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Aspectual Coercion in Eye Movements

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Abstract Comprehension includes interpreting sentences in terms of aspectual categories such as processes (*Harry climbed*) and culminations (*Harry reached the top*). Adding a verbal modifier such as *for many years* to a culmination coerces its interpretation from one to many culminations. Previous studies have found that coercion increases lexical decision and meaning judgment time, but not eye fixation time. This study recorded eye movements as participants read sentences in which a coercive adverb increased the interpretation of multiple events. Adverbs appeared at the end of a clause and line; the post-adverb region appeared at the beginning of the next line; follow-up questions occasionally asked about aspectual meaning; and clause type varied systematically. Coercive adverbs increased eye fixation time in the post-adverb region and in the adverb and post-adverb regions combined. Factors that influence the appearance of aspectual coercion may include world knowledge, follow-up questions, and the location and ambiguity of adverbs.

Keywords Time course of integration · Semantic processing · Aspectual coercion · Sentence comprehension · Syntax semantics correspondence

Time is a universal experience, and so it is hardly surprising that speakers are always saying something about it. For example, a wealth of aspectual meaning appears in *Howard sent a large check to his daughter for many years* (adapted from Todorova et al. 2000). The aspectual meaning of this sentence includes (A)–(C):

A. *Sent a large check* suggests a punctual event prior to the time of speech.
B. *For many years* indicates the time interval that contains this event.
C. *For many years* "coerces" the interpretation of this single event to multiple events of sending different checks.

These meanings describe the beginning, ending, duration, and frequency of events. They concern the "when, how frequently, and for how long" of "who did what to whom." Like anaphoric reference and conjunction, aspectual meaning glues together events in discourse.

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Despite the clarity of (C), researchers have had difficulty finding evidence of it in normal reading. This study presents new evidence of (C). In the next section, I use the framework of Moens and Steedman (1988) to classify aspectual meanings. This section will show that considerable ambiguity exists in aspectual interpretation and that morphological, semantic, and pragmatic factors combine to favor one. I then review evidence that comprehenders begin (C) immediately. Next, I consider structural and methodological conditions that may have made (C) elusive in studies of normal reading. Then I describe an experiment that shows that coercive adverbs increase eye fixation time under optimal conditions. (For ease of exposition, I use the term "adverb" to refer to "adverbial phrase"). The paper ends with a discussion of issues about aspectual coercion and eye tracking that arise from this demonstration of (C).

Aspectual Meanings

Narratives generally present events in the order in which they occurred in the world. However, these events are more than temporally-ordered; they are "contingently-related" to an *event nucleus* (Moens and Steedman 1988). An event nucleus consists of a preparatory process, a culmination, and a consequent state. Different aspectual types highlight different parts of the event nucleus:

1.	a.	*Harry hiccupped*	[Point]
	b.	*Harry reached the top*	[Culmination]
	c.	*Harry climbed*	[Process]
	d.	*Harry climbed to the top*	[Culminated Process]

A *point* is a punctual event without any consequent state. A *culmination* is a punctual event that causes an important new state. A *process* extends in time without any culmination. A *culminated process* extends in time and causes a new state. Thus, processes and culminated processes have temporal extension; culminations and culminated processes have consequent states. Many authors have classified events in a similar fashion (e.g., Dowty 1979; Mourelatos 1981; Pustejovsky 1995; Vendler 1957). This section reviews various kinds of linguistic information that influence the interpretation of a sentence in terms of these aspectual categories.

Auxiliary verbs and adverbs can modify relations between parts of the event nucleus and reference time, the moment of time under discussion (Binnick 1991; Klein 1994; Moens and Steedman 1988; Pulman 1997; Reichenbach 1947; de Swart 1998). The perfect, for example, indicates that the state that follows from a culmination persists to reference time.

2.	a.	*Harry had reached the top*	[Culmination]
	b.	*Harry has reached the top*	[Culmination]
	c.	#*Harry has hiccupped*	[Point]

In (2a) the time of speech is now; reference time is earlier than speech time; event time is earlier than reference time. In (2a) the consequent state of Harry being on the top continues up to reference time. In (2b) Harry's being on top also persists until reference time but in this case, reference time coincides with speech time. Sentence (2c) is odd because a hiccup normally lacks a consequent state, which the perfect requires. (The symbol # indicates an odd interpretation.) Context, of course, may provide a consequent state for the perfect. For example, (2c) is meaningful if Harry is a spy and has agreed to signal acquisition of secret information by hiccupping surreptitiously. In such a context, the interpretation of (2c) changes to a culmination.

Now consider the progressive. It indicates that a process is in progress at reference time. As in (2a), reference time in (3a) is earlier than speech time. Unlike (2a), event time in (3a) coincides with reference time.

3.	a.	*Harry was climbing*	[Process]
	b.	*Harry was hiccupping*	[Point → Point, Point,…]
	c.	*Harry was climbing to the top*	[Culminated Process → (∼Culminated Process]
	d.	*Harry was reaching the top*	[Culmination → Culminated Process → Process]

When the progressive appears with an aspectual type other than a process, coercion occurs. In (3b) the progressive coerces a point into a series of points that extends over time. (We can represent a series of points as [Point, Point,…] and coercion as "→".) In (3c) the progressive coerces a culminated process by emphasizing its preparatory process without implying its culmination. Moreover, in (3d) the progressive coerces a culmination by implying that the punctual event that caused the consequent state actually had a preparatory process (Moens and Steedman 1988).

An adverb such as *in an hour* often describes the duration of the process part of a culminated process. Sentence (4a), for example, specifies that the climbing continued for an hour until culminating in the state of being on top.

4.	a.	*Harry climbed to the top in an hour*	[Culminated Process]
	b.	*#Harry climbed in an hour*	[Process]
	c.	*Harry reached the top in an hour*	[Culmination → Culminated Process]
	d.	*Harry reached the top in a balloon*	[Culmination]
	e.	*Harry reached the top in several balloons*	[Culmination → Culmination, Culmination,…]

When *in an hour* appears without a culminated process, its interpretation is either odd or coerced. Sentence (4b), for example, is odd because it lacks the culminated process that *in an hour* requires. It does, of course, have an interpretation in which *in an hour* describes the length of time for the climbing event to begin (cf., Hitzeman 1997). In this case, climbing is the consequent state of the culminated process of preparing to climb. Sentence (4c) is coerced. The interpretation of *reached the top* changes to a culminated process because *in an hour* must describe a preparatory process with extended duration. Sentence (4d) shows that the meaning and specificity of the prepositional object affects aspectual interpretation. It has the same form as (4c), but coercion is unnecessary because *in a balloon* refers to a location rather than a time interval. On the other hand, coercion does occur in (4e) because the multiple locations *in several balloons* suggest a series of culminations. Thus, multiple locations induce coercion.

A *for*-adverbial often describes the duration of a non-culminated process or state. For example, *for an hour* in (5a) describes how long Harry's climbing lasted. The end-point of Harry's climbing is arbitrary because it does not culminate in a new state.

5.	a.	*Harry climbed for an hour*	[Process]
	b.	*Sue played a sonata for several reasons*	[Culminated Process]
	c.	*Sue played a sonata for several seconds*	[Culminated Process → (∼Culminated) Process]
	d.	*Sue played a sonata for several days*	[Culminated Process → Culmination, Culmination,…]
	e.	*Howard sent a check to his daughter for several years*	[Culmination → Culmination, Culmination,…]
	f.	*Howard sent a check to his daughter each year*	[Culmination → Culmination, Culmination,…]

Coercion depends on word meaning and world knowledge. Consider, for example, the culminated process *Sue played a sonata*. Adding a *for*-adverbial that is neither a location nor a measure of time, such as *for several reasons* in (5b), has little effect on this interpretation. In (5c) though, *for several seconds* induces coercion because we know that playing a sonata to completion typically requires more than several seconds. Interpreting (5c) therefore involves deleting the culmination of *played a sonata* and leaving its preparatory process. Sentence (5c) conveys no implication that Sue played the entire sonata. On the other hand, we also know that playing a complete sonata typically takes less than several days. Consequently, we

interpret (5d) as a series of culminations over several days. Sentence (5d), therefore, coerces the culminated process into an iterative process that consists of a series of culminations over a period of several days. The most plausible interpretation of sentence (5e) also is a series of culminations. Sentence (5f) shows that the distributive adverb *each year* produces only the interpretation of a series of culminations (Pickering et al. 2006).

Aspectual interpretation depends on the specificity of the direct object. For example, the verb *send* and the sentence *Howard sent a check to his daughter* both refer to a culmination. However, in *Howard sent checks to his daughter* the bare plural *checks* introduces more possibilities for interpretation. (A bare plural is "an NP with plural head that lacks a determiner" Carlson 1977, p. 413.) This sentence may describe a culmination in which there is a single punctual event of sending several checks. Alternatively, it may coerce the interpretation of *sent* to a series of culminations in which multiple sending events occur over a period of time (Verkuyl 1989). Adding *for several years* may modify either of these interpretations. Thus, a *for*-phrase introduces ambiguity about the duration of a process, a series of culminations, or a consequent state, as well as the possibility of non-aspectual interpretation.

Clearly, aspectual interpretation requires combining number marking on nouns, auxiliary verbs, the meanings of verbs and adverbs, and pragmatic knowledge about the world. Consequently, we say that aspectual interpretation is "enriched" rather than syntactically transparent (Jackendoff 1997). The nearly continuous flow of bits and pieces of aspectual information presents a challenge for understanding aspectual interpretation. The next sections examine evidence on aspectual interpretation in comprehension and conditions that may affect its appearance in normal reading.

The Coercion Hypothesis

The beginning of aspectual interpretation is reasonably clear: It begins with rapid activation of the aspectual meaning of words and other aspectual markers. Words that refer to completed events such as *built* require more processing than words that refer to on-going states such as *loved* (Gennari and Poeppel 2003; see also Coll-Florit and Gennari 2009; McKoon and Macfarland 2002; Proctor et al. 2004). Progressive forms such as *was cooking* rapidly activate the typical locations of events (*kitchen*) whereas perfect forms such as *had cooked* do not (Amato et al. 2009; Ferretti et al. 2007).

The end of aspectual interpretation also is reasonably clear: It ends by placing the meaning of a sentence into a situational model of discourse (Zwaan and Radvansky 1998). This model encodes discourse information on several dimensions, including time. It includes information about when an event occurred, how long it lasted, and its temporal relation to other events. Research has demonstrated several instances of these processes at the discourse level. For example, sentences that describe a preparatory process as in (6a) require more processing than those that describe a culminated process as in (6b) (Magliano and Schleich 2000; see also Carreiras et al. 1997; Madden and Zwaan 2003; Townsend and Seegmiller 2004):

6. a. *The firemen were rescuing a survivor*
   b. *The firemen rescued a survivor*
   c. *Sally decided to have lunch with her friend Cleo whom she had not seen for many years. They spent five minutes at the restaurant.*

In addition, reading times are longer for sentences that specify a time period (*five minutes*) that conflicts with the typical duration of the culminated process it describes, as in (6c) (adapted from Therriault and Raney 2007; see also Anderson et al. 1983).

There are, of course, many details to work out on word- and discourse-level processes of aspectual interpretation. However, we know even less about the way in which we get from morphological, lexical, and semantic markers of aspectual meaning to the aspectual interpretation of a sentence: How does the sentence processor combine the bits and pieces of aspectual meaning during comprehension?

The *Coercion Hypothesis* maintains that the processor begins to resolve incompatible aspectual interpretations immediately. The evidence for this hypothesis is mixed. Some studies have reported an immediate cost for coercion, suggesting that the processor continually updates an aspectual interpretation. Others have failed to find an immediate cost, suggesting that the processor delays aspectual interpretation.

Consider the evidence for immediate aspectual coercion. Todorova et al. (2000) used a stops-making-sense task: Participants judged whether a sentence makes sense roughly after each phrase as they read the sentence. Todorova et al. found that judgment time on *for many years* was longer when paired with a culmination as in (7a) rather than a potential series of culminations as in (7b).

7. a. *Even though Howard sent a large check to his daughter for many years…*
   b. *Even though Howard sent large checks to his daughter for many years.…*
   c. *The man kicked the little bundle of fur for a long time.*
   d. *Throughout the day the student sneezed in the back of the classroom.*
   e. *After twenty minutes the student sneezed in the back of the classroom.*
   f. *Leslie consumed Polar Purity's ice cube with zeal for eight minutes.*
   g. *Leslie monitored Polar Purity's ice cube with zeal for eight minutes.*
   h. *The worker loaded the wheelbarrow for twenty years.*
   i. *The worker loaded the wheelbarrow for twenty minutes.*

This result suggests that reinterpreting a culmination as a series of culminations immediately increases processing. Pinango et al. (1999); Pinango et al. (2006) reported similar results with a cross-modal lexical decision task. They found that lexical decision time for unrelated word probes increased within 250 ms after an adverb that shifts the interpretation from a culmination to a series of culminations, as in (7c). Brennan and Pylkkanen (2008) measured self-paced word reading time combined with a sensibility judgment at the ends of sentences such as (7d) and (7e). Brennan and Pylkkanen found that reading time was greater on *sneezed* when the context specified an interval of time (7d) rather than a point in time (7e). Proctor et al. (2004) used a phrase-by-phrase self-paced reading task with follow-up questions about aspectual properties. Proctor et al. found that response time on *for eight minutes* was longer when it appeared with a culminated process, as in (7f), rather than a process, as in (7g). Bott (2008, 2010) used a phrase-by-phrase self-paced reading task with a post-sentence sensibility judgment. Bott found that reading time on an adverb following a culminated process was longer on *for twenty years* (7h) than on *in twenty minutes* (7i). These studies suggest that comprehenders begin to resolve aspectual conflicts immediately.

Now consider evidence for the absence of coercion in normal reading. Pickering et al. (2006) recorded eye movements as participants read materials similar to those of Pinango et al. (1999) and Todorova et al. (2000). Among other differences, Pickering et al. presented coercive adverbs in an initial main clause, as in (8), whereas Todorova et al. presented them in an initial subordinate clause, as in (7a–7b). I return to this difference between the studies in the next section.

8. *Howard sent a large check to his daughter every year, even though…*

After reading each sentence, participants answered a question such as "Were the checks large?" Pickering et al. (Experiment 4) found that when the object was singular (*a large*

check, as in (8)), *every year* and *last year* produced similar first pass time. When the adverb was coercive (*every year*, as in (8)), *a large check* and *large checks* also produced similar first pass time on the adverb. These results suggest that when a culmination appears with a potentially coercive adverb, readers fail to re-interpret it as a series of culminations. In addition, Pickering et al. were unable to replicate the Pinango et al. results using self-paced reading or eye tracking (see also Bott 2008, 2010). Readers apparently "under-specify" interpretation because of the multitude of factors that influence aspectual interpretation.

Evidence for immediate processing of other kinds of aspectual inconsistencies is inconclusive as well. As noted earlier, *large checks* can shift the interpretation of *sent* from a culmination to a series of culminations. Some studies have found immediate effects of this aspectual coercion (Husband et al. 2008; O'Bryan et al. 2005; Pickering et al. 2006, Experiment 4). Other studies have found no such effect (Proctor et al. 2004; Townsend and Seegmiller 2004). On the other hand, evidence for "complement coercion" is clear: Longer fixation time on *the novel* in *The teenager began the novel* than in *The teenager read the novel* suggests immediate re-interpretation of *the novel* as an event such as "reading the novel" (Frisson and McElree 2008; see also McElree et al. 2006; Traxler et al. 2002, 2005).

Clearly, aspectual meaning is important in processing individual words and entire sentences. Far from clear is the process of getting from the meanings of words to the interpretation of an entire sentence. Studies of continuous reading have failed to reveal evidence for aspectual coercion. Studies that interrupt reading have.

The Under-Specification Hypothesis

This section reviews the methodological implications of the proposal that readers underspecify aspectual interpretation. It also considers some reasons why aspectual coercion has not appeared in earlier research.

The *Under-Specification Hypothesis* states that readers normally postpone aspectual interpretation (Pickering et al. 2006; Pylkkanen and McElree 2006). Under-specification may occur because aspectual interpretation depends on many factors, as described earlier. Rather than updating an interpretation whenever additional information comes in, it may be more efficient to postpone aspectual decisions until the end of the sentence. Evidence refuting under-specification has appeared in studies of lexical decision, meaning judgment, and self-paced reading, perhaps because these tasks force an immediate decision that does not occur in normal reading.

The Under-Specification Hypothesis, of course, has a methodological flaw: To support it, we must prove the null hypothesis. We must show that eye fixation time does *not* differ for coercive and non-coercive adverbs. In addition, the Under-Specification Hypothesis fails to explain why the processor activates aspectual information immediately if it does not use this information until the end of the sentence (e.g., Gennari and Poeppel 2003). Thus, it is important to either replicate the Pickering et al. (2006) result, or show that it is wrong.

We can test Under-Specification by setting up conditions that encourage aspectual interpretation. If conditions that are favorable for aspectual interpretation still produce no coercion effect, our confidence in the Under-Specification Hypothesis increases. However, if favorable conditions do produce a coercion effect, we must reject the Under-Specification Hypothesis. Such an outcome would pave the way for exploration of the mechanisms of aspectual interpretation.

Several conditions may influence the appearance of coercion in normal reading. First, materials that demonstrably produce a coerced interpretation off-line are more likely to elicit evidence of coercion on-line.

Second, the structural location of coercive material may affect coercion. In general, semantic properties have greater effects at the end of a clause rather than its middle (Green et al. 1981; Just and Carpenter 1980; Mitchell and Green 1978; Rayner et al. 2000; Townsend and Bever 1988). These "wrap-up" effects apparently involve fixing an interpretation for a structural unit. Accordingly, placing the adverb at the end of a clause may enhance the appearance of coercion. However, that may not be enough to reveal aspectual interpretation, since Pickering et al. (2006) so located adverbs and found no coercion effect.

The location of adverbs in the visual display may increase the visibility of coercion. Previous studies show that the placement of line breaks and spaces at structural boundaries affects reading performance, perhaps by isolating structural units (e.g., Jandreau and Bever 1992; Le Vasseur et al. 2006). In addition, line breaks may encourage more thorough processing as the reader prepares for a long saccade to the left of the display. The inaccuracy of these longer saccades may reduce the probability of a fixation at the beginning of a line (cf., Rayner 1998). The possibility of failures to fixate in a line-initial region raises a practical question: Should we interpret a failure to fixate on a line-initial region as a fixation time of zero ms or as missing data? If a fixation failure occurs because the linguistic computations at that point are negligible, the appropriate strategy is to count it as a fixation time of zero ms. If it occurs, however, because of the mechanics of moving the eyes, counting it as a fixation time of zero ms distorts estimates of linguistic processing. In the absence of any reason to believe that linguistic processes at the end of a line cause a fixation failure on the following line-initial region, the appropriate strategy treats it as missing data.

Follow-up questions and secondary tasks may affect accessibility to different kinds of information (e.g., Sanford 2002; Swets et al. 2008; Townsend and Bever 1991; Townsend et al. 2000). Using questions that concern "when, how frequently, and for how long" may draw attention to aspectual meanings over the course of an experiment. A related point is that the type of clause that contains coercive material may affect accessibility to aspectual meaning. For example, main clauses increase accessibility to semantic information, but subordinate clauses increase accessibility to word order information (Bever and Townsend 1979; Townsend and Bever 1978; Townsend et al. 2000). Thus, semantic interpretations are more accessible in main clauses. Moreover, self-paced reading times are shorter for subordinate clauses than for initial main clauses (Rummer et al. 2003). As noted earlier, Todorova et al. (2000) found an effect of aspectual coercion on sensibility judgments at the end of an initial subordinate clause. On the other hand, Pickering et al. (2006) found no aspectual coercion effect on fixation time at the end of an initial main clause. Although studies of processing different clause types lead us to expect greater effects of aspectual interpretation in initial main clauses rather than in initial subordinate clauses, differences in clause type may have contributed to the different outcomes in these studies.

These conditions warrant reconsideration of the Coercion Hypothesis. They suggest how we might observe aspectual coercion and remain within the bounds of normal reading.

This Study

My question is modest: Can we demonstrate aspectual coercion during normal reading? The Coercion Hypothesis predicts that processing *for many years* is harder when it modifies a culmination (*sent a large check*) rather than a series of culminations (*sent large checks*). The Under-Specification Hypothesis predicts that aspectual adverbs have no effect during normal reading. I tested these hypotheses by setting up conditions to increase the chances of observing aspectual coercion. I used validated materials such as those in Table 1. I placed the potentially coercive adverb at the end of either a main clause or a subordinate clause,

Table 1 Conditions and scoring regions for one item

Condition	Example
Main clause:	
SC	*Howard sent| a large check| to his daughter| for many years,| even though | she still had money.*
PC	*Howard sent| large checks| to his daughter| for many years,| even though| she still had money.*
SN	*Howard sent| a large check| to his daughter| last year,| even though| she still had money.*
PN	*Howard sent|large checks|to his daughter| last year,|even though|she still had money.*
Subordinate clause:	
SC	*Even though Howard sent|a large check|to his daughter| for many years,| she still| ran out of money.*
PC	*Even though Howard sent| large checks| to his daughter| for many years,| she still| ran out of money.*
SN	*Even though Howard sent|a large check| to his daughter| last year,| she still| ran out of money.*
PN	*Even though Howard sent| large checks| to his daughter| last year,| she still| ran out of money.*

S singular object; *P* bare plural object; *C* coercive adverb; *N* non-coercive adverb. *Vertical lines* indicate scoring regions

and at the end of a line. I measured fixation time on the line-ending adverb and on the line-initial post-adverb region. Some follow-up questions concerned aspectual meaning, such as "Did he make one contribution?," and some concerned thematic roles, such as "Was it her mother?" The goal of this study, however, was not to isolate the effects of clause boundaries, line breaks, or follow-up questions on coercion, or to determine details of its time course. It was merely to demonstrate the existence of aspectual coercion in normal reading.

To assess the effect of the line break on patterns of fixation, I recorded three measures of fixation rate. First pass fixation failure is the proportion of trials that participants failed to fixate in a region before fixating on a later region. Total fixation failure is the proportion of trials that participants failed to fixate in a region at any time before ending the trial. Regressions-in is the proportion of trials that participants fixate on a region after having fixated on a later region. If the rate of fixation failures depends on the location of a region around the line break, it is appropriate to treat a failure to fixate on a region as missing data rather than a fixation time of zero.

To assess the role of aspectual coercion on processing difficulty, I recorded three measures of fixation time. First pass time is the sum of fixation time from the first fixation in a region until leaving it to the right or left. Go-past time is the sum of fixation time from first entering a region until leaving it to the right. It includes fixation time on the target region prior to leaving it to the right, on previously read material following a leftward regression from the target region, and on the target region after returning to it from a leftward regression. Total time is the sum of all fixation time in a region including first pass fixations and fixations following a regression. Researchers typically infer the time course of processing from these measures (cf., Liversedge et al. 1998; Kennedy and Murray 1987; Rayner 1998; Rayner et al. 1989). The usual interpretation is as follows. Increased first pass time in a region suggests early detection of a problem and an attempt to resolve it before leaving the region. Increased go-past time also suggests early detection of a problem and an attempt to resolve it by re-reading previously read material. Increased total time in a region suggests an attempt to resolve a problem after reading material that follows the region, particularly in the absence of an increase in first pass time or go-past time.

The goal of this study was to establish that aspectual coercion occurs in uninterrupted reading. The presence of a line break complicates the interpretation of measures of fixation

time in terms of the time course of aspectual interpretation (see below). Let us assume for the moment the typical interpretation of an effect of aspectual coercion on measures of fixation time. If the processor detects and resolves an aspectual mismatch before leaving the coercive material, aspectual coercion will increase first pass time. If the processor detects an aspectual mismatch and attempts to resolve it by re-reading earlier material, aspectual coercion will increase go-past time. If the processor attempts to resolve an aspectual mismatch only after leaving the region to the right, aspectual coercion will increase total time. Such an interpretation of total time, of course, depends on finding no effect in first pass time or go-past time, since these measures contribute to total time.

As noted above, however, since the current study presented the coercive adverb and the post-adverb region straddling the line break, processing that occurs because of the end or beginning of a line may complicate these interpretations. Whereas we normally interpret an effect of linguistic complexity on fixation time in a region to show that linguistic complexity caused additional processing while reading the region, the appearance of the adverb at the end of a line weakens such a conclusion: The processor may focus resources on the adverb just because it falls at the end of a line. Fixation time may increase at the end of a line because the processor assembles an interpretation before leaving the line. Similarly, we normally would interpret an effect on fixation time in the post-adverb region to suggest that processes that began on the adverb spill over into the next region. In our case, some spillover processing may occur as the eyes move from the end of one line to the beginning of the next. Thus, any aspectual interpretation that occurs during movement from one line to the next will reduce the effect of aspectual coercion in the post-adverb region. In addition, go-past time might increase in the region that begins the second line because a regression from the beginning of the second line to the preceding region requires that the eye travel farther. Thus, we must be cautious in interpreting patterns that appear across different measures of eye fixation time.

Lastly, we can predict how aspectual coercion might interact with clause type. If the processor focuses resources on meaning more for main clauses than for subordinate clauses, we expect that aspectual coercion will be more apparent in main clauses: The effects of aspectual coercion will be greater in main clauses than in subordinate clauses.

Method

Participants

The participants were forty undergraduate students (35 female) from the subject pools at the Eye-Tracking Lab and the Department of Psychology at the University of Massachusetts Amherst. Participants from the subject pool at the Eye-Tracking Lab previously had participated for pay in eye-tracking experiments unrelated to the present study; these participants had expressed interest in participating in further experiments for pay. Participants from the subject pool in the Department of Psychology generally had not participated previously in eye-tracking experiments; these participants had the option of receiving course credit or payment for their participation. All participants had normal or corrected to normal vision, all were native speakers of English and all were naïve about the purpose of the experiment. The experiment lasted about 40 min.

Materials

Each of 24 sets of test sentences had eight conditions depending on initial Clause Type, Adverb Type, and Object Type. The initial clause was either main or subordinate. It contained a singular or bare plural direct object and an adverb. The adverb was either coercive (e.g., *for many years; each week; in many towns*) or non-coercive (e.g., *last year; in Amherst*). The conditions for one set appear in Table 1. The complete set of test sentences appears in the Appendix. The average number of words in the test sentences was 20.5. Each sentence consisted of the following elements: either a subject phrase, or a subordinating conjunction and a subject phrase; a verb; a direct object; a prepositional phrase; an adverb; and the final clause, which consisted of a two-word post-adverb region and the remainder of the sentence. The average number of characters in the adverb was 14.9; by Adverb Type, the breakdown was 16.7 characters for coercive adverbs and 13.1 characters for non-coercive adverbs, $F\,(1, 23) = 31.9$, $MSE = 19.3$, $p < .001$. The average number of characters in the post-adverb region (i.e., the first two words of the final clause) was 10.7; by Clause Type, the breakdown was 9.9 characters for sentences with an initial subordinate clause and 11.5 characters for sentences with an initial main clause, $F\,(1, 23) = 30.8$, $MSE = 4.11$, $p < .001$. The 24 sets of test sentences contained a variety of coercive adverbs. In nine sets the coercive adverb was a "durative" phrase, as in *for many years*; in eleven it was a distributive phrase, as in *each week*; in four it was a locative phrase, as in *in many towns*.

Pre-test

An independent survey revealed that interpretations of multiple events were greater when the sentence contained a coercive adverb rather than a non-coercive adverb. In this survey, fifty-six participants from an undergraduate course at Montclair State University read one of four versions of each of the 24 experimental items. The versions were singular object with a coercive (SC) versus non-coercive adverb (SN) and bare plural object with a coercive (PC) versus non-coercive adverb (PC). The items were single clause sentences, as in *Howard sent a large check to his daughter for many years*. Each of four booklets contained 24 items so that across booklets, each version of an item appeared once. Each booklet contained six examples of each of the four versions (SC, SN, PC, and PN). Seven participants read each booklet. After reading each sentence, participants indicated whether (a) the most likely interpretation is one instance of the action specified by the verb; (b) it is more than one instance of the action; (c) interpretations (a) and (b) are equally likely; or (d) neither (a) nor (b) is likely. (Using materials unrelated to those of the present study, Townsend and Seegmiller (2004), developed this four-choice procedure as a less-restrictive means of determining whether participants agree with the investigators' interpretation). Table 2 shows the proportion of times participants made each of these choices depending on Object Type (singular vs. plural) and Adverb Type (coercive vs. non-coercive). Three results show that the sentences produced the intended interpretation.

For coercive adverbs, interpretations of multiple events were more frequent than interpretations of single events (see Table 2). For 21 of the 24 sentences that contained a singular object and a coercive adverb, interpretations of multiple acts were more frequent than interpretations of one event, $p < .001$ by binomial test. The overall mean proportions were 0.68 and 0.17 for multiple versus single event respectively. On the other hand, for all 24 sentences containing a singular object and a non-coercive adverb, interpretations of multiple events were less frequent than interpretations of one event. The overall mean proportions of choices were 0.02 for an interpretation of multiple events versus 0.94 for an interpretation

Table 2 Proportion of choices of most likely interpretation depending on adverb and object type

Most likely interpretation	Singular object: *a large check*		Bare plural object: *large checks*	
	Coercive (SC): *for many years*	∼Coercive (SN): *last year*	Coercive (PC): *for many years*	∼Coercive (PN): *last year*
One event	0.17	0.94	0.11	0.54
Multiple events	0.68	0.02	0.74	0.29
Both	0.14	0.04	0.14	0.15
Neither	0.01	0.00	0.01	0.01

S singular object; *P* bare plural object; *C* coercive adverb; *N* non-coercive adverb

of one event. The Appendix shows these difference scores for each item (i.e., proportion of interpretations of multiple events minus proportion of interpretations of a single event).

Interpretations of multiple events were more frequent for coercive adverbs than for non-coercive adverbs (see Table 2). For singular objects, an interpretation of multiple events was more common with coercive adverbs than with non-coercive adverbs in all 23 sentences that showed a difference. For singular objects, the overall mean proportions of interpretations of multiple events were 0.68 for coercive adverbs and 0.02 for non-coercive adverbs. For bare plural objects, interpretations of multiple events were more common with coercive adverbs than with non-coercive adverbs in all 24 sentences. The overall mean proportions were 0.74 and 0.29 for coercive and non-coercive adverbs respectively.

Sentences with a singular object and a non-coercive adverb were less ambiguous than other sentences (see Table 2). The mean proportions of choices that both single- and multiple-event interpretations occurred were 0.04 for SN compared to 0.14, 0.14, and 0.15 for SC, PC, and PN respectively, all $ps < .05$ or better. Thus, the sentences with a coerced interpretation (SC) were no more ambiguous than sentences that contain a coercive adverb but do not induce coercion (PC, PN).

Procedure

The experiment was conducted with an SR Research Eye Link 1000 eye-tracking system and a View Sonic CRT monitor. The monitor was 50 cm from the participant. Each participant rested his or her chin and forehead on bars. The system was calibrated for right eye tracking with corneal reflection. Maximum drift error was set at 0.4 degrees at the beginning of an experimental session and checked several times during each session. A trial began when the participant focused on a circle in the center of the screen. When the participant's gaze was stable, the Eye Track software presented a square near the left edge of the screen. (The source of all referenced software is http://www.umass.edu/eyelab/software/). When the participant shifted gaze to the square, the software presented the sentence. The font was Courier New 12. The screen width was 160 characters with a resolution of 1280 by 1024. Sentences with two lines had one-inch space between the lines. Each test sentence had a line break at the end of the initial clause. The potentially coercing adverb appeared at the end of the first clause and line. Participants were instructed to read each sentence as they normally read sentences. When they reached the end of the sentence, participants shifted their gaze to a sequence of XXX one line below and 3–5 spaces to the right of the period. Once they focused on the XXX, they pressed a button on the left side of a game controller. This button press either initiated the sequence of another trial or presented a "yes"/"no" follow-up question.

Participants indicated their answer to the question by pressing one of two buttons on the right side of the game controller, the top blue button for "yes" or the bottom yellow button for "no."

Each participant read 128 sentences consisting of 24 test sentences and 104 filler sentences. The test sentences had the form of those in Table 1. Each of eight lists had three test sentences in each of eight conditions: 2 (Adverb Type: coercive vs. non-coercive) × 2 (Object Type: singular vs. bare plural) × 2 (Clause Type: subordinate clause vs. main clause). The filler sentences in this experiment were test and filler sentences in other experiments: 32 sentences had a center-embedded relative clause, 24 had clauses conjoined with *and*, 24 had clauses conjoined with *so* or *while*, and 24 were a mixture of one- and two-clause sentences.

Follow-Up Questions

To encourage participants to attend to sentence meaning, a question followed approximately 40 % of both filler and test sentences. Half of the questions following both filler and test sentences concerned thematic roles such as agent, patient, etc. (e.g., *Was it her mother*?); half concerned aspectual meaning such as single versus iterative events (e.g., *Did the chef do this on many occasions*?). For test sentences, five questions concerned thematic roles and four concerned aspectual meaning. These questions were linked with nine sentence sets across lists. As a result, the same 15 sentence sets had no follow-up question in any list. In addition, the condition associated with a question varied across lists. This design entailed that in each list, some conditions had two follow-up questions, some had one, and some had no follow-up question.

To determine whether the questions were effective, one thematic test question (for item 6) was discarded because both answers were possible. On the remaining eight questions for test sentences, participants correctly answered 0.59. The proportion of correct answers differed from chance performance, $p < .01$ by binomial test. For two reasons, the statistical analysis of fixation time included trials on which participants answered the question incorrectly: Excluding trials with errors on questions would assign greater weight to sentences without a question and it would assign weight unequally to conditions within a list.

Data Analysis

The eye movement software adjusted vertical displacement. The software combined fixations that were shorter than 80 ms. It excluded trials in which gaze duration exceeded 2,000 ms (2.1 % of the trials). The data processing software excluded from the analysis trials in which no fixation occurred in the region. For the adverb region, 2.0 % of the trials had missing first pass data. For the post-adverb region, 28 % of the trials had missing first pass data. The distribution of missing data across regions and conditions is reported.

First pass time, go-past time, and total time are reported for the adverb and for the next two words (*for many years* / *last year* and *even though* / *she still* respectively in Table 1). I evaluated the statistical significance of differences with analysis of variance by participants and by items. I conducted statistical tests using data from these regions separately and combined. The variables in these analyses were Adverb Type (coercive vs. non-coercive), Object Type (singular vs. bare plural), and Clause Type (initial main clause vs. initial subordinate clause). To control for variability in region length, analyses of first pass time and total time used residual reading times (Ferreira and Clifton 1986; Trueswell et al. 1994). The residual reading time in a region is the difference between the actual fixation time and the fixation time that linear regression predicts from the number of characters in the region.

Table 3 Mean proportion of first pass fixation failure, total fixation failure, and regressions-in for adverb and post-adverb regions depending on adverb and object type

Region	Condition	First pass FF		Total FF		Regressions-in	
		Mean	SE	Mean	SE	Mean	SE
Adverb	SC	.033	.016	.008	.006	.019	.009
	PC	.021	.011	.000	.000	.008	.006
	SN	.017	.008	.000	.000	.004	.004
	PN	.008	.006	.008	.006	.004	.004
Post-adverb	SC	.325	.047	.012	.007	.354	.042
	PC	.262	.047	.004	.004	.335	.044
	SN	.268	.044	.021	.009	.363	.047
	PN	.264	.043	.008	.006	.340	.037

FF fixation failure; *S* singular object; *P* bare plural object; *C* coercive adverb; *N* non-coercive adverb; *SE* standard error

Table 1 shows the regions used for estimating residual reading time: the subordinating conjunction (if present), subject, and verb; the direct object; the prepositional phrase; the adverb region; the two-word post-adverb region; and the remainder of the sentence. The analysis of go-past time used raw fixation time because go-past time includes fixations outside the region.

Results

Table 3 shows the proportion of first pass fixation failures, total fixation failures, and regressions in the adverb and post-adverb regions. The overall proportion of first pass fixation failures was .02 for the adverb region and .28 for the post-adverb region. Two results in Table 3 suggest that the high rate of first pass fixation failure for the post-adverb region occurred because of saccades that landed on the second line short of the target post-adverb region. First, the overall proportions of total fixation failure were similar for the adverb (.004) and post-adverb regions (.011). Second, the overall rates of regressions into the adverb and post-adverb regions were .009 and .348 respectively. Moreover, coercive materials failed to influence fixation failure. In first pass reading of the post-adverb region, the .325 proportion of fixation failures in the coercion condition (SC) appears higher than that for other conditions. The interaction between Adverb Type and Object Type in first pass reading of the post-adverb region, however, was not significant, $F1(1, 39) = 1.94$, $MSE = 0.035$, $p > .15$, $F2 < 1$.

Since the coercion manipulation had no effect on rate of fixation failure, these trials were treated as missing data in the analysis of fixation time. Separate analyses of fixation time treated participants and items as random variables. The combined data for the adverb and post-adverb regions are presented first, followed by the data broken down into the two regions separately.

Combined Analysis of Regions

The interactions between Adverb Type and Object Type for the adverb and post-adverb regions combined appear in Fig. 1. Figure 1 shows first pass time, go-past time, and total time averaged over these two regions. Inspection of Fig. 1 shows that for coercive ad-

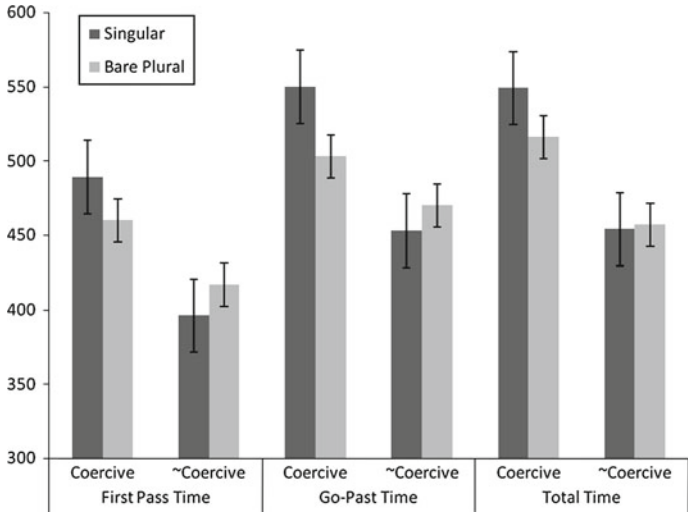

Fig. 1 Effects of adverb and object type on first pass, go-past, and total time in adverb and post-adverb regions combined (ms). *Error bars* show standard errors

verbs, fixation time on all measures was longer for singular objects (SC) than for bare plural objects (PC). For non-coercive adverbs, the opposite occurred: Fixation time was longer for bare plural objects (PN) than for singular objects (SN). The interaction between Adverb Type and Object Type was significant by participants and by items in first pass time, $F1(1, 39) = 8.03, MSE = 12{,}487, p < .01, F2(1, 23) = 4.79, MSE = 24{,}743, p < .05$. The interaction was significant by participants in go-past time, $F1\ (1, 39) = 5.60, MSE = 28{,}646, p < .05,\ F2(1, 23) = 2.12, MSE = 35{,}001, p = .159$, and total time, $F1(1, 39) = 4.62, MSE = 12{,}936, p < .05, F2(1, 23) = 3.65, MSE = 16{,}826, p = .069$.

A *Coercion Effect* occurs if fixation time in a sentence with a coercive adverb is longer when the direct object is singular (SC) rather than bare plural (PC). Inspection of Fig. 1 shows that this was the case for each of the three measures. Fixation time was longer by participants in SC than in PC in first pass time (489 vs. 460 ms), $F1(1, 39) = 5.09, MSE = 14{,}980, p < .05, F2(1, 23) = 3.44, MSE = 26{,}647, p = .077$, and in go-past time (549 vs. 503 ms), $F1(1, 39) = 5.34, MSE = 32{,}525, p < .05, F2(1, 23) = 2.93, MSE = 30{,}458, p = .10$. The effect of Object Type for coercive adverbs in the combined regions was significant in total time in both analyses (549 vs. 516 ms), $F1(1, 39) = 4.40, MSE = 21{,}220, p < .05, F2(1,23) = 5.65, MSE = 16{,}147, p < .05$.

Inspection of Fig. 1 also suggests that fixation time was longer on coercive adverbs than on non-coercive adverbs. This difference was significant in first pass time (475 vs. 406 ms), $F1(1, 39) = 7.98, MSE = 20{,}120, p < .01, F2(1, 23) = 12.0, MSE = 10{,}397, p < .01$, and in go-past time (526 vs. 461 ms), $F1(1, 39) = 19.6, MSE = 34{,}716, p < .001, F2(1, 23) = 11.4, MSE = 35{,}543, p < .01$. The overall adverb effect was significant by participants in total time (533 vs. 456 ms), $F1(1, 39) = 5.23, MSE = 21{,}944, p < .05,\ F2(1, 23) = 2.33, MSE = 14{,}925, p = .141$.

Four other significant effects appeared in the combined analysis of regions. Go-past time was shorter for subordinate clauses than for main clauses (471 vs. 516 ms), $F1(1, 39) = 8.69, MSE = 327{,}173, p < .01, F2(1, 23) = 4.92, MSE = 10{,}508, p < .05$. Go-past time was also shorter for the post-adverb region than for the adverb region (378 vs. 609 ms),

$F1(1, 39) = 86.5, MSE = 98{,}902, p < .001$, $F2(1, 23) = 29.4, MSE = 111{,}349, p < .001$. An interaction between Adverb Type and Region appeared in go-past time, $F1(1, 39) = 21.4, MSE = 27{,}449, p < .05$, $F2(1, 23) = 8.00, MSE = 40{,}889, p = .069$. Go-past time was shorter for non-coercive adverbs than for coercive adverbs in the adverb region (547 vs. 672 ms), $F1(1, 39) = 33.3, MSE = 37{,}973, p < .001$, $F2(1, 23) = 11.8, MSE = 62{,}088, p < .01$, but not in the post-adverb region (376 vs. 381 ms), both Fs < 1. An interaction between Clause Type and Region appeared in first pass time, $F1(1, 39) = 4.98, MSE = 22{,}872, p < .05$, $F2(1, 23) = 3.98, MSE = 10{,}434, p = .058$. Details of the Clause Type × Region interaction appear below.

Separate Analysis of Regions

Fixation time was analyzed separately for adverb and post-adverb regions. These analyses showed a trend in the adverb region toward shorter first pass time for initial subordinate clauses than for initial main clauses (487 vs. 527 ms, $F1(1, 39) = 5.06, MSE = 21{,}265, p < .05$, $F2(1, 23) = 1.59, MSE = 21{,}414, p > .10$). The trend toward shorter fixation time for initial subordinate clauses also appeared in the adverb region in total time (552 vs. 582 ms, $F1(1, 39) = 3.54, MSE = 16{,}607, p = .067$, $F2 < 1$, and in the post-adverb region in go-past time (350 vs. 406 ms, $F1(1, 39) = 7.8, MSE = 32{,}558, p < .01$, $F2(1, 23) = 1.72, MSE = 11{,}522, p > .10$). Clause Type did not interact with any other variable, all ps > .10.

Table 4 shows mean fixation time in the adverb versus post-adverb regions depending on Adverb Type and Object Type. Inspection of Table 4 reveals longer fixation time for SC than for PC on all measures in both regions. Significant differences, however, appeared only in the post-adverb region. For the adverb region, fixation time was non-significantly longer in SC than in PC in first pass time (576 vs. 563 ms), $F1(1, 39) < 1, F2(1, 23) = 1.03, MSE = 26{,}511, p > .10$; in go-past time (697 vs. 647 ms), $F1(1, 39) = 3.23, MSE = 30{,}882, p = .08$, $F2(1, 23) = 2.3, MSE = 20{,}059, p > .10$; and in total time (654 vs. 620 ms), $F1(1, 39) < 1, F2(1, 23) = 3.3, MSE = 16{,}964, p = .082$. For the post-adverb region, fixation time was significantly longer by participants in SC than in PC in first pass time (402 vs. 358 ms), $F1(1, 39) = 7.25, MSE = 12{,}707, p = .01, F2(1, 23) = 2.92, MSE = 23{,}685 p > .10$, and in total time (445 vs. 412 ms), $F1(1, 39) = 7.83, MSE = 9{,}343, p < .01, F2(1, 23) = 2.58, MSE = 14{,}108, p > .10$. For the post-adverb region the Object Type effect in go-past time fell short of significance in both analyses (402 vs. 359 ms), $F1(1, 39) = 3.27, MSE = 22{,}876, p = .078, F2(1, 23) = 1.35, MSE = 31{,}989, p > .10$. Means for first pass time and go-past time were similar or identical in the post-adverb region due to regressions out of this region on less than 0.2 % of the trials. The outcomes of statistical tests for first pass time and go-past time differ because the analysis of the former used residual reading times and the analysis of the latter used raw reading times.

Non-coercive adverbs provide a control for evaluating the effect of Object Type (see SN and PN in Table 4). For non-coercive adverbs, the only effect of Object Type that approached significance was in the by-participant analysis of first pass time in the adverb region: Singular objects produced non-significantly shorter first pass time than the bare plural objects (428 vs. 461 ms), $F1(1, 39) = 2.85, MSE = 15{,}811, p = .10, F2(1, 23) = 1.36, MSE = 18{,}792, p > .10$. No other test of the effect of Object Type for non-coercive adverbs approached significance, all ps > .10.

The interaction between Adverb Type and Object Type evaluates the relative effect of Object Type for coercive and non-coercive adverbs. For the adverb region this interaction fell short of significance in first pass time, $F1(1, 39) = 2.74, MSE = 16{,}297, p >$

Table 4 Overall eye fixation time (ms) in two regions depending on adverb and object type

Region	Condition	First pass time		Go-past time		Total time	
		Mean	SE	Mean	SE	Mean	SE
Adverb	SC	576	27.7	697	33.5	654	33.3
		(23.1)	(19.1)			(−3.51)	(18.7)
	PC	563	26.7	647	31.9	620	31.0
		(9.33)	(18.2)			(−29.0)	(23.3)
	SN	428	26.0	527	32.3	483	28.3
		(−50.6)	(18.5)			(−67.8)	(20.1)
	PN	461	24.6	566	31.1	511	25.7
		(−17.1)	(16.8)			(−36.2)	(19.3)
Post-adverb	SC	402	30.5	402	30.5	445	26.5
		(9.25)	(17.9)			(−29.2)	(19.3)
	PC	358	25.0	359	24.9	412	21.8
		(−38.7)	(13.1)			(−71.9)	(15.9)
	SN	363	27.0	379	29.4	425	24.9
		(−30.5)	(13.7)			(−57.1)	(17.9)
	PN	373	27.4	373	27.4	404	21.7
		(−25.6)	(12.0)			(−79.7)	(14.3)

S singular object; *P* bare plural object; *C* coercive adverb; *N* non-coercive adverb; *SE* standard error. Residual reading times appear in parentheses

.10, $F2(1, 23) = 2.25, MSE = 23{,}488, p > .10$; in go-past time, $F1(1, 39) = 3.84, MSE = 41{,}022, p = .057, F2(1, 23) = 4.15, MSE = 20{,}292, p = .053$; and in total time, $F1(1, 39) = 2.73, MSE = 23{,}946, p > .10, F2(1, 23) = 4.06, MSE = 18{,}720, p = .056$. For the post-adverb region the interaction between Adverb Type and Object Type was significant in first pass time, $F1(1, 39) = 8.14, MSE = 6{,}867, p < .01, F2(1, 23) = 4.77, MSE = 13{,}838, p < .05$. This interaction was not significant in go-past time, $F1(1, 39) = 1.91, MSE = 15{,}093, p > .10, F2(1, 23) < 1$, or in total time, both Fs <1.

Discussion

The Coercion Hypothesis states that a mismatch between the aspectual type an adverb requires and the aspectual type a predicate expresses forces an immediate reinterpretation. For example, *for many years* must modify a process or state with temporal extension. Its appearance with a culmination, such as *sent a large check,* forces reinterpretation to a series of events that extends over time. The Under-Specification Hypothesis states that such mis-matches do not cause immediate re-interpretation during normal reading. The present data, however, show that aspectual mismatches increase fixation time in the adverb and post-adverb regions combined. Thus, we reject the Under-Specification Hypothesis and conclude that aspectual coercion can produce a measurable cost during normal reading.

We reach this conclusion cautiously. A potential concern is whether the rate of fixation failure makes first pass time in the post-adverb region unreliable. Since the rate of fixation

failure was much higher in the post-adverb region than in the adverb region, relatively few data points count toward the mean first pass time in the post-adverb region. The possibility that experimental conditions affected rates of fixation failure compounds this concern. Two features of the data, however, suggest that estimates of first pass time are reliable. Although first pass fixation failures did tend to be higher for the coercion condition than for other conditions, the difference was statistically unreliable. Since we cannot attribute the high fixation failure rate in the post-adverb region to linguistic processes, we must assume that fixation failure in the line-initial region depends on the mechanics of moving the eyes from one line to the next. A second feature of the data that increases our confidence in the reliability of first pass time is the similarity in patterns of fixation time for first pass time and total time. If measures of first pass time were unreliable, a similar pattern in total time would be unlikely. Thus, it appears that the means for first pass time in the post-adverb region are indeed reliable. Consequently, the entire set of results leads us to reject the Under-Specification Hypothesis.

This conclusion is consistent with studies that found an immediate cost for aspectual coercion (Pinango et al. 1999; Pinango et al. 2006; Proctor et al. 2004; Todorova et al. 2000). Those studies, however, used tasks that disrupt comprehension. The present study sought to determine whether we can observe aspectual coercion without any interruption of reading. Since an earlier attempt showed no immediate cost of coercion (Pickering et al. 2006), this study set up conditions that might enhance aspectual processing in normal reading. Since moving the eyes from one line to the next is a "normal" disruption in reading, this study placed the critical regions at the ends of lines and clauses. Such a design, however, confounds processing the adverb and post-adverb regions with processing the ends and beginnings of lines and clauses. Consequently, it prevents conclusions about the detailed time course of coercion.

Nevertheless, two important outcomes follow from this study. First, if line breaks caused the appearance of aspectual coercion in fixation time, placing critical materials around line breaks may be a useful tool for revealing more subtle linguistic processes within the bounds of normal reading. The present design, of course, does not permit the conclusion that it was line breaks that caused the appearance of coercion, as discussed below. A second important outcome from this study is the demonstration that coercion occurs during normal reading. This demonstration allows exploration of the mechanisms of aspectual interpretation to move forward.

What conditions increase the visibility of aspectual coercion? We can only speculate. In addition to the line break, several conditions in this study may contribute to the appearance of aspectual coercion. The remaining discussion considers how possible interpretations of adverbs, the role of world knowledge, the effect of follow-up questions, and the role of inter-clause relations may affect observation of aspectual coercion.

Interpretations of Adverbs

Consider first the possible interpretations of various adverbs. To increase the chance of observing aspectual coercion, the materials contained several kinds of coercive adverbs. Sound methodology requires demonstrating that the materials actually do produce the intended interpretation. A test of off-line judgments of aspectual meaning revealed that the materials did produce the intended shift: The preferred interpretation of a sentence with a singular object and a coercive adverb is reference to multiple events. The preferred interpretation of the same sentence with a non-coercive adverb replacing the coercive adverb is reference to one event. Consequently, we conclude that the observed fixation time is due to processes that produce the intended interpretation. Further research on adverbs may reveal details about the representations and operations that integrate adverbs and predicates.

There is reason to expect similar processing for temporal and locative phrases: Our terms for describing space and time frequently overlap. For example, we often use spatial terms to refer to time, as when we speak of a '*long* meeting' (Srinivasan and Carey 2010). Jackendoff (1990, 1991, 1996) proposed a representation of space and time that binds conceptual categories such as Event, Thing, and Place. When sentences refer to indefinite objects or locations, an operator applies to this representation to map a single Event onto a series of Events (Jackendoff 1990). This operator explains iterative meanings involving Things and Places, as in *Bill ate hot dogs* and *Bill ran into houses.* In both cases, an inference rule produces an iterative interpretation. If aspectual interpretation involves forming and operating on a conceptual structure that binds Event, Thing, and Place, we might expect similar operations in the interpretation of *sent a check each year* and *painted a courthouse in many towns*.

A closer look, however, reveals variation in the meanings of adverbial phrases: *Every year* following a predicate has an unambiguous iterative interpretation (Bott 2010). In contrast, a *for*-phrase yields several interpretations, as noted in the introduction (see also Dowty 1979; Hitzeman 1997; Jackendoff 1990; Pickering et al. 2006). *For many years* has an interpretation in which the duration of a single event was many years. This interpretation appears in *Bill took a book out of the library for many years and paid a huge fine when he finally returned it.* This durative interpretation is not available when *every year* replaces *for many years* (Jackendoff 1990). *Sent a check for many years* also has an iterative interpretation that distributes sending across many individual checks. Although *for many years* allows for an occasional missing year that is not possible with the universally quantified phrase *every year*, the iterative interpretation appears with both adverbs. In addition, a *for*-phrase may have a purpose interpretation as in *for her tuition* (Jackendoff 1990). This interpretation also is unavailable with *every year.* Thus, it appears that the number of interpretations is greater for *for*… than for *every*….

A constraint satisfaction model (CS) predicts that the ambiguity of a *for*-phrase makes it harder than *every year*. A CS model claims that the processor maintains multiple interpretations (e.g., MacDonald et al. 1994). Semantic and statistical properties of the verb and prepositional object combine in graded fashion with object definiteness to favor one interpretation. Maintaining multiple interpretations of *for* until the evidence clearly favors one makes *for many years* harder than *every year*.

A minimal semantic commitment model (MSC) also predicts that processing is harder for a *for*-phrase. The MSC model asserts that when multiple interpretations are possible, the processor immediately adopts the simplest (Frazier et al. 1999). Frazier et al. (1999) argued that collective interpretations are simpler than distributive interpretations. In a collective interpretation of *John and Mary ate a cupcake* the processor assigns the event *ate a cupcake* once to John and Mary together. In this case, John and Mary shared a single cupcake in a single eating event. A distributive interpretation requires an operator that distributes *ate a cupcake* across John and Mary individually. In this case, John and Mary each ate a different cupcake in two eating events, one for John and one for Mary. Part of the ambiguity of *sent a check for many years* corresponds to this collective/distributive ambiguity. *For many years* may assign the "sending" action to a single check to produce a single sending event that lasts many years. Alternatively, it may distribute the "sending" action across many checks to produce many sending events over a period of many years. The MSC model would predict that the processor initially adopts the simpler, single-event interpretation in which the duration of sending a single check is many years. However, unlike taking a book out of the library, it is rather implausible that sending a single check would last many years. Consequently, the processor shifts from the simpler collective interpretation to a distributive interpretation. A shift in interpretation does not occur when the predicate plausibly allows a durative inter-

pretation, as in *took a book out of the library for many years*. In this case, the initial collective interpretation is acceptable. Neither does a shift occur when the adverb is *every year* because it is unambiguously distributive. Therefore, the MSC model, like the CS model, predicts that *for many years* is harder than *every year*. One way to decide between these models is to determine whether a biasing context reduces processing difficulty (supporting CS) or preserves it (supporting MSC).

The present data provide mixed evidence on the question of whether the ambiguity of adverbs affects fixation time. The interpretation test showed that among the sentences with singular objects, participants judged that those with coercive adverbs were more ambiguous than those with non-coercive adverbs. The eye tracking experiment showed that participants also fixated longer on sentences with coercive adverbs. This result shows a relation between ambiguity and fixation time. On the other hand, the interpretation test showed that for sentences with coercive adverbs, those with bare plural objects were just as ambiguous as the coerced sentences with singular objects. Yet, participants fixated less on sentences with bare plural objects. This result suggests that ambiguity alone does not increase fixation time. Rather, ambiguity that involves a shift from one aspectual type to another increases fixation time.

World Knowledge

World knowledge and adverbs interact in aspectual interpretation. Aspectual adverbs may describe the duration of a preparatory process, a culminating state, or a series of culminations. Which time period an adverb modifies partly depends on our knowledge about the typical duration of events. Sentence (9a), for example, is a culminated process.

9.	a.	*John ate a breakfast.*	[Culminated Process]
	b.	*John ate a breakfast for three minutes.*	[Culminated Process → (∼Culminated) Process]
	c.	*John ate a breakfast for three weeks*	[Culminated Process → Culmination, Culmination,…]
	d.	*The Earth circled the Sun for three weeks*	[Culminated Process → (∼Culminated) Process]

Suppose that the typical duration of eating a breakfast is 20 min. Since 3 min is less than this typical duration, the durative adverb in (9b) "strip offs" the culmination of (9a) and leaves the preparatory process for the adverb to modify. On the other hand, since 3 weeks exceeds the typical duration of eating a breakfast, the adverb in (9c) forces an interpretation of a series of culminations so that it describes the duration of the series rather than the duration of a single breakfast. Now consider (9d). We know that the Earth circles the Sun in 52 weeks. Since 3 weeks is less than our expectation about the duration of circling the Sun, our interpretation of (9d) is similar to (9b) rather than (9c), even though (9d) and (9c) have the same adverb. Clearly, aspectual interpretation depends on an interaction of knowledge about the typical duration of events and the meanings of adverbs. The present results do not show when and how the computations in (9b)–(9d) occur. They do not show whether stripping off a culmination (9b) and serializing a culmination (9c) are distinct computations (see Bott 2010, for evidence that they are). They do not even show that world knowledge affects coercion. They do show, however, that shifts in aspectual interpretation occur during normal reading.

Follow-Up Questions

The procedure for enforcing normal reading may influence the appearance of aspectual coercion. Reading researchers typically instruct participants to read sentences normally. To ensure compliance, participants often must answer follow-up questions after some proportion of the test sentences. After each of their self-paced reading trials, Proctor et al. (2004) asked about

aspectual meaning. They found a significant coercion effect. After each of their eye-tracking trials, Pickering et al. (2006) asked about agent and patient roles or their modifiers. They found no significant coercion effect. The present study struck a compromise: approximately 20 % of the trials had a follow-up question about aspectual meaning, 20 % had one about thematic roles, and 60 % had no follow-up question. A significant coercion effect appeared. Thus, one explanation for the mixed results in earlier studies is that follow-up questions that draw attention to aspectual meanings make aspectual processes more visible, just as lexical decision or meaning judgment do (Husband et al. 2008; Pinango et al. 1999; Todorova et al. 2000). Since this study combined several methods to enhance aspectual coercion, we cannot isolate the effect of follow-up questions from that of other conditions. However, even if we demonstrated conclusively that follow-up questions affect the appearance of aspectual coercion, questions about its mechanisms would remain unanswered.

Inter-clause Relations

Inter-clause relations affect semantic processing within a clause (Townsend and Bever 1978). Todorova et al. (2000) placed coercive phrases at the end of an adverbial subordinate clause. Pickering et al. (2006) placed them at the end of a main clause. The different outcomes in these studies may have occurred because of differences in processing main and subordinate clauses. To examine this possibility, I systematically varied clause type. The results showed an effect of clause type on fixation time, but interactions between clause type and aspectual properties failed to appear. Still, we cannot entirely rule out clause type as a factor in the appearance of coercion. The question of how inter-clause relations affect processing within a clause is certainly critical for theories of sentence comprehension. Understanding the nature of inter-clause processing, however, fails to reveal the mechanisms of aspectual coercion.

Conclusion

This research shows that when we combine validated materials, line breaks after adverbs, appropriate follow-up questions, and variation in clause types, coercion appears in normal reading. Thus, the research establishes the basic phenomenon of coercion. However, questions remain about its time course and mechanisms, how structural, semantic, and pragmatic information interact, and whether different operations on aspectual interpretations differ in cost. Having established that aspectual coercion occurs in normal reading, we can now address these questions.

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Appendix

Parts (a) and (b) present materials with an initial subordinate versus main clause respectively. Within Clause Types, Object Types appear as [singular / bare plural] and Adverb Types as [non-coercive / coercive].

Parts (c) and (d) show the results of the interpretation test. Part (c) shows the proportion of interpretations as multiple events minus the proportion of interpretations as a single event for singular objects with coercive adverbs (SC); for singular objects with non-coercive adverbs (SN); for bare plural objects with coercive adverbs (PC); and for bare plural objects with non-coercive adverbs (PN). Part (d) shows evidence of ambiguity. It shows the proportion of judgments that sentences have both single- and multiple-event interpretations.

Part (e) shows follow-up questions; these questions appeared after items 1, 4, 6, 9, 11, 14, 16, 19, and 21.

1. a. Even though Howard sent [a large check / large checks] to his daughter [last year / for many years], she still ran out of money.
   b. Howard sent [a large check / large checks] to his daughter [last year / for many years], even though she still had money.
   c. SC: 0.73; SN: −1.0; PC: 0.93; PN: 0.36
   d. SC: 0.13; SN: 0.0; PC: 0.07; PN: 0.21
   e. Was it her mother?
2. a. Though the president shipped [a box / boxes] of documents to the special prosecutor [last week / each week], he still withheld crucial evidence.
   b. The president shipped [a box / boxes] of documents to the special prosecutor [last week / each week], though the documents contained no new information.
   c. SC: 0.86; SN: −1.0; PC: 0.5; PN: −0.72
   d. SC: 0.0; SN: 0.0; PC: 0.07; PN: 0.14
3. a. Although a marshal served [a warrant / warrants] for arrest to a top official [last week / each week], there were rumors of further indictments.
   b. A marshal served [a warrant / warrants] for arrest to a top official [last week / each week], although the administration denied it.
   c. SC: 0.21; SN: −0.86; PC: 0.74; PN: 0.20
   d. SC: 0.21; SN: 0.0; PC: 0.0; PN: 0.13
4. a. Though the president presented [a medal / medals] of honor to a war hero [last Wednesday / on alternate Wednesdays], many other soldiers deserved recognition.
   b. The president presented [a medal / medals] of honor to a war hero [last Wednesday / on alternate Wednesdays], though many other soldiers deserved recognition.
   c. SC: 0.64; SN: −1.0; PC: 0.80; PN: −0.54
   d. SC: 0.29; SN: 0.0; PC: 0.07; PN: 0.20
   e. Did the president make one presentation?
5. a. Though Joanne placed [a spare house key / spare house keys] underneath the door mat [last year / for many years], she still was locked out.
   b. Joanne placed [a spare house key / spare house keys] underneath the door mat [last year / for many years], though she never needed [it / them].
   c. SC: −0.27; SN: −0.93; PC: 0.0; PN: −0.65
   d. SC: 0.27; SN: 0.07; PC: 0.43; PN: 0.07
6. a. Although the quarterback threw [a long pass / long passes] to the fullback [on the last play / on several plays], a victory was not certain.
   b. The quarterback threw [a long pass / long passes] to the fullback [on the last play / on several plays], even though a victory was not certain.
   c. SC: 0.71; SN: −0.86; PC: 1.0; PN: 0.40
   d. SC: 0.29; SN: 0.07; PC: 0.0; PN: 0.20
   e. Was it the halfback?

7. a. Although the president announced [a large tax cut / large tax cuts] to the reporters [last year / every year], the surplus grew smaller.
   b. The president announced [a large tax cut / large tax cuts] to the reporters [last year / every year], although the surplus grew smaller.
   c. SC: 0.14; SN: −0.86; PC: 0.14; PN: −0.93
   d. SC: 0.07; SN: 0.14; PC: 0.20; PN: 0.07
8. a. Although Family Services separated [a young child / young children] from the mother [last month / many times], the court did not intervene.
   b. Family Services separated [a young child / young children] from the mother [last month / many times], although the court intervened.
   c. SC: 0.93; SN: −0.93; PC: 0.71; PN: −0.14
   d. SC: 0.07; SN: 0.0; PC: 0.21; PN: 0.21
9. a. Although Rick gave [a substantial check / substantial checks] to the Democratic Party [last year / for many years], they still couldn't win elections.
   b. Rick gave [a substantial check / substantial checks] to the Democratic Party [last year / for many years], although they still couldn't win elections.
   c. SC: 0.93; SN: −1.0; PC: 0.86; PN: 0.43
   d. SC: 0.07; SN: 0.0; PC: 0.14; PN: 0.29
   e. Did he make one contribution?
10. a. Though an expert called [a creationist theory / creationist theories] scientific in [a lower court / lower courts], the judge declared [it / them] religion.
    b. An expert called [a creationist theory / creationist theories] scientific in [a lower court / lower courts], though the judge declared [it / them] religion.
    c. SC: −0.86; SN: −0.93; PC: −0.27; PN: −0.53
    d. SC: 0.14; SN: 0.07; PC: 0.07; PN: 0.07
11. a. Although Ellen loaded [a diesel bulldozer / diesel bulldozers] onto a trailer [last summer / for several summers], she didn't enjoy it.
    b. Ellen loaded [a diesel bulldozer / diesel bulldozers] onto a trailer [last summer / for several summers], although she didn't enjoy it.
    c. SC: 0.74; SN: −0.93; PC: 0.64; PN: 0.07
    d. SC: 0.0; SN: 0.07; PC: 0.36; PN: 0.21
    e. Was it her regular activity?
12. a. Though the chair allocated [an hour / hours] to committee reports [in the last meeting / for several meetings], the faculty still felt uninformed.
    b. The chair allocated [an hour / hours] to committee reports [in the last meeting / for several meetings], though the faculty expressed opposition.
    c. SC: 0.21; SN: −0.86; PC: 0.07; PN: −0.6
    d. SC: 0.21; SN: 0.0; PC: 0.27; PN: 0.07
13. a. Though an artist gave her [painting / paintings] to a wealthy benefactor [last year / for several years], she was already quite successful.
    b. An artist gave her [painting / paintings] to a wealthy benefactor [last year / for several years], though she was financially independent.
    c. SC: 0.13; SN: −1.0; PC: 0.50; PN: −0.43
    d. SC: 0.07; SN: 0.0; PC: 0.21; PN: 0.21
14. a. Though the artist painted [a biblical scene / biblical scenes] on the courthouse in [Amherst / many towns], religious displays were prohibited.
    b. The artist painted [a biblical scene / biblical scenes] on the courthouse in [Amherst / many towns], though religious displays were prohibited.
    c. SC: 1.0; SN: −0.93; PC: 0.79; PN: −0.50

d. SC: 0.0; SN: 0.07; PC: 0.14; PN: 0.36
e. Was there more than one painting?

15. a. Although Barb hammered [a small nail / small nails] into the plaster wall in [her kitchen / several rooms], it violated her lease agreement.
b. Barb hammered [a small nail / small nails] into the plaster wall in [her kitchen / several rooms], although it violated her lease agreement.
c. SC: −.93; SN: −0.86; PC: 1.0; PN: 0.67
d. SC: 0.07; SN: 0.0; PC: 0.0; PN: 0.13

16. a. Although the teacher granted [a hall pass / hall passes] to a young student [yesterday / for several days], hall passes were not required.
b. The teacher granted [a hall pass / hall passes] to a young student [yesterday / for several days], although hall passes were not required.
c. SC: −0.7; SN: −1.0; PC: 0.6; PN: −0.20
d. SC: 0.21; SN: 0.0; PC: 0.27; PN: 0.0
e. Did the teacher give permission?

17. a. Although the judge explained [a court procedure / court procedures] to the jury on [one occasion / several occasions], the lawyers filed for a mistrial.
b. The judge explained [a court procedure / court procedures] to the jury on [one occasion / several occasions], although the lawyers filed a dispute.
c. SC: 1.0; SN: −1.0; PC: 0.79; PN: −0.6
d. SC: 0.0; SN: 0.0; PC: 0.07; PN: 0.14

18. a. Though the police blamed [a traffic accident / traffic accidents] on bad weather [yesterday / in many cases], the roads were dry.
b. The police blamed [a traffic accident / traffic accidents] on bad weather [yesterday / in many cases], though the roads were dry.
c. SC: 0.71; SN: −0.86; PC: 0.67; PN: −0.47
d. SC: 0.29; SN: 0.14; PC: 0.07; PN: 0.13

19. a. Although the chef blended [an organic egg / organic eggs] with heavy cream [this morning / every morning], my diet required low cholesterol.
b. The chef blended [an organic egg / organic eggs] with heavy cream [this morning / every morning], although my diet required low cholesterol.
c. SC: 0.50; SN: −1.0; PC: 0.87; PN: −0.74
d. SC: 0.07; SN: 0.0; PC: 0.13; PN: 0.0
e. Did the chef do this on many occasions?

20. a. Though the secretary scheduled [a news conference / news conferences] with the president [yesterday / every day], there was no good news.
b. The secretary scheduled [a news conference / news conferences] with the president [yesterday / every day], though there was no good news.
c. SC: 0.40; SN: −1.0; PC: 0.43; PN: −0.19
d. SC: 0.20; SN: 0.0; PC: 0.29; PN: 0.07

21. a. Though the builder turned [a vacant lot / vacant lots] into a housing complex in [Hadley / many cities], there was not enough housing.
b. The builder turned [a vacant lot / vacant lots] into a housing complex in [Hadley / many cities], though there was enough housing.
c. SC: 1.0; SN: −1.0; PC: 0.93; PN: −0.5
d. SC: 0.0; SN: 0.0; PC: 0.07; PN: 0.21
e. Was the building needed?

22. a. Although vandals sprayed [a can / cans] of paint onto a subway car [last night / several nights], the police did not increase security.

b. Vandals sprayed [a can / cans] of paint onto a subway car [last night / several nights], although the police had increased security.
c. SC: 0.50; SN: −0.79; PC: 0.80; PN: −0.67
d. SC: 0.07; SN: 0.0; PC: 0.0; PN: 0.0

23. a. While the teacher gave [a candy bar / candy bars] to the best student [last year / for many years], the nurse discouraged it.
b. The teacher gave [a candy bar / candy bars] to the best student [last year / for many years], while the nurse discouraged it.
c. SC: 0.87; SN: −0.86; PC: 0.79; PN: −0.36
d. SC: 0.13; SN: 0.0; PC: 0.07; PN: 0.36

24. a. While Cheryl's husband packed [a cardboard box / cardboard boxes] with books [last weekend / for several weekends], they still could not move.
b. Cheryl's husband packed [a cardboard box / cardboard boxes] with books [last weekend / for several weekends], while they still could not move.
c. SC: 0.07; SN: −0.64; PC: 0.67; PN: 0.20
d. SC: 0.21; SN: 0.21; PC: 0.07; PN: 0.13

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