the design that would converge (Barr et al. 2013): random intercepts for frame and for participant, and random slopes for participant by *only* position.[8] The model results are shown in **Table 6**.

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[8] The specific R syntax was (dataModelExp2a = glmer(Response~ OnlyPositionContrastCoding * AccentPresenceContrastCoding + (1 + OnlyPositionContrastCoding|participant) + (1|frame), data = dataSet, family = "binomial")).

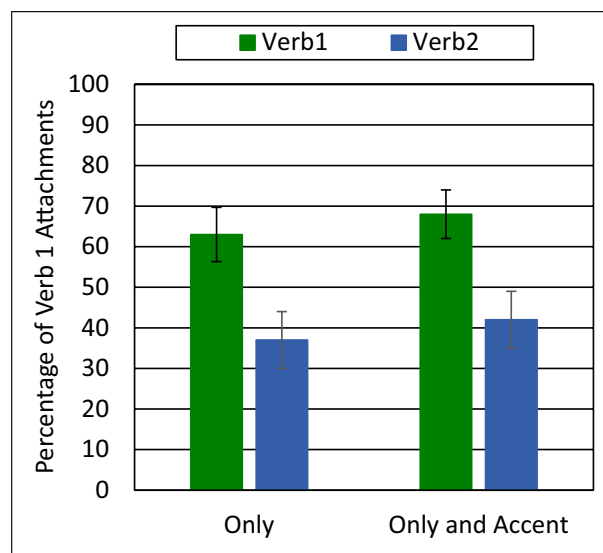|	Estimate	Std. Error	z value	Pr($>$|z|)
(intercept)	0.21	0.30	0.69	0.49
Only Position	1.75	0.29	6.02	1.71e-09
Accent Presence	0.39	0.16	2.64	0.02
Only Position: Accent Presence	0.09	0.33	0.28	0.78

Table 6: Statistical analysis of the results of Experiment 2.

Figure 3: Results of Experiment 2a.

The results are shown in **Figure 3**. Conditions with *only* before the first verb received more high attachment responses than those with the particle before Verb2, as shown in a main effect of *only* height ($\beta = 1.75 \pm 0.29$, $z = 6.02$, $p < .001$), and the presence of an accent increased high attachments slightly regardless of position ($\beta = 0.39 \pm 0.16$, $z = 2.64$, $p = 0.02$). There was no interaction between these factors ($p \geq 0.78$).[9]

The major finding is that the position of *only* strongly affected attachment of the adverbial in an auditory study, with a change of over 20 percentage points in attachment responses. *Only* drew attachment to the VP whose verb it preceded. In fact, the effect of focus particle placement was larger than expected given previous results with accents (e.g., Carlson & Tyler 2018), which involved shifts of less than 10 percentage points in responses. These results thus replicate the

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[9] High attachment rates by item varied between 35% and 69%. Items with low rates of high attachment included 9, 11, and 19; those with high rates were 3, 8, and 20. High attachment rates by subject ranged from 5% to 95%.

results of the written Experiment 1a in an auditory domain, and suggest that accents have a lesser effect on attachment than focus particles.

Accenting either verb slightly increased high attachments. But we expected an interaction between the two factors, with an accent on the second verb increasing attachment to the lower VP and thus decreasing high attachments (or no effect of accent).

One possible explanation for the lack of interaction is that the prosodic boundary interfered with the perception of accents. All conditions had an intermediate phrase boundary after Verb2. Perhaps the presence of this boundary influenced the perception of the preceding word. Accents and prosodic boundaries both affect the duration and pitch contours of words, and words at the ends of prosodic phrases can be heard as accented or vice versa (Byrd & Riggs 2008; Lee & Garnsey 2012). This could have obscured any difference between conditions (18c–d), making Verb2 sound accented in both conditions due to the prosodic boundary despite only bearing a contrastive accent in condition (d). To test this possibility, we carried out a new version of Experiment 2a without the prosodic boundary: Experiment 2b.

3.2 Experiment 2b

This experiment was a version of Experiment 2a with the sentences re-recorded without prosodic boundaries before the final adverbial. We expected this to lower the overall rate of high attachments, as a pre-PP boundary favors high attachment (Carlson et al. 2001; Watson & Gibson 2005). We asked whether the absence of this prosodic boundary would change the effects of accent placement compared to Experiment 2a.

3.2.1 Method

3.2.1.1 Materials

This experiment contained the same 20 items as Experiment 2a (see Appendix C), recorded in the four conditions in (20).

(20) a. Sammy only heard that Bill had called on Monday.
     b. Sammy only HEARD that Bill had called on Monday.
     c. Sammy heard that Bill had only called on Monday.
     d. Sammy heard that Bill had only CALLED on Monday.

Conditions (a–b) had *only* before the first verb, and (c–d) placed it before the second verb. Conditions (a/c) had neutral downstepping prosodic contours with H* accents on most content words, and no contrastive accents within the sentence. Conditions (b/d) had L+H* contrastive accents on the first or second verb. No conditions had any prosodic boundaries above the word level. Acoustic measurements to substantiate this description are in **Table 7** and an example set of pitch tracks in **Figure 4**.

condition	Subject Peak/Dur.	Verb1 Peak/Dur.	Verb2 Peak/Dur.	Verb2 Dip	Pause Dur.	Adverbial Peak
F0 averages						
V1 Only	334	228	185	178		215
V1 Only Accent	236	**298**	171	166		215
V2 Only	327	251	184	174		220
V2 Only Accent	251	225	**275**	180		223
Duration averages						
V1 Only	359	400	400		0	
V1 Only Accent	336	**466**	383		0	
V2 Only	316	407	389		0	
V2 Only Accent	303	394	**418**		0	

Table 7: F0 averages for items in Experiment 2b in Hz and duration averages in ms by condition; accented verb measurements shown in bold.
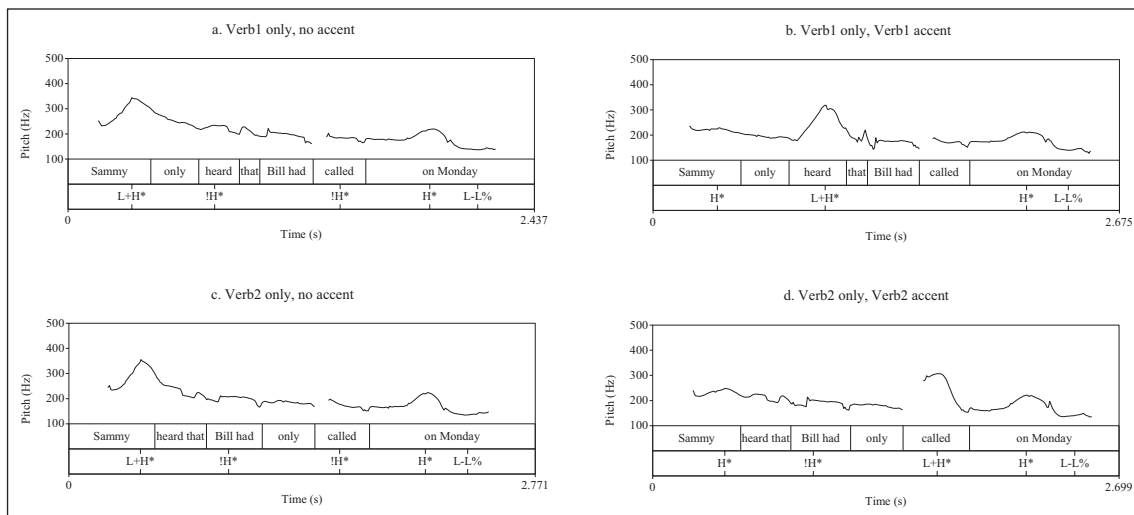

Figure 4: Pitch tracks for example stimuli in Experiment 2b.

The prosodic contours were very similar to those in Experiment 2a, with the same large F0 and duration differences between contrastively accented and unaccented verbs. The primary difference was that there was no pause between the second verb and the adverbial, and the Verb2 durations averaged over 150 ms shorter than the Experiment 2a versions. These two properties suggest a lack of an ip boundary before the adverbial. As before, the initial subject measurements show higher F0s and longer durations in the conditions without accented verbs.

Each recorded sentence was followed by a comprehension question and two answers as in (21). The audio files were recorded in .wav format and converted to high bitrate .mp3s (320kbit/s) using ffmpeg.

(21)   What happened?
    a.   Sammy heard something on Monday.
    b.   Bill called on Monday.

Participants also heard 79 filler items, including 24 ambiguous comparative ellipsis sentences, 20 sentences containing conjoined clauses with ambiguous causality, 23 partial sentences with two possible completions, and 12 unambiguous filler sentences.

3.2.1.2 Participants

Fifty-nine self-reported American native English-speaking participants were recruited through AMT and paid $3.12 for their participation. Data from the 52 participants who had over 90% performance on unambiguous attention check items was analyzed.

3.2.1.3 Procedure

The 20 experimental sentences and 79 filler items were combined into 12 pseudo-randomized lists of 99 items in a latin square design. The questions and answers (or completions) for each item were visible on the screen along with an audio player which participants clicked to hear the sound files. There was no time limit on answers. The study was presented in Qualtrics and most participants completed the experiment within 20 minutes.

3.2.2 Results

The results are shown in **Figure 5**.

The data was analyzed using a linear mixed-effects model with a binomial link function (Bates et al. 2015). The dependent variable was the participant response disambiguating the stimuli as high or low attachment (1 = high attachment; 0 = low attachment). The independent variables were the presence of *only* before the matrix verb (contrast coded as = 0.5) or the embedded verb (coded as = –0.5) and the presence of a contrastive pitch accent on the verb adjacent to *only*
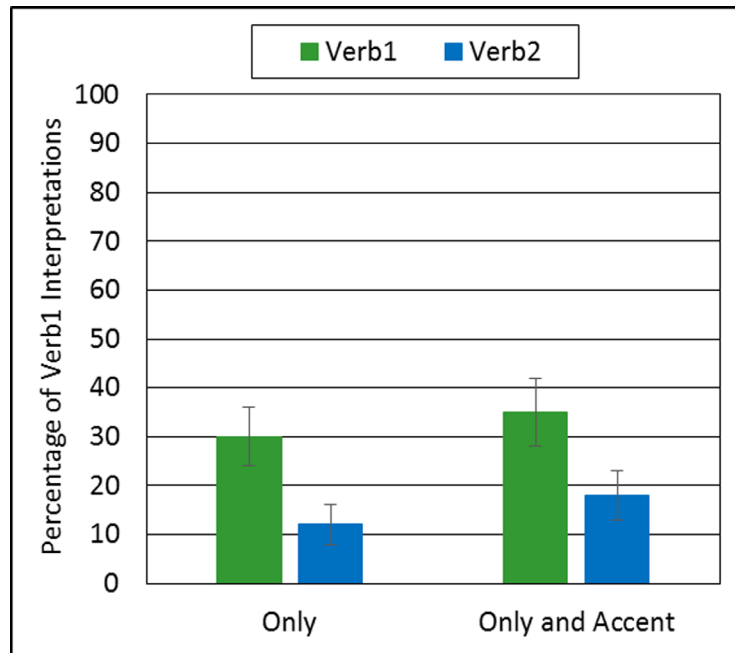
Figure 5: Results of Experiment 2b.

(coded as = 0.5) or no contrastive pitch accent (coded as = –0.5). These variables were each introduced into the model as fixed effects, and the model included the maximal random effects structure justified by the design that would converge (Barr et al. 2013): random intercepts for frame and for participant, and random slopes for participant by *only* position. Random slopes and intercepts for position of *only* by participant were decorrelated.[10] The model results are shown in **Table 8**.

	Estimate	**Std. Error**	**z value**	**Pr(> |z|)**
(intercept)	–1.93	0.30	–6.33	2.43e-10
Only Position	1.43	0.31	4.55	5.42e-06
Accent Presence	0.54	0.19	2.85	0.005
Only Position:Accent Presence	–0.30	0.38	–0.79	0.43

Table 8: Statistical analysis of Experiment 2b results.

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[10] The specific R syntax was (dataModelExp2b = glmer(Response~ OnlyPositionContrastCoding * AccentPresenceContrastCoding + (1 + OnlyPositionContrastCoding||participant) + (1|frame), data = dataSet, family = "binomial")).

Overall, there were many fewer high attachment responses than in Experiment 2a, because the lack of a prosodic boundary after the second verb favors low attachment (Carlson et al. 2001; Watson & Gibson 2005).[11]

As in Experiment 2a, the position of *only* significantly affected attachment, as conditions with the particle before Verb1 had more high attachments: significant main effect of *only* (β = 1.43 $\pm$ 0.31, z = 4.55, p < .001). Also as in Experiment 2a, accenting either verb slightly raised the rate of high attachment: significant main effect of accent presence (β = 0.54 $\pm$ 0.19, z = 2.85, p = .005). There was no significant interaction between the two factors (p > 0.43), so accenting Verb2 still did not increase low attachments as was expected.

3.2.3 Discussion

This experiment replicated Experiment 2a very closely. Placing *only* before either verb focused that VP, leading to a change in attachment preferences of 15 or more percentage points. The significant effect of accent position was small and consistent: accenting either verb, with *only* before that verb, slightly increased attachments to the first VP. The only difference between the experiments was in the overall level of high attachments, as the prosodic boundary before the PP increased high attachments in Experiment 2a as expected.

Together, Experiments 2a–b revealed effects of the presence and location of both *only* and contrastive pitch accents on attachment preferences. The focus particle *only* likely does not cue the verb it precedes as focused, since Experiment 1b showed that *only* is compatible with multiple alternative focus structures. Nonetheless, *only* still drew attachment to the VP that it immediately preceded. This suggests that the resolution of attachment ambiguities can be guided not just by direct cues for focus, but also by other information-structural cues like *only*.

However, Experiments 2a–b also showed no interaction between the position of *only* and accent presence. The location of *only* drew attachment, but, unexpectedly, accents adjacent to *only* increased high attachment slightly whether the particle and accent were low or high. Prior results led us to expect that accenting Verb2 should lead to fewer high attachments than when *only* marks low focus alone (Carlson & Tyler 2018): we expected an interaction between accents and *only*, with the accents drawing attachment in different directions depending on their position.

It's possible that even without a prosodic boundary in the recordings, Verb2 accents gave the impression of a prosodic boundary (due to the falling F0 after the high peak), which then increased high attachments (see Hirose (2019) on ambiguity of a particular acoustic F0 movement; also Lee & Garnsey (2012) and Jun & Bishop (2015)). This is the reverse of the perceptual illusion suggested after Experiment 2a. There, we hypothesized that a prosodic boundary after Verb2

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[11] High attachment rates by item varied from 10% to 46%. Items with relatively low high attachment rates were 4, 6, 9, and 19, and ones with relatively high rates were 8, 14, and 20. High attachment rates by subject varied from 0% to 65%.

led to perceived accentuation of Verb2, but Experiment 2b ruled that out. Here, we suggest that the accent on Verb2 led to a perceived boundary after it, whether or not it was present. That perceived boundary then raised high attachments in this condition compared to ones without a Verb2 accent.

Another possibility is that a confound in the Verb2 *only* no-accent conditions (e.g., (18/20c): *Susie heard that Bill had only called (ip) on Monday*) increased low attachments. In both no-accent conditions, no contrastive accent signals that *only* should associate with either verb. Instead, the H*-accented final adverbial itself (*on Monday*) could be the focus with which *only* associates. This leads to pressure for the modifier to attach low if *only* is before Verb2, because *only* must c-command the focused element it associates with. Only by attaching low can the ambiguous modifier associate with *only*. This extra lowering of high attachment rates in conditions (18/20c) then gives the impression that conditions (18/20d), with low *only* and a Verb2 accent, have more high attachments due to the added accent. They do have more high attachments, not because of focus attraction but because *only* does not associate with the modifier and force it low. Other conditions do not face this confound, and so conditions (18/20a–b) show the expected increase in high attachments with Verb1 accented.

Overall, Experiments 2a–b are consistent with Experiment 1a in finding a strong effect of the position of *only* on attachment preferences. These results favor the spirit of the Focus Attraction Hypothesis, in which various cues for focus and information structure can affect modifier attachment.

4 Experiment 3

In Experiment 3, we explored a fuller range of conditions, with single and multiple focus markers, in order to better understand how they might interact. In particular, we compared sentences with and without *only* before Verb1 in three prosodic conditions: with Verb1 contrastively accented, Verb2 accented, or both verbs accented. We predicted that the conditions with *only* high would generally show more high attachments than those without. The different accent conditions tested whether the highest cue to focus position has an invariant effect, with more high attachments whenever a contrastive accent is on Verb1; or whether multiple cues matter, and conditions with both verbs contrastively accented should differ from conditions with either accent alone. Finally, if high *only* and low accent are interpreted together, then this condition might show a low attachment preference similar to the low accent condition without *only*.

4.1 Method
4.1.1 Materials

This experiment tested ambiguous attachment sentences in six different conditions, as in (22). The first three varied the presence of contrastive accents on Verb1, both verbs, or Verb2. The

next three conditions had the same accents as (a–c) but also had *only* before Verb1. All conditions had ip boundaries before the final phrase. To accommodate six conditions, we increased the set of sentences by four for a total of 24 (see Appendix C).

(22) a. Sammy HEARD that Bill had called [ip] on Monday.
      b. Sammy HEARD that Bill had CALLED [ip] on Monday.
      c. Sammy heard that Bill had CALLED [ip] on Monday.
      d. Sammy only HEARD that Bill had called [ip] on Monday.
      e. Sammy only HEARD that Bill had CALLED [ip] on Monday
      f. Sammy only heard that Bill had CALLED [ip] on Monday.

Acoustic measurements to substantiate this description are shown in **Table 9** and sample pitch tracks are shown in **Figure 6**. Measurements for accented verbs are shown in bold. The audio files were recorded in .wav format and converted to high bitrate .mp3s (320kbit/s) using ffmpeg. The acoustic measurements and pitch tracks show the same critical properties as those for Experiments 2a–b: when each verb was contrastively accented, its average F0 height was at least 80 Hz higher and its average duration at least 70 ms longer than when unaccented, whether the condition had both verbs accented or only one. Low F0 levels at the end of Verb2 and pauses of over 150 ms support the presence of an ip boundary before each adverbial. As in prior experiments, the F0 averages on the initial subject were higher in conditions with Verb1 not contrastively accented than in those with it accented, for metrical reasons.

Each auditory sentence was accompanied by a written two-choice comprehension question, as in (23).

(23) What happened?
      a. Sammy heard something on Monday.   (high attachment)
      b. Bill called on Monday.   (low attachment)

Participants also heard 78 fillers and experimental items from unrelated experiments. The unrelated items included both single-talker and two-talker dialogues with various syntactic configurations (24 single-speaker ambiguous stripping ellipsis sentences with negation, 24 dialogues with it-clefts or ellipsis for rating of pronoun binding, and 30 pure fillers of different structures). Participants were asked to either rate the acceptability of these items, or indicate which of two interpretations was more likely.

4.1.2 Participants

Sixty-five self-reported American native speakers of English were recruited through AMT and the data of 44 participants who passed attention checks was analysed. The 61 participants who completed the experiment were paid $5.00 for participation.

Condition **F0 averages**	**Subject Peak/Dur.**	**Verb1 Peak/Dur.**	**Verb2 Peak/Dur.**	**Boundary L-**	**Pause Dur.**	**Adverbial Peak**
V1 Accent	221	**326**	165	148		229
Both Accent	216	**321**	**248**	141		219
V2 Accent	264	217	**282**	147		224
V1 Only,V1 Accent	230	**316**	160	143		220
V1 Only, Both Accent	231	**308**	**247**	140		218
V1 Only, V2 Accent	252	196	**280**	143		221
Duration averages						
V1 Accent	315	**495**	488		163	
Both Accent	302	**488**	**575**		170	
V2 Accent	341	410	**561**		154	
V1 Only, V1 Accent	323	**478**	487		191	
V1 Only, Both Accent	334	**491**	**558**		196	
V1 Only, V2 Accent	358	403	**567**		163	

Table 9: F0 averages for items in Experiment 3 in Hz and duration averages in ms by condition; accented verb measurements shown in bold.

4.1.3 Procedure

The 24 experimental sentences were combined with 78 additional items into twelve pseudorandomized lists in a latin square design. The questions and answers (or rating scale) for each item were visible on screen while participants heard the sound files. There was no time
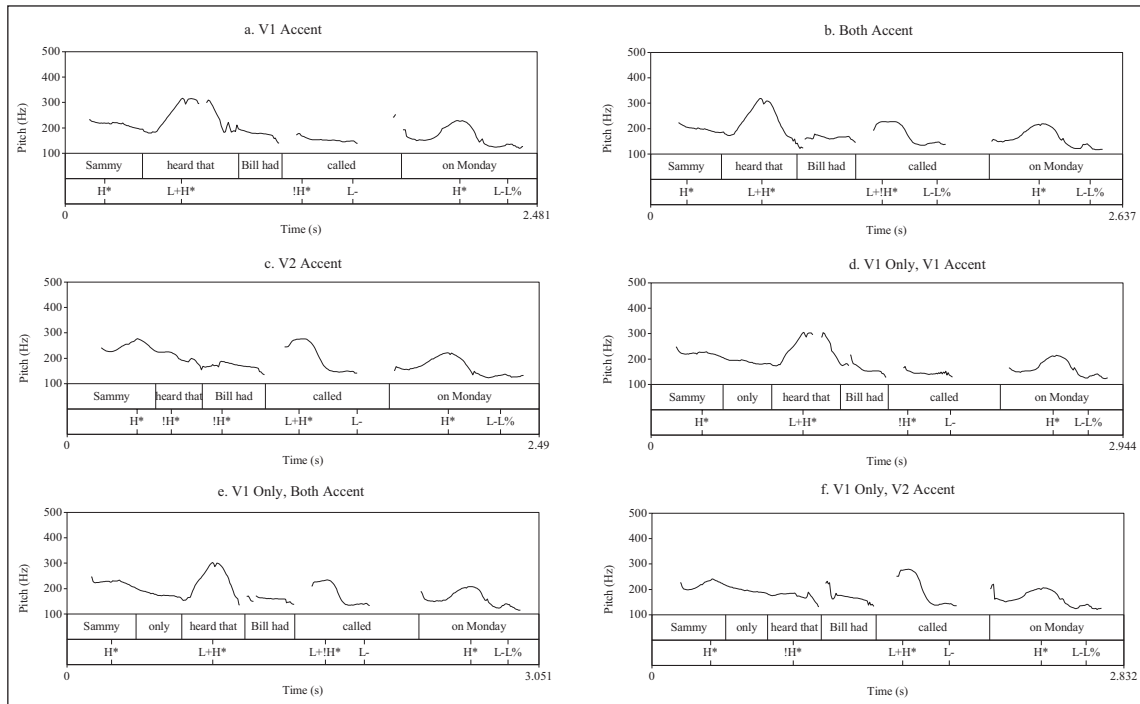
Figure 6: Pitch tracks for an example item from Experiment 3.

limit on answers. The study was presented using the Northwestern University survey tool as in Experiment 1c and most participants completed the experiment within 30 minutes.

4.2 Results and Discussion

The data was analyzed using a linear mixed-effects model with a binomial link function (Bates et al. 2015). The dependent variable was the participant response disambiguating the stimuli as high or low attachment (1 = high attachment; 0 = low attachment). The independent variables were the presence of *only* before the matrix verb (contrast coded as = 0.5) or its absence (coded as = –0.5) and the location of contrastive pitch accent(s), which was helmert coded. This involves coding the three levels in this factor as two fixed effects. In one, the low accent condition (helmert coded as –0.5) was contrasted with the high and both accent conditions (each helmert coded as 0.25), and in the second, the high accent condition (helmert coded as –0.5) was contrasted with the both accent condition (helmert coded as 0.5). The model included the maximal random effects structure justified by the design that would converge (Barr et al. 2013): random intercepts for frame and for participant, and random slopes for participant by *only* position and accent position.[12] The model results are shown in **Table 10**.

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[12] The specific R syntax was (dataModelExp3 = glmer(Response~ OnlyPositionContrastCoding * (HighContrastHelmertCoding + LowContrastHelmertCoding) + (1 + OnlyPositionContrastCoding * (HighContrastHelmertCoding + LowContrastHelmertCoding)|participant) + (1|frame), data = dataSet, family = "binomial")).

	Estimate	Std. Error	z value	Pr(> |z|)
(intercept)	–0.36	0.34	–1.08	0.28
Only Presence	2.27	0.30	7.58	3.82e-14
Low Contrast	0.66	0.29	2.22	0.03
High Contrast	–0.45	0.27	–1.70	0.09
Only Presence: Low Contrast	–0.28	0.60	–0.47	0.64
Only Presence: High Contrast	0.44	0.55	0.8	0.43

Table 10: Statistical analysis of the results of Experiment 3.
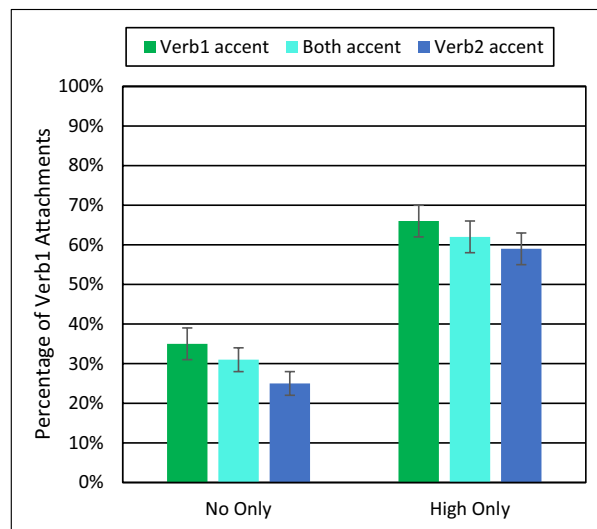
Figure 7: Results from Experiment 3.

The results of this experiment (in **Figure 7**) showed that both focus markers affected attachment preferences.[13] There was a significant effect of the presence of *only*: *only* before Verb1 increased high attachments compared to conditions without the particle ($\beta = 2.27 \pm 0.30$, $\chi^2 = 7.54$, $p < 0.001$). As in earlier experiments, this was a robust effect, with a change of more than 30 percentage points in high attachment. There was also a significant effect of contrastive accent position: low accents led to fewer high attachments than conditions with high or both accents ($\beta = 0.65 \pm 0.29$, $\chi^2 = 2.34$, $p = 0.03$). There was a marginal effect of high vs.

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[13] High attachment rates by item ranged from 31% to 68%. Items with relatively low rates were 9 and 15; items with relatively high rates were 8, 20, and 22. High attachment rates by subject varied from 4% to 100%.

both accents ($\beta = -0.45 \pm 0.27$, $\chi^2 = 1.70$, p $= 0.09$), and no interaction between the effects.[14] Here, there was no tendency for accents to behave differently in the presence of *only*. Instead, across conditions with *only*, there was the same linear trend in attachment preferences for accent positions. Contrastively accenting Verb1 led to the most high attachments, an accent on Verb2 to the least, and having both verbs accented led to intermediate results.

These results therefore suggest that every marker of focus position influences attachment preferences, and that markers have independent rather than dependent or interactive effects. With or without *only*, each contrastive accent increased attachment to the phrase headed by the accented word. Two accents led to intermediate results compared to single-accent conditions because the accents pulled attachment preferences in opposite directions. These results harmonize with Lee & Watson's (2011) first experiment on relative clause attachment, which included conditions with just the first noun accented, the second noun accented, or both accented. The both-accents condition produced high attachment rates between the two single-accent conditions, suggesting that each accent drew attachment to a certain extent.

Similarly, regardless of accent positions, *only* placed before the higher verb strongly drew attachment to the higher VP. The condition with *only* high but an accent on Verb2 did not show a preference for low attachment, as we would expect if the position of the focused element under *only* is what draws attachment. Instead, this condition showed over 50% high attachments, as did all three conditions with *only* before Verb1. This demonstrates that it is the position of the focus particle and its syntactic scope, not the later focused element with which it associates, that draws attachment.

These results do not show the odd pattern found in Experiments 2a–b, in which accenting Verb2 appeared to increase high attachments, because different conditions are being compared. In Experiment 3, all conditions had at least one contrastive accent in them. In that context, the conditions with Verb2 accent alone showed more low attachment than any other accented conditions.

5 Conclusions

These experiments show that the information structure of a sentence can influence its syntactic structure, in addition to the known effects of prosodic phrasing on attachment. Prior work concentrated on how pitch accents, as cues of focus, affected attachment (Schafer et al. 1996; Lee & Watson 2011; Carlson & Tyler 2018), while Carlson & Potter (in press) showed that preceding wh-questions also affected attachment by focusing specific phrases in a target sentence. Here we found that focus particles affect attachment, too, and explored how they interact with accents.

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[14] The statistical patterns are the same if reversed helmert coding is used, so that high accent conditions are compared to both and low accent conditions: a significant effect of *only* presence, and of each comparison, but no interaction.

The results of our experiments show that the Salience Hypothesis of Lee & Watson (2011) does not explain the full range of focus effects on attachment, due to its concentration on accents as markers of salience or on choosing accented answers in post-sentence questions. In Experiments 1–3, modifiers were attracted to the highest syntactic domain in the scope of *only*, even when the nearest verb was not accented. Thus, it seems that the attraction of a modifier to an attachment site is not driven by the perceptual salience of a focused element (within the critical sentence or in forced-choice answers). The Focus Attraction Hypothesis, in spirit at least, is more consistent with these findings, because it identifies focus position as the key factor underlying the attraction effect. Whether focus is cued by a pitch accent, a preceding *wh*-question, or the focus-sensitive operator *only*, perceivers preferentially attach a modifier to a potential attachment site that is focused.

However, the Focus Attraction Hypothesis must be modified to actually account for how the focus particle *only* works to attract a modifier. Since *only* associates with a focused element within its c-command domain, the most obvious way for the hypothesis to work would have been for a modifier to be drawn to the position of that focused element. Instead, attachment in the presence of *only* is drawn near the position of the focus particle itself. With pitch accents, what draws attachment is focus on the head of a phrase into which the modifier could attach, but *only* is neither the head of a phrase nor accented. It is therefore unlikely that the modifier is literally attaching to the particle. Instead, it attaches into the VP preceded by *only*. The original Focus Attraction Hypothesis from Schafer et al. (1996) stated that "a phrase that is neither a complement nor syntactically obligatory is preferentially taken to modify a focused phrase unless this violates linguistic (grammatical or pragmatic) constraints" (p. 149). This is consistent with how pitch accents (Carlson & Tyler 2018) and wh-questions (Carlson & Potter in press) affect attachment, because each of those mark focused phrases into which the modifier could attach. For the operation of *only*, though, we suggest the following revision, italicized below:

(24) Revised Focus Attraction Hypothesis: a phrase that is neither a complement nor syntactically obligatory is preferentially taken to modify *the highest syntactic domain associated with a focus operator, or any focused phrase,* unless this violates linguistic (grammatical or pragmatic) constraints.

This hypothesis picks out the highest syntactic domain under *only* to account for the results of Experiment 3: when *only* precedes the highest VP but associates with an accented lower verb, it is not the lower VP but the higher one which draws attachment. With this modification, the Focus Attraction Hypothesis now fits the results of the experiments in this project. They showed that all focus markers present in the sentence drew attachment to greater or lesser extents. The picture is basically additive rather than showing any more complicated interaction between focus markers.

Interestingly, none of the experiments supported the idea that the lowest focus, the one most local to the ambiguous modifier, would draw attachment more strongly than other focused elements. Several studies on focus expectations in ellipsis sentences have shown a preference for low/late focus in English and German (e.g., Frazier & Clifton 1998; Carlson 2002; Stolterfoht et al. 2007; Carlson, Dickey et al. 2009; Harris & Carlson 2018; among others). This expectation was strong enough to affect interpretation preferences in ambiguous ellipsis sentences despite salient accents (or clefting) placing focus elsewhere. Such focus markers did influence interpretation, but did not overturn a general bias toward a low focus position. Why, then, doesn't the lowest focus marker draw attachment? That would seem most consistent with this other body of results on the surface.

In fact, we think there are important differences between these situations. In ellipsis processing, each remnant of ellipsis needs to contrast with a phrase in the complete antecedent clause (or clauses). So ellipsis experiments all involve people working backwards from the second member of a contrast to find the first member, and using various sources of information to do so, including overt focus markers and expectations about the position of focus. Thus the processor figures out the antecedent material to be copied or reaccessed in place of the ellipsis (Frazier & Clifton 2005; Martin & McElree 2008). But the antecedent material has already been syntactically structured, and its information structure probably computed. In the current experiments, by contrast, no sentence has been completed and the processor is working to finish the process of syntactic attachment. The active phrase needs to be attached into some other phrase that already exists, and focused attachment sites are privileged above non-focused sites.

There are interesting parallels between this research and Gotzner (2019)'s findings. She studied calculation of exhaustive implicatures while manipulating the presence of *only* and type of pitch accent (H* vs. L+H*). Specifically, given a contrast set of two individuals, and the statement *CARL likes herring* or *Only Carl likes herring,* she asked whether people would reject the statement that the other individual liked herring. As expected, the focus particle *only* led to high rates of exhaustive interpretation (rejecting the statement), as did a L+H* accent or the two together. H* accents also suggested exhaustivity, but less strongly. Crucially, the combination of *only* plus contrastive L+H* accents did not increase exhaustive interpretations over either marker alone, though it did raise the certainty of the interpretation. Gotzner suggested that once the particle had made its contribution to the interpretation, the intonation had little left to do. This is consistent with the small effects of contrastive pitch accents on attachment when *only* already indicated a particular VP, in Experiments 2a–b. In two different domains of language processing, then, the focus particle *only* has a stronger influence on interpretation than pitch accents, despite their similar effects on sentence meaning.

One contribution of this research is that we can see that focus, expressed by accents or other means, overlaps with prosodic boundaries in the type of effects it can have on sentence

processing. It would have been reasonable for prosodic boundaries, which mark the grouping of words into prosodic phrases, to affect attachment while focus did not. It is intuitively sensible for processing to favor matching of syntactic and prosodic groupings of words; for a modifier to be attracted to prominent or contrastive information in the sentence is less obvious. But research on focus attraction shows that there is a preference to attach a modifier to a focused attachment site or syntactic domain. This broadens the range of factors that we understand to affect the basic syntactic structuring of a sentence. Conversely, this research also broadens our expectations about what focus can influence in sentence processing. In ellipsis research, Carlson, Frazier, & Clifton (2009) found that prosodic boundaries did not affect the resolution of bare remnant ellipsis while accents on contrasting phrases did, and therefore suggested that different prosodic features affect different types of ambiguities. They proposed a separate roles hypothesis, on which pitch accent effects are restricted to domains like ellipsis processing or pronoun resolution, rather than basic syntactic structure. This hypothesis is therefore shown to be too strong in its differentiation of where accents (and focus) vs. prosodic boundaries have effects.

The Focus Attraction Hypothesis, as modified to account for the effects of the position of *only* within a sentence, is the most consistent with these results as well as the prior literature (Schafer et al 1996; Lee & Watson 2011; Carlson & Tyler 2018; Carlson & Potter in press). We believe that the reason that focused elements or the highest syntactic domain of the operator *only* draw attachment is because they are the most important information in the sentence. Given the choice, people prefer attaching a modifier to important information rather than that which is given or backgrounded. A similar idea prompted the Main Assertion Hypothesis of Frazier & Clifton (2005) for ellipsis processing: an ellipsis clause following a sentence boundary is more likely to relate to the main assertion of the antecedent even if that is high in the sentence. Similarly, Traxler & Frazier (2008) used this idea to explain attachment of a PP into a main clause rather than to a subordinate clause.

Finally, there is the question of why the modifier is drawn to the highest predicate in the scope of *only*, though *only* can associate with a focused element that is high or low within its scope. In these sentences out of the blue, it appears that the widest syntactic domain within which focus could be located under *only* is what draws attachment. Perhaps the widest scope is preferred because it satisfies the widest Question Under Discussion (QUD: Roberts 1996). That is, in a discourse context, a sentence with *only* might be answering a more specific QUD and be consistent with a narrow focus; but these sentences out of context led perceivers to take the highest VP and all of its complements as focused, allowing the broadest QUD to be answered. Interestingly, though, accent effects on attachment do not seem to involve listeners taking the widest focus possible for an accent position. Accents on the lower verbs in our sentences could have been interpreted as indicating wide focus on the entire sentence. Instead, accents on verbs

seemed to be taken as narrow verb focus, drawing attachment to a specific VP. We hope to continue to explore differences between focus markers like this asymmetry.

Appendix A

Stimuli for Experiment 1a and 1c (without the final phrase in 1c); adverbials start at #

1. Sammy (only) heard that Bill had (only) called # during Monday's emergency meeting.
2. Sally (only) discovered that Pam had (only) returned # very late on a Thursday afternoon.
3. Brian (only) announced that Tim was (only) promoted # after the annual evaluation process.
4. Sandy (only) claimed that Robbie had (only) left # prior to the end of the semester.
5. Louie (only) found out that Bob had (only) quit # around the middle of January.
6. Mona (only) insisted that Dennis had (only) been mistaken # during a furious conversation.
7. Linda (only) reported that Thomas was (only) bribed # at a meeting with the company's CEO.
8. Tony (only) denied that Kevin had (only) left early # after an argument with co-workers.
9. Sarah (only) testified that Mark had (only) disappeared # during the recent court proceedings.
10. Lucy (only) confirmed that Beth had (only) stepped down # at the beginning of February.
11. Kathie (only) claimed that Alex had (only) lied # in an email exchange with the manager.
12. Sharon (only) said that Jason had (only) been rude # in the second meeting with the clients.
13. David (only) admitted that Alison (only) went bankrupt # shortly before the sale of the house.
14. Matt (only) learned that Lisa had (only) eloped # on the last weekend of September.
15. Cathy (only) announced that Jeff had (only) been elected # at the last union meeting before vacation.
16. Danny (only) mentioned that Emma had (only) moved out # after a big party in October.
17. Anna (only) revealed that Galen had (only) graduated # after the 4th of July party.
18. Robert (only) claimed that Ellen had (only) run away # after a long interview with the police.
19. Mary (only) stated that Andrew (only) got engaged # before the employee orientation.
20. Penny (only) heard that Joe (only) got in trouble # during biology class on Thursday.

Appendix B

Stimuli for Experiment 1b

1. Susie (only) heard that Bill had (only) called, she/he didn't _____
2. Sally (only) discovered that Pete had (only) returned, she/he didn't _____
3. Brianna (only) announced that Tim was (only) promoted, she/he didn't _____
4. Sheila (only) claimed that Robbie had (only) left, she/he didn't _____
5. Louise (only) found out that Bob had (only) quit, she/he didn't _____
6. Mona (only) insisted that Dennis was (only) mistaken, she/he didn't _____
7. Linda (only) reported that Thomas was (only) bribed, she/he didn't _____
8. Tony (only) denied that Kristen had (only) left early, he/she didn't _____
9. Sarah (only) testified that Mark had (only) disappeared, she/he didn't _____
10. Jerry (only) confirmed that Beth had (only) stepped down, he/she didn't _____
11. Kathie (only) claimed that Alex had (only) lied, she/he didn't _____
12. Sharon (only) complained that Jason was (only) rude, she/he didn't _____
13. David (only) admitted that Alison (only) went bankrupt, he/she didn't _____
14. Matt (only) learned that Lisa had (only) eloped, he/she didn't _____
15. Cathy (only) announced that Jeff had (only) been elected, she/he didn't _____
16. Danny (only) mentioned that Emma had (only) moved out, he/she didn't _____
17. Anna (only) revealed that Galen had (only) graduated, she/he didn't _____
18. Robert (only) claimed that Ellen had (only) run away, he/she didn't _____
19. Mary (only) stated that Andrew (only) got engaged, she/he didn't _____
20. Penny (only) heard that Joe (only) got in trouble, she/he didn't _____

Appendix C

Stimuli for Experiments 2a–b, 3

Experiment 2a had prosodic boundaries at #

Experiment 2b had no prosodic boundaries

Experiment 3 had 4 additional items and "only" just in the first position

1. Sammy (only) heard that Bill had (only) called # on Monday.
2. Sally (only) discovered that Pam had (only) returned # on Sunday.
3. Brian (only) announced that Tim was (only) promoted # on Friday.
4. Sandy (only) claimed that Robbie had (only) left # last week.
5. Louie (only) found out that Bob had (only) quit # in June.
6. Mona (only) insisted that Dennis had (only) been mistaken # last night.

7. Linda (only) reported that Thomas was (only) bribed # last May.
8. Tony (only) denied that Kevin had (only) left early # on Tuesday.
9. Sarah (only) testified that Mark had (only) disappeared # last month.
10. Lucy (only) confirmed that Beth had (only) stepped down # last week.
11. Paula (only) claimed that Alex had (only) lied # on Monday.
12. Sharon (only) complained that Jason had (only) been rude # on Friday.
13. David (only) admitted that Alison (only) went bankrupt # last year.
14. Matt (only) learned that Lisa had (only) eloped # last Wednesday.
15. Cathy (only) announced that Jeff had (only) been elected # on Tuesday.
16. Danny (only) mentioned that Emma had (only) moved out # last week.
17. Anna (only) revealed that Galen had (only) graduated # in May.
18. Robert (only) claimed that Ellen had (only) run away # last Friday.
19. Mary (only) stated that Andrew (only) got engaged # last week.
20. Penny (only) heard that Joe (only) got in trouble # on Thursday.

additional items for Experiment 3

21. Lucy (only) suspected that Steve had messed up # last Thursday.
22. Felix (only) assumed that Eliza had worked out # yesterday.
23. Noreen (only) whispered that Eddie looked good # on Saturday.
24. Deanna (only) guessed that Glenn had become sick # last Friday.

Acknowledgements

Competing interests

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