The Online Composition of Events

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Abstract

Linguistic events have long been known to systematically differ with respect to whether they proceed to a natural and necessary end point, or not. Semantic and syntactic accounts of these systematic differences disagree as to which kind of event is more complex, and thus more computationally costly, but both approaches identify the VP (not the verb alone) as the domain for aspectual interpretation. We review the existing processing literature, which is broadly consistent with VP-domain hypotheses but does not address the issue of representational complexity. We present a series of experiments that provide a more detailed look at the time course of aspec- tual interpretation, providing clear support for the VP hypothesis. We also argue that syntactic and semantic complexity effects can be seen in aspectual processing. Terminative syntactic structure and durative semantic interpretation are both costly.

Keywords aspect, incremental interpretation, lexical semantics, sentence processing, telicity

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1 Introduction

The classification of linguistic events in terms of whether they last for any length of time and whether they have an inherent end point has a long history (going back at least to Aristotle, as noted in Folli and Harley (2006)) and continues to excite considerable interest today in both linguistic (Borer (2005); MacDonald (2008); Ramchand (2008); Rothstein (2004); Thompson (2006)) and psycholinguistic (Frazier et al. (2006); Pickering et al. (2006); Piñango et al. (1999); Piñango et al. (2006); Todorova et al. (2000)) research. Much of this recent work has focused on the linguistic properties of telicity, including which properties of a sentence determine terminative and durative interpretations, and whether these interpretations are constructed early during sentence comprehension.[1]

Event classification systems, of which the most well known and widely adopted comes from Vendler (1957), have attempted to establish the range of possible event types and demonstrate how these classes interact with other aspects of the linguistic system. Dowty (1979), for instance, showed that the classes proposed in Vendler (1957) can be distinguished on the bases of adverbial modification tests, among others. The test we focus on here is *in X time*. This test for telicity rests on the acceptability of end point modification; for instance a terminative event can be modified with *in an hour* with the interpretation that the event took an hour to finish. An event is said to be terminative, or telic, if it allows this end point modification, and durative, or atelic, if it blocks this end point modification. Research on aspect has also focused on the linguistic primitives which contribute to the building of aspectual interpretations.

The telicity of some events appears to be entirely determined by the lexical semantics of the verb itself. *Explode* and *find,* for instance, are inherently terminative (1), allowing end point modification, whereas *sleep* and *fly* are inherently durative (2), blocking end point modification. This observation has led researchers to refer to

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[1]The terminology of aspect is notoriously complicated and some clarification for this paper is in order. The term *aspect* here will refer to what is called lexical aspect, situation aspect, inner aspect, or aktionsarten in other work. *Grammatical aspect* (also called viewpoint aspect or outer aspect) will be explicitly mentioned when necessary. We will focus in particular on the dimension of *telicity* (whether an event has a natural end or not) and use *durative* (*atelic*) and *terminative* (*telic*) to refer to the two aspectual interpretations of interest here.

this phenomenon as lexical aspect.[2]

(1) **Inherently terminative events**

a. The bomb exploded in ten minutes.
b. John found beer in ten minutes.
c. John found the beer in ten minutes.

(2) **Inherently durative events**

a. John slept #in eight hours.
b. John flew planes #in eight hours.
c. John flew the plane #in eight hours.

For these verbs, other elements of the sentence, including changes in the properties of the internal argument, do not affect the event interpretation. However, Verkuyl (1972) demonstrated that for many events, telicity often depends on the count or mass syntax of the internal argument, and not on lexical properties of the verb alone (3).

(3) **Internal argument dependent events**

a. John drank beer #in ten minutes.
b. John drank the beer in ten minutes.
c. John built planes #in eight hours.
d. John built the plane in eight hours.

For verbs like *drink* and *build*, the terminative interpretation depends on properties of the internal argument; count internal arguments give rise to terminative interpretations while mass internal arguments give rise to durative interpretations.[3] Based on these observations, Verkuyl (1972) argued that 'lexical aspect' is actually a VP phenomenon since the VP is the first point where verbal and nominal sources of aspectual information can combine together. Subsequent research has supported this phrasal-level understanding of aspectual interpretation, although studies on 'punctual' verbs (the so called achievement verbs such as *explode*, *find*, and *notice*) have continued to argue for their inherently terminative nature Borer (2005); Mittwoch

[2]Sentence judgments are as follows: a $*$ indicates ungrammaticality, a # indicates an unavailable reading. Often # will indicate that the event modified by *in X time* cannot receive an end point interpretation.

[3]Both mass nouns like *beer* and bare plurals like *planes* are known for allowing durative interpretations. Bare plurals are argued to allow "aspectual leaks" because of the cumulativity of their denotation (Verkuyl, 1989). A syntactic hallmark of these two phrases, and of mass interpretation in general, is their lack of determiner.

(1991); Smith (1997). Taken together, the following calculus of events emerges based on both verbal and nominal properties.

Table 1: Vendler's (1957) aspectual classes and their feature decomposition

	Telic	**Atelic**
Durative	ACCOMPLISHMENT	ACTIVITY
	Harry ate the pizza.	*John pushed the cart.*
Non-Durative	ACHIEVEMENT	STATE
	Sarah solved the puzzle.	*Lisa knew the answer.*

This summary suggests that the presence of any kind of terminative element, including an inherently terminative verb or a count internal argument, leads to a terminative, or telic, interpretation. The absence of both of these elements leads to a durative, or atelic, interpretation.

1.1 Theories of Event Complexity

While approaches to aspect generally agree that aspectual interpretation requires composition, precisely which verbal and nominal properties contribute to telicity and how these elements are composed to yield aspectual interpretations have been the object of considerable research. Of the many questions that have come out of this work, we are particularly interested in the representational complexity of events here. Claims about representational complexity have largely depended on the framework adopted by the theory in question since the representations which syntactic theory and semantic theory assume are not necessarily the same.

Differences in the kind of formal approach to events that is adopted have led to different analyses of the source of telicity and different conclusions concerning the representational complexity of events. In semantic theories, the properties of the model-theoretic interpretation of events are central to understanding the interpretation of telicity. Syntactic theories focus on the functional primitives needed to account for syntactic structures which are linked to different aspectual interpretations.

1.1.1 The Semantics of Aspect

Semantic theories of aspect have focused on the ontological commitments necessary to capture the differences between telic and atelic interpretations. Bach (1986) represents an early approach which connected algebraic structures familiar in the analysis of count and mass individuals to telic and atelic events. Enriching the domain of events in a way similar to Link (1983)'s enrichment of the domain of individuals has allowed researchers to understand how nominal properties like the count/mass distinction in the domain of individuals can affect events. This work has also lead researchers to define notions such as homogeneity over the model structures of individuals and events which capture the differences between count and mass interpretations and durative and terminative interpretations, and link up with other important properties, such as the sub-interval property of durative events (Bennett and Partee, 2004).

A major concern has been to understand how telicity is related to the properties of these event structures. Using Bach's enriched event domain, Krifka (1992, 1998) and Verkuyl (1993) formulated formal properties of predicates to capture the telic/atelic distinction. Krifka presented the first compositional semantic theory of telicity in a series of influential papers which made two important insights. First, he proposed a mapping between the individual denoted by the internal argument of the verb and the event denoted by the verb itself. This mapping captured the intuition behind Tenny (1987, 1994)'s measuring out of an event by its internal argument, creating a relationship between the part structure of the individual and the part structure of the event. He also proposed to capture the homogeneity of atelic events through a cumulative property of their resulting event structure. The event structure of telic events in turn was argued to be quantized. Krifka's approach formalized these properties of event structure with the following definitions.

(4) **Cumulative:** $\exists x,y\ [P(x) \wedge P(y) \wedge \neg x = y] \wedge \forall x,y\ [P(x) \wedge P(y) \rightarrow P(x \oplus y)]$

P is cumulative iff this is an x and y (x distinct from y) with property P such that the sum of x and y also have property P.

(5) **Quantized:** $\forall x,y\ [P(x) \wedge P(y) \rightarrow \neg y <_P x]$

P is quantized iff for all x and y with property P, y is not a proper part of x.

(Krifka, 1998)

Although these definitions have been shown to be too restrictive and to fail to capture certain kinds of telic and atelic predicates, they represent an important advance in understanding the model-theoretic representation of events. By assuming

that events have structure, one can formulate a relationship between the structure of an event and the aspectual interpretation of that event.

Refinements of Krifka's initial properties have lead to a deeper understanding of telicity and the semantic distinctions between predicates. (Kiparsky, 1998) emphasized other important properties such as divisiveness as a requirement of atelic predicates. This property captured those predicates which are cumulative but have telic interpretations, such as *eat more than two apples*. Borer (2005), noting that other examples of telic interpretations, like *read fewer than three books* and *fill the room with smoke* were problematic for earlier approaches, modified Krifka's notion of quantization and made further refinements by proposing that while homogeneous predicates are syntactically simple (6), they carry both cumulative and divisive requirements for their model-theoretic interpretation, leading to the revised formulations in (7) and (8), and the addition of (9).

(6) **Homogeneous:** P is homogeneous iff P is cumulative and divisive.

(7) **Cumulative:** $\forall x,y\ [P(x) \wedge P(y) \rightarrow P(x) \cup y)]$
P is cumulative iff for all x and y with property P, the union of x and y have property P.

(8) **Divisive:** $\forall x\ [P(x) \rightarrow \exists y\ [P(y) \wedge y < x] \wedge \forall x,y\ [P(x) \wedge P(y) \wedge y < x \rightarrow P(x - y)]$
P is divisive iff for all x with property P there is a y with property P that is part of x and for all x and y with property P such that y is a part of x, the subtraction of x and y also has property P.

(9) **Quantity**: P is quantity iff P is not homogeneous.

(Borer, 2005)

Borer's theory claims that predicates which are telic are those which violate either cumulativity or divisiveness; that is, their event structures fail to be homogeneous throughout.

The notion that there is something more complicated underlying the interpretation of atelic events pervades inquiry into the semantics of aspect. Since the representations of atelic predicates require the ability to see inside their temporal interval and make reference to their sub-events, the model-theoretic objects needed to capture the homogeneity of atelic events are complex in a way that those needed for the representation of telic events are not. While a telic event like *drink a beer* has no subevents which are also *drink a beer* events and therefore is atomic, an atelic event like *drink beer* has subevents which are also *drink beer* events. The event models which semantic interpretation builds must encode this kind of distinction. As such, while the event model representation of a telic event does not encode subevents, the

event model representation of an atelic event encodes an often unbounded number of subevents as schematized in Figure 1 (Bach, 1986; Link, 1998). By structuring the domain of events, atelic events can be modelled through part structures which have properties like homogeneity. Note that although the homogeneous structure in Figure 1 is finite and has atoms at its base, homogeneous structures in general do not necessarily have to be finite or have atoms for sub-events.

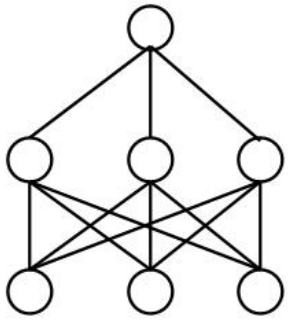

Figure 1: A semantic model for a homogeneous event

1.1.2 The Syntax of Aspect

In research on the syntax of aspect, the role of the internal argument has been a central concern. Tenny (1987, 1994) represents an early attempt at understanding the syntactic consequences of telicity with respect to the use of the internal argument. Her Aspectual-Interface Hypothesis, which claims that thematic structure and syntactic argument structure are governed by aspectual properties, links the syntactic position of an argument to the argument's event role. She further proposed that internal arguments in some sense "measure out" or delimit an event, a notion that has continued to resonate in the semantics of aspect. Further research uncovered syntactic phenomena that were tightly related to aspectual interpretations. Dowty (1991), for instance, noted a systematic relationship between unergative/unaccusative diagnostics and telicity; agentive and atelic sentences are always unergative, while those that are non-agentive and telic are always unaccusative. Since unergatives and unaccusatives are diagnosed in part based on the presence of an internal argument, these studies further linked the role of the internal argument to telicity. This work has led researchers to explore the consequences of telicity in terms of core syntactic features.

Expanding the functional lexicon to include aspectual heads responsible for licensing aspectual interpretations has produced several interesting theories of aspect in recent years. These functional heads have been important in understanding the relationship between the internal argument and aspectual interpretation by formalizing the tight link between argument realization and telicity. Borer (1994, 1998, 2005) and Ramchand (1997, 2008) exemplify theories that introduced the idea of aspectual phrases (AspP) in the functional syntax. These proposals link verbal arguments to their event participant roles by appearing in these aspectual projections at LF, the syntactic representation which receives semantic interpretation. The syntactic mechanisms used to project arguments into these aspectual phrases were often driven by syntax-internal factors such as case assignment, suggesting that aspectual interpretations are triggered by the syntax for reasons unrelated to aspectual interpretation itself. Schmitt (1996), van. Hout (1998, 2000), and Ritter and Rosen (1998, 2000) made this notion explicit by claiming Agr_OP, a phrase initially conceived as the locus of structural case assignment to the internal argument, as the domain for the interpretation of telicity. In these theories, the internal argument is required to move to the specifier of an AspP (Agr_OP) dominating the VP. In doing so, it creates the right syntactic configuration for a telic predicate at LF.

Research focused on the syntax of aspect has led to a number of interesting conclusions. Syntactic theories of telicity all argue that the structure of telic predicates is more complex than the structure of atelic predicates. Depending on the particular implementation, the aspectual phrase of atelic predicates remains unfilled by a delimiting argument or may not be projected in the syntax at all. On the other hand, every syntactic theory of telicity requires the aspectual phrase of a telic predicate to be present and licensed either by a verb's event semantics or by a delimitating argument, typically a count noun phrase. This suggests that telic predicates are overall more complex syntactic objects than atelic predicates.

In addition, the syntax of aspect gives us a compositional way to derive the calculus of events. Making a few simplifying assumptions along the guidelines established by research in the syntax of aspect, the derivation of AspP can derive the calculus of events in Table 1 in two stages. Once the verb and its direct object have formed the VP, Asp is grammatically licensed and its derivation is triggered. In the first stage, Asp merges with the VP and the verb is allowed to assign an event semantics to Asp if the verb has one to assign (in the calculus of events above, only terminative verbs in (Table 1: 3-4) have event semantics; Fig. 2A). In the second stage, the direct object NP moves to Asp for case assignment. If the verb has not already assigned Asp an event semantics, the NP assigns an event semantics to Asp depending on whether the NP has a determiner or not (Fig. 2B). NPs with determiners assign

terminative event semantics whereas NPs without determiners assign durative event semantics. This derivation of telicity demonstrates how both the verb and internal argument contribute compositionally to the telicity of a sentence.

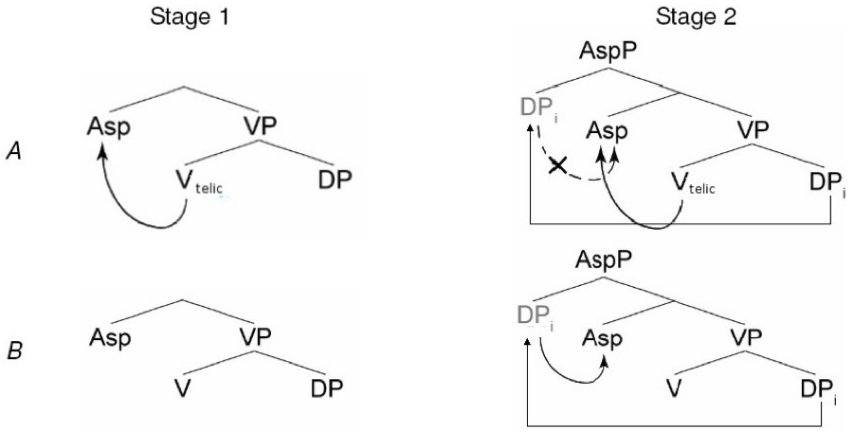

Figure 2: Syntactic structures demonstrating the derivation of the calculus of events.

2 Online event interpretations

The representations discussed above involve several factors important for aspectual interpretation which have implications for the processing of aspect. We identify three critical questions:

1. What is the domain over which the parser interprets aspect?
2. What factors guide the parser in aspectual interpretation online?
3. Does the parser immediately commit to an aspectual interpretation?

Different researchers have adopted different positions on these questions. Many researchers take the verb to be the initial domain for aspectual processing even though linguistic theory argues that the whole VP is required. A highly incremental parser may in fact use verbal information immediately in guiding interpretative commitments. Indeed, the assumption implicit in much of the research on semantic

processing assumes that all interpretation is done immediately and completely as each word is processed Marslen-Wilson and Tyler (1980). However, recent research suggests interpretation may be more complicated. Frazier (1999) argues for a principle of immediate partial interpretation, which contrasts with the commonly-held assumption that all interpretation is immediate and complete.

(10) **Immediate partial interpretation** (Frazier, 1999)
Perceivers must choose between grammatically incompatible meanings of a word or constituent immediately, by the end of the word or constituent, unless this conflicts with the dictates of the grammar.

Applying this principle requires a clear understanding of what kinds of meanings are grammatically incompatible and what kinds of underspecification the grammar permits. We assume that different model-theoretic events count as distinct and incompatible interpretations. Homogeneous event models are distinct from non-homogeneous event models and give rise to incompatible aspectual interpretations (§1.1.1). As such, the parser is not allowed to underspecify telicity after completion of the VP as telic and atelic event models, and likewise their resulting aspectual interpretations, are incompatible.

We also assume, following Dickey (2001), that distinct LFs cannot be underspecified. The LF of a telic predicate contains a licensed AspP while the LF of an atelic predicate lacks an AspP (1.1.2). Since the grammar requires a complete VP to trigger the derivation of AspP, this proposal further argues for the parser to immediately commit to an aspectual interpretation upon completion of the VP constituent, but not before as this would violate the dictates of the grammar.

Given the above assumptions, immediate partial interpretation provides us with explicit predictions concerning the processing of aspect. First, since aspect is a VP phenomenon, processing related to telicity is predicted to occur upon completion of the VP constituent since earlier commitment to an aspectual interpretation would be in violation of the grammar of aspect. Even in the face of a verb with unambiguous event semantics, the parser should delay commitment to an aspectual interpretation until it has processed the full VP. Second, the parser should commit to an aspectual interpretation when an event requires a homogeneous or non-homogeneous model for its interpretation. The point at which this decision is anchored is also the VP constituent.

Previous experimental research has taken strides to answer our three questions concerning the domain, factors, and time course of the processing of aspect. Below we review some of the important findings which have contributed to our current understanding of aspectual processing.

2.1 Costs associated with accessing lexical semantics

Some recent work has focused on the contribution of lexical properties of the verb to aspectual interpretation. Gennari and Poeppel (2003) examined stative verbs, such as *know*, and eventive verbs, such as *build*, in both self-paced reading and lexical decision experiments. Based on linguistic theories of the lexical semantic representation of verbs, eventive verbs are considered to be more complex than stative verbs (Dowty, 1979; Parsons, 1990; Rappaport Hovav and Levin, 1998; Vendler, 1957), and thus should result in longer processing times due to the recovery of their extra structure. In both lexical decision and self-paced reading studies, Gennari and Poeppel (2003) found that eventive verbs incurred longer processing times compared to stative verbs, suggesting that event information is retrieved from the lexicon online and affects verb processing.

Focusing on events only, McKoon and Macfarland (2002) examined the processing of externally caused events, such as *break*, compared to internally caused events, such as *bloom*. Externally caused events are predicted to incur a processing cost compared to internally caused events due to the number of event participants: two in externally caused events, one in internally caused events. Using comprehension and production measures, McKoon and Macfarland (2002) found that the more complex externally caused events took longer to process than the less complex internally caused events independent of transitivity. This provides further evidence that event structure plays an active role in verbal processing.

These studies together suggest that the event semantics of the verb carries immediate consequences for processing. What remains to be shown is whether the processing cost associated with verb event semantics is due to retrieval of semantic information from the lexicon, as assumed by Gennari and Poeppel (2003) and McKoon and Macfarland (2002), or if the parser is also committing to an aspectual interpretation, contrary to our assumptions concerning the VP domain of aspectual interpretation.

2.2 Using adverbial modification

Considerable research has been devoted to investigating the processing mechanisms associated with combining temporal modifiers (*for years*, *until dawn*) and verb phrases with different aspectual interpretations. Piñango et al. (1999, 2006); Todorova et al. (2000); Brennan and Pylkkänen (2008) all find costs associated with reading sentences such as (11a), in which a durative modifier (*for months*) is combined with a terminative event, as compared to the same terminative event modified by a modifier

with neutral aspect (*last month*) (11b).

(11) a. Harold sent a letter to his daughter for months. [coercion]
b. Harold sent a letter to his daughter last month. [control]

Resolving the mismatch between the durative requirements of the adverbial and the terminative event supplied by the verb phrase requires that the event be either iterated into a multiple event interpretation, such that Harold sent many letters to his daughter over the span of several months, or somehow stretched beyond its usual temporal extent, such that a single event of sending a letter can be construed as taking several months to complete. Whichever solution is arrived at, successful interpretation of sentences like (11a) requires extra work above and beyond the normal processing required to understand sentences like (11b). This extra work is often called coercion (Pustejovsky, 1995; Jackendoff, 1990, 1997).

Piñango et al. (1999) investigated aspectual coercion using cross-modal lexical decision. Participants heard sentences containing verbs like *jump* or *sneeze*, which denote highly punctual events and adverbial modifiers like *until* that denote extended spans of time. At the offset of the adverbial, a letter string appeared on the screen, and participants made a lexical decision to this letter string. Piñango et al. found that lexical decisions were significantly slower in the coercion sentences (12a) than in the control (12b).

(12) a. The insect hopped effortlessly until ^ it reached. . . [coercion]
b. The insect glided effortlessly until ^ it reached. . . [control]

Brennan and Pylkkänen (2008) reversed the order of the key elements in the Piñango et al. (1999) study such that the temporal adverbial preceded the verb, in order to more tightly assess the time course in which aspectual interpretations are constructed. They found immediate processing costs associated with sentences like (13a) relative to (13b).

(13) a. Throughout the day the student sneezed in the . . . [coercion]
b. After twenty minutes the student sneezed in the . . . [control]

Using a self-paced reading task, they found that verbs were read more slowly in aspectual coercion sentences compared to controls, again confirming the processing cost associated with aspectual coercion. They also collected MEG responses to reading these types of sentences to probe for neural correlates of online aspectual interpretation. The verbs in the aspectual coercion condition evoked greater activity than the same verbs in the control condition at two neural components. The first

component onset at 350ms after the presentation of the verb in frontal and temporal regions, and the second component onset 450ms after the presentation of the verb in anterior midline frontal regions. The 350ms response, called the M350, is a response component associated with the activation of stored lexical semantic representations (Pylkkänen and Marantz, 2003; Stockall and Marantz, 2006; Harris et al., 2008). The anterior midline frontal response, or AMF, is a response associated with complement coercion (Pylkkänen and McElree, 2007).

Like aspectual coercion which results from a mismatch between the aspectual requirements of an adverbial modifier and those of the VP, complement coercion is also required to resolve mismatches in sentences like (14a) as compared to (14b).

(14) a. John began the book.
b. John began to read the book.

Verbs like *begin*, *start*, *try*, etc typically take clausal complements that denote events, as in (13b). When these verbs are combined with simple nominal direct objects, Pustejovsky (1995) argues that comprehenders must coerce the nominal (*the book*) into some kind of event to resolve the mismatch between the verb's eventive selectional requirements and the direct object's non-eventive properties. A number of studies report reading time and related measures showing that, like aspectual coercion, complement coercion is behaviorally costly (McElree et al., 2001, 2006b,a; Pickering et al., 2005; Traxler et al., 2002, 2005; Pylkkänen and McElree, 2007).

Both the Brennan and Pylkkänen (2008) and the Piñango et al. (1999) results make it clear that the terminativity property of verbs is accessed very rapidly in processing. Todorova et al. (2000) expand on these findings by investigating sentences where the coercion is accomplished within the verb phrase. When a verb is combined with an internal argument with mass semantics, such as *letters*, the resulting event is one with no necessary or specific end point. *John sent a letter* denotes a single, terminative, event of letter sending, but *John sent letters* denotes an unbounded event in which John sends some unknown number of letters over the space of some unspecified span of time. Thus when a phrase like *John sent letters* is combined with a durative adverbial, no further coercion should be necessary if aspectual interpretation and mismatch resolution are accomplished rapidly.

Todorova et al. compare processing costs associated with modifying these kinds of **T**erminative and **U**nbounded verb phrases by temporal adverbials that either require a **D**urative event, or are **N**eutral with respect to event duration, as in (15).

(15) a. Even though/ Howard sent/ a large check/ to his daughter/ for many years/ she refused to accept his money. [**TD**]

b. Even though/ Howard sent/ large checks/ to his daughter/ for many years/ she refused to accept his money. **[UD]**
c. Even though/ Howard sent/ a large check/ to his daughter/ last year/ she refused to accept his money. **[TN]**
d. Even though/ Howard sent/ large checks/ to his daughter/ last year/ she refused to accept his money. **[UN]**

Using a self-paced stop-making-sense reading paradigm in which participants evaluated the sensicality of the sentences they were reading, region by region, Todorova et al. found significantly greater reading times and greater sensicality rejections for the adverbial region in the mismatch condition (15a) as compared to the other conditions.

Overall, research using adverbial modifiers to probe aspectual interpretations during sentence processing has shown that the parser commits to a terminative or durative interpretation of a VP rapidly online. Processing costs increase when the telicity of the VP mismatches the aspectual requirements of an adverbial modifier.

2.3 Apparent Counterexamples

2.3.1 Proctor et al. (2004)

Proctor, Dickey, and Rips (2004) manipulated several factors known to affect telicity, including verb semantics (**T**elic or **A**telic), the noun semantics of the internal argument (**M**ass or **C**ount), and the aspectual requirements of adverbial modification (*for eight minutes* (atelic) / *in eight mintues* (telic)). They also probed subjects' aspectual interpretations offline with a post-sentential comprehension question which asked whether the specified action had been completed halfway through the time given by the adverbial modifier. Below is a subset of their items demonstrating the first two manipulations.

(16) a. Leslie consumed/ Polar Purity's/ ice water/ with zeal/ ... **[AM]**
b. Leslie consumed/ Polar Purity's/ ice cube/ with zeal/ ... **[AC]**
c. Leslie monitored/ Polar Purity's/ ice water/ with zeal/ ... **[TM]**
d. Leslie monitored/ Polar Purity's/ ice cube/ with zeal/ ... **[TC]**

Each of these sentences was continued with the adverbial modifier region. Proctor et al. found an online effect of aspectual interpretation on the adverbial modifier region; processing slowed when the adverbial modifier conflicted with the telicity of the VP. In addition, they found an offline effect of telicity in comprehension responses. A

sentence with an atelic verb, mass noun, and atelic modifier were more likely to be interpreted as atelic (responding 'yes' to a question about the sub-interval of the event) than a telic verb, count noun, and telic adverbial modifier. Taken together, Proctor et al argue that the parser commits to an aspectual interpretation online, but somewhat more slowly than might be expected given assumptions concerning incrementality.

While these results are interesting in that they provide further support for the online interpretation of telicity and its offline consequences in comprehension, some caution must be taken concerning the items used. The reported example item makes use of a possessive noun phrase before the internal argument. Possessive NPs act as determiners and trigger a telic interpretation as shown in (17).

(17) a. Leslie drank ice water #in eight minutes.
b. Leslie drank the ice water in eight minutes.
c. Leslie drank John's ice water in eight minutes.

As a result, (16a) above does not in fact involve an internal argument with mass semantics, and thus is not predicted to contrast with (16b).

Also, the distinction between mass and count nouns may not trigger atelic and telic interpretations respectively. Instead, the syntactic properties of count and mass interpretations, driven by the presence or absence of a determiner seem to be necessary to trigger telicity. Note that singular count nouns require a determiner (17a) and trigger a telic interpretation (17b) while plural count nouns without a determiner still trigger an atelic interpretation (17c).

(18) a. *Leslie ate ice cube in eight minutes.
b. Leslie ate an ice cube in eight minutes.
c. Leslie ate ice cubes #in eight minutes.

The late effects of telicity found by Proctor, Dickey, and Rips may have resulted from these factors.

2.3.2 Pickering et al. (2006)

Pickering, McElree, Frisson, Chen, and Traxler (2006) used self-paced reading and eye-movement measures to investigate the time course of aspectual interpretations. They based their experiments on the materials and manipulations of Piñango et al. (1999) and Todorova et al. (2000).

Pickering et al.'s first two experiments used the same materials as Piñango et

al (1999) with one additional manipulation: the relative order of the verb and the durative adverbial were permuted (fronted (+F) or unfronted (-F) adverbial), along with the **T**erminative/**U**nbounded manipulation, resulting in materials as in (18)

(19) a. The insect glided effortlessly until it reached the far end of the garden. It was in a hurry to return to its nest. **[-FU]**
b. The insect hopped effortlessly until it reached the far end of the garden. It was in a hurry to return to its nest. **[-FT]**
c. Until it reached the far end of the garden, the insect glided effortlessly under the moonlight. It was in a hurry to return to its nest. **[+FU]**
d. Until it reached the far end of the garden, the insect hopped effortlessly under the moonlight. It was in a hurry to return to its nest. **[+FT]**

Using both self-paced reading and eye-movement measures, Pickering et al. failed to find any effect of aspectual mismatch between the bounded verb and durative adverbial.

Given that Pickering et al. themselves suggest that Piñango et al.'s (1999) stimuli may not have been sufficiently sensitive to reliably demonstrate effects (p.14), and that Brennan and Pylkkänen (2008) successfully find significant costs for durative adverb + punctual verb sentences in both self-paced reading times and evoked neuromagnetic activation, it is likely that Piñango et al. (1999)'s stimuli in fact are not well controlled enough to reliably test online event interpretation construction in relatively natural language comprehension tasks.

Of considerably more interest are Pickering et al.'s (2006) experiments, which partially replicate Todorova et al. (2000). Instead of using durative modifiers as Piñango et al. (1999), Piñango et al. (2006), Todorova et al. (2000), and Brennan and Pylkkänen (2008) did, Pickering et al. (2006) compared **F**requency adverbials (*every week*), with **N**eutral adverbials as modifiers of verb phrases involving **S**ingular or **P**lural direct objects as in (19).

(20) a. Howard sent/ a large check/ to his daughter/ every year/ but as/ usual, she refused/ to accept his money. **[SF]**
b. Howard sent/ large checks/ to his daughter/ every year/ but as/ usual, she refused/ to accept his money. **[PF]**
c. Howard sent/ a large check/ to his daughter/ last year/ but as/ usual, she refused/ to accept his money. **[SN]**
d. Howard sent/ large checks/ to his daughter/ last year/ but as/ usual, she refused/ to accept his money. **[PN]**

Pickering and colleagues were motivated by a concern raised by Todorova et al. (2000) that durative adverbials might trigger different kinds of event extensions when combined with terminative predicates. In most cases, the most natural way to resolve the mismatch would be to interpret the terminative event as occurring iteratively, throughout the time span specified by the durative adverbial (*John sent a letter for years = John sent letter after letter for years*). However, it is also possible to resolve the mismatch by stretching the duration of a single event beyond its natural time span (*John sent a letter for years = It took years for John to send a letter*). These different solutions to the mismatch, which could vary from sentence to sentence and participant to participant, could plausibly introduce a source of noise into the data that Pickering et al. sought to avoid.

The resulting interpretation in (19a) is very similar to that in (15a): the sentence refers to multiple events of letter sending, distributed over years. However, Pickering et al. failed to find any significant costs associated with this interpretation as compared to a control condition with a modifier such as *last year* (19c), or a durative VP such as *send checks* (19d).

Pickering et al. conclude that the failure to find processing costs suggests that aspectual interpretations are not computed incrementally, but may be underspecified. This result conflicts with the previous and subsequent findings of highly incremental aspectual interpretation. However, we argue that the lack of a cost for (19a) is expected given the semantics of universal event quantification (Rothstein, 1995).

2.3.3 Universal Event Quantification

Rothstein (1995) considers sentences such as (20) in which a universally quantified temporal adverbial imposes a matching relationship on two events.

(21) I met a friend every time I went to the bakery.

Following Boolos (1981), she notes that sentences of this type have the general structure in (21), and that sentences with this structure are truth-conditionally equivalent to "There are at least as many Bs as As". Every event of going to the bakery is claimed to be matched with an event of meeting a friend.

(22) For every A, there is a B.

Rothstein argues that not only do such sentences impose a matching requirement, such that every A event has a corresponding B event, but she also argues that each B event must be a distinct B event, and that this distinctness requirement is

determined by the grammar, and not by pragmatics. She points to the contrast between the adverbial use of *every time* in (22a) and the nominal use of *every time* in (22b).

(23) a. I regretted it every time I had dinner with John.
b. I regret every time I had dinner with John.

The sentence in (22a) requires that there be a unique regretting event for each having dinner with John event, while (22b) makes no such requirement. If pragmatic inference were responsible for the uniqueness interpretation in (22a) it is hard to see why the same inference would not be generated for (22b). Furthermore, this requirement is not cancellable, as would be expected if it were the result of pragmatic inference, as illustrated in (23).

(24) a. Every girl (and there were many of them) saw a movie last night. In fact they all saw Aladdin.
b. #Every time the bell rang last night (and it rang many times) Mary opened the door. In fact Mary only opened the door once.

Rothstein notes that (23b) is incoherent, since it asserts the existence of many bell ringings, and at least as many door openings as bell ringings, yet also asserts only a single bell ringing. To account for these facts, Rothstein proposes the function M which is a function from the set of events e′ onto the set of events e, such that every e′ maps to a distinct e.

Thus the iterated event interpretation that results in sentences with universally quantified temporal modifiers is argued by Rothstein to be the result of straightforward semantic composition, and not the result of any additional pragmatic inferences.

While the combination of a durative modifier and a bounded event is truly a mismatch that must be resolved by coercing the bounded event into an iterated event, no such coercion is required in (19a). The combinatorial semantics of (19a) require that every month contain at least one letter-writing event, however this interpretation is the straightforward result of semantic composition, not the result of resolving a mismatch between the aspect of the VP and the aspectual requirements of the adverbial. Thus there is no reason to expect (19a) to evoke any coercion effects in Pickering et al.'s experiments.

2.4 Aspect and Transitivity

Coming from a different perspective but still focused on the inherent terminativity of particular verbs, O'Bryan (2003) examined the correlation between terminativity and verb transitivity. Drawing on insights relating terminativity and unaccusative-unergative diagnostics (Dowty, 1991), she noted that inherently terminative verbs are obligatorily transitive (requiring an internal argument), while unspecified verbs are optionally transitive.

(25) **Internal argument dependent events, optionally transitive verbs**

a. Yesterday, John studied the book. [terminative]
b. Yesterday, John studied books. [durative]
c. Yesterday, John studied. [durative]

(26) **Inherently bounded events, obligatorily transitive verbs**

a. Yesterday, John described the book. [terminative]
b. Yesterday, John described books. [terminative]
c. *Yesterday, John described. [n/a]

O'Bryan argued that rapid access to the aspectual interpretation of inherently terminative verbs would ease garden-path recovery from misanalysis of reduced relative clause structures. Since obligatorily transitive verbs must take internal arguments, the appearance of the by-clause without an overt direct object would more quickly signal a parsing error.

(27) a. The letter sent by the teacher fell. . . [obligatorily transitive]
b. The letter studied by the teacher fell. . . [optionally transitive]

She found that inherently bounded verbs (27a) were disambiguated more rapidly than unspecified verbs (27b), providing confirmation that the event semantics of the verb are accessed very quickly by the parser.

This issue was also addressed by Frazier et al. (2006) at the level of grammatical aspect (the difference between perfective and imperfective aspectual interpretations). They examined the effect of grammatical aspect on temporary direct object/subject ambiguities in which the parser may initially take the post-verbal NP to be the direct object of the subordinate clause, by manipulating the grammatical aspect of the subordinate clause between either the simple past tense (28a) or the progressive (28b).

(28) a. As John hunted the frightened deer escaped through the woods.

b. As John was hunting the frightened deer escaped through the woods.

Since the simple past tense conveys an event-external viewpoint, the event itself is typically taken to have an endpoint; that is, be telic. Frazier et al note that a (count) direct object can provide such an end point and therefore the parser has to abandon a parse with expected semantic properties (telic) for one that is less expected (atelic) in these temporarily ambiguous sentences. However, a subordinate clause in the progressive conveys an event-internal viewpoint which allows it to be neutral with respect to the presence or absence of an end point, and thus be neutral to the expected properties of the direct object.

In both cases, the parser is garden-pathed; it interprets the post-verbal NP as the direct object of the verb. Given that all post-verbal NPs were count in Frazier et al's experiment, a semantic commitment to a telic interpretation was licensed, providing an end point to the event and, in addition, fulfilling the expectation established by the simple past tense. Although subjects were garden-pathed by both types of sentences, the processing costs associated with recovery from a subordinate clause in the past tense (28a) were more severe than those in the progressive (28b). This suggests that diagnosis and recovery of a garden-path effect can be aided or hampered by the kinds of semantic commitments the parser makes in the course of sentence processing and that semantic commitments to telicity are made rapidly by the parser upon completion of the VP.

Cases of garden-path recovery, like earlier studied discussed above, support the VP domain of aspectual interpretation. The processing consequences of aspectual interpretation have been shown to result from the processing of the VP constituent. However, all of these studies have relied on indirect processing consequences of aspectual interpretation. The next set of studies explore the initial processing of the VP itself to further test the hypothesis that the VP, not the V is the domain of aspectual interpretation.

3 Direct measurements of VP composition

Husband et al. (submitted) report two experiments designed to investigate the time course in which aspectual interpretations are initially constructed and the relative costs of terminative vs. durative interpretations.

3.1 Self-paced reading experiment

Husband et al (submitted) investigate verbs such as *watch*, *run*, *host*, *drink*, *build*, etc., that are lexically unspecified for telicity. When they are combined with direct objects with count semantics, the resulting event has a specific end-point (29b and 29d), but when they are combined with mass direct objects, the resulting event is unbounded, with no necessary end-point (29a and 29c).

(29) a. John drank beer #in ten minutes.
b. John drank the beer in ten minutes.
c. John built planes #in eight hours.
d. John built the plane in eight hours.

Husband et al (submitted) conducted a self-paced reading study specifically investigating the individual contributions of the verb and the direct object to aspectual interpretations. They constructed materials which paralleled the calculus of events in Table 1. Sentences varied in verb class (**T**erminative or **U**nspecified) and NP determiner (**D**efinite [count] or **N**ull [non-count]) as in (30).

(30) a. TD=TELIC: The expert physicist lost the files on the formation of black holes.
b. TN=TELIC: The expert physicist lost files on the formation of black holes.
c. UD=TELIC: The expert physicist read the files on the formation of black holes.
d. UN=ATELIC: The expert physicist read files on the formation of black holes.

Verbs were classified into bounded or unspecified using Dowty (1979)'s tests and rated for acceptability with *in X time* modification. Verbs which were judged acceptable with end point modification were classified as terminative, while verbs which were judged acceptable with *in X time* modification when they took count direct objects, but unacceptable with non-count objects were classified as unspecified. Participants performed a self-paced word-by-word moving window reading task. After each sentence, participants were asked to rate the acceptability of sentences on a 1 to 5 scale (5=good).

Husband et al (submitted) found a main effect of NP determiner on the noun position and the noun+1 position, and an interaction between verb class and NP determiner at the noun+1 position. Planned comparisons between means on the noun+1 position revealed significant differences between unspecified definite and unspecified null conditions (30c vs. 30d) and terminative null and unspecified null

conditions (30b vs. 30d). Word by word reading times are shown in Figure 3.

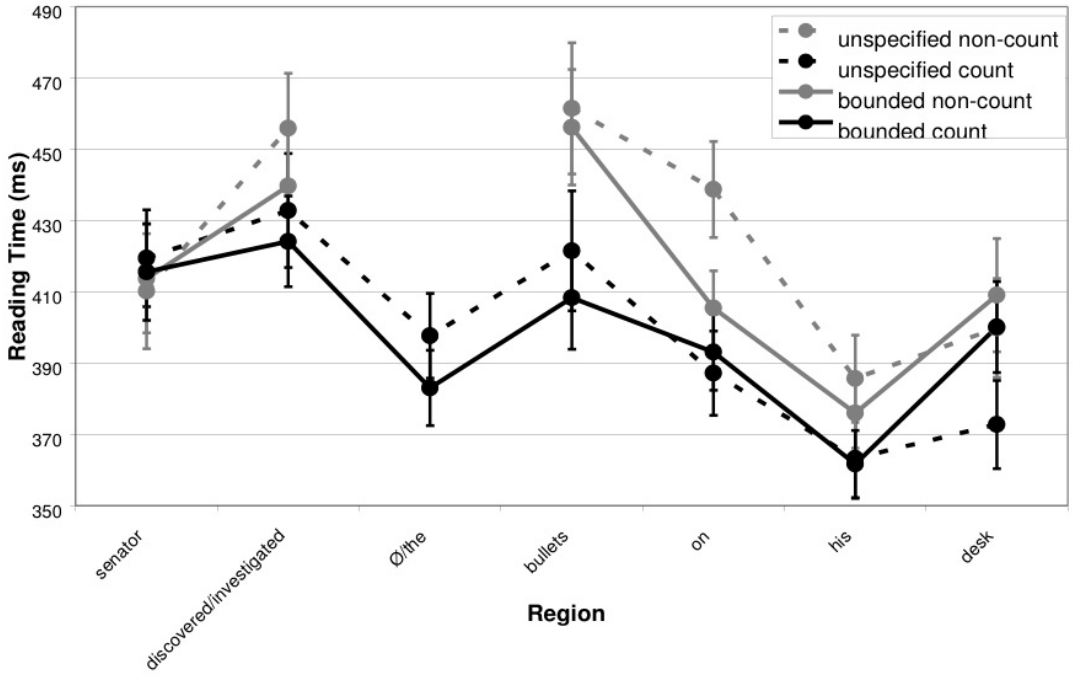

Figure 3: Reading times from Husband et al. (submitted)

The initial main effect of determiner type on noun reading time is not surprising. The overt definite determiner plausibly provides a highly reliable cue that the upcoming word is likely to be a noun, while no such cues are available for nouns without a determiner. Crucially, this initial main effect is very short lived. By the time the next word is encountered, the terminative null sentences no longer evoked different responses from the terminative definite and unspecified definite sentences, while the slowdown for the unspecified null sentence persists. This is of interest to aspectual interpretation since the unspecified null condition is the only condition which triggers an atelic interpretation; all other conditions trigger a telic interpretation.

This sustained slowdown in the durative event sentences relative to terminative event sentence suggests that properties of both the direct object and the verb are used immediately in aspectual interpretation. Unspecified verbs combined with non-count objects (*build planes*) are associated with significant reading time slow downs as compared to the same verb with a count object (*build the planes*), or the same non-count object with a terminative verb (*crash planes*). To our knowledge, this is the first evidence of a processing correlate directly associated with aspectual composition specifically and compositional semantics more generally that does not rely on coercion due to a mismatch effect (Brennan and Pylkkänen, 2008; Piñango et al., 1999; Todorova et al., 2000) or a 'noncompositional' structure (McElree et al., 2001, 2006; Pylkkänen and McElree, 2007).

Interestingly, no significant main effects of verb class were revealed during online sentence processing. This could be evidence that telicity is only computed for full VPs, or that self-paced reading is not sensitive enough to verbal semantics. This second possibility was tested in a lexical decision experiment.

3.2 Lexical decision experiment

Husband et al (submitted) used the infinitival versions of the same verbs from their self-paced reading experiment in a single word lexical decision experiment designed to see whether verbs lexically specified for terminative aspect would evoke different processing responses from verbs underspecified for aspect when they were processed in isolation with no sentential context.

Although a lexical decision paradigm was successful in uncovering different processing responses to stative vs. eventive verbs (Gennari & Poeppel, 2003), and has been argued to be more sensitive to effects of verbal semantics (Balota (1994), Husband et al (submitted) found no differences in either error rate or response time between terminative and underspecified verbs. This result suggests that initial lexical processing of terminative verbs and unspecified verbs does not differ, consistent

with the findings in the verb region from the self-paced reading experiment.

The results of these two experiments show that durative events take longer to process than terminative events. The direction of this effect is predicted by the model-theoretic approaches to aspect outlined in (§1.1.1). Durative events are argued to be representationally more complex than terminative events. The observed processing cost in the self-paced reading experiment is thus support for this kind of analysis of event semantics. This effect does not seem to be the direct result of lexical semantic differences between verbs, but instead arises from the composition of the event information supplied by the verb with the event information supplied by the internal argument.

These results also point to differences between terminative and unspecified verb classes. While there were no significant differences between terminative and unspecified verbs in lexical decision, we do see clear differences between them in the interaction of verbal semantics with internal argument semantics in sentence reading. Given both these effects, the lack of any effect in lexical decision is somewhat surprising. One possibility is that infinitival verbs do not project a VP when processed in isolation and aspectual differences require that full VP. Another possibility is that lexical decision is only sensitive to the semantic properties of aspect and not sensitive to the syntactic properties of aspect present in verbs. These two options were tested in two further experiments.

3.3 Evidence for Syntactic Complexity?

The above experiments demonstrate effects of semantic complexity due to aspectual interpretation of the VP. Self-paced reading shows semantic complexity effects upon completion of the VP but neither lexical decision measures nor self-paced reading show effects of complexity for verbs themselves. Also, no evidence has been found for the syntactic complexity predicted by the syntax of aspect. In no case have terminative verbs been shown to be more difficult to process compared to verbs with no event semantic properties.

Two further experiments tested the syntactic event properties of terminative and unspecified verbs. First, a lexical decision task was constructed to test for effects of the syntactic presence of AspP. According to syntactic theories of aspect, AspP is projected between the verb and the functional projection for tense, TP. To parse a tense morpheme, the parser projects a TP, but, in doing so, the parser may be required to also project AspP following the hierarchy of functional projections (Borer, 2005). If the presence of tense on verbs requires the projection of AspP as well as TP, we may expect to see processing costs associated with its projection when

processing terminative verbs which assign their event properties to AspP, compared to unspecified verbs which have no event properties to assign to AspP and may not project AspP at all.

Forty subjects were run in a lexical decision task which manipulated both verb class (terminative vs. unspecified) and tense (past vs. infinitive tense) using the same procedure and verbs as in Husband et al. (submitted). While no statistically significant differences were found, the difference in processing costs associated with adding tense to a terminative verb was 14.7ms more than that of adding tense to an unspecified verb (terminative: 38.0ms; unspecified: 23.7ms). Though non-significant, this effect trends in the expected direction, suggesting that a more sensitive measure may find significant differences between our verb classes.

A second study further tested for the syntactic complexity of aspect using MEG in a sentence reading paradigm. While lexical decision and other behavioural studies have failed to find significant differences between our verb classes, MEG may be more sensitive to the early effects of syntactic projection of AspP.

Twelve subjects were run in a word-by-word sentence comprehension study using the sentences from Husband et al. (submitted). Sentences were presented using rapid serial visual presentation. Analyses were time locked to the onset of the verb. An analysis of the average sensor activity was done over four quadrants using several time windows which encompassed known MEG components in visual word recognition studies, including one from 270-400ms, the time window associated with the M350 response (Pylkkänen & Marantz, 2003). Analysis of the 270-400ms time window revealed an effect of verb class in the left anterior quadrant: terminative verbs elicited greater activity compared to unspecified verbs. This effect was marginally significant (terminative: 3.63 picoTeslas (PT); unspecified: 1.42pT; $t(11) = 1.782$, $p = .102$). Figure 4 shows representative data from a single subject in which the peak latency of the M350 is delayed by 38ms for terminative verbs compared to unspecified verbs (terminative: 300ms, Fig. 4A; unspecified: 242ms, Fig. 4B).

Overall then, these two experiments provide preliminary evidence for early effects of syntactic complexity due to the syntactic properties of aspect. Though subtle, these effects demonstrate the interplay of syntax and semantics in the processing of aspect. The presence of a tensed verb requires the projection of several phrases due to the hierarchy of functional projections, including TP and AspP. These early effects on the verb appear to be due to terminative verbs assigning their event properties to AspP, a step prior to the parser's commitment to telicity which is delayed until the VP is parsed.

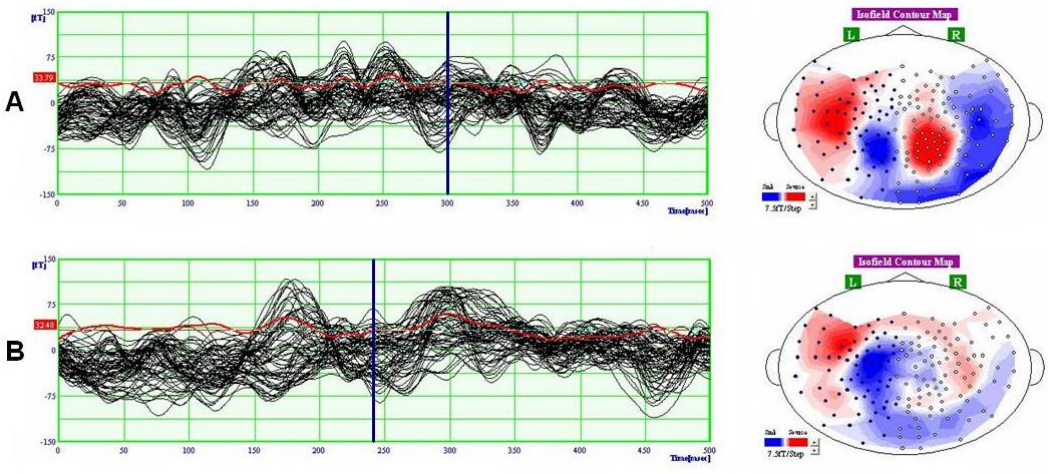

Figure 4: Representative MEG data from a single subject

4 Conclusions:

Half a century of research on the linguistics of event interpretations has established a general consensus concerning the syntactic and semantic representation of telicity. Aspectual interpretation involves a complex system with information distributed over several sentential constituents. To license telicity, these constituents compose together at the structural level of the VP. Interpretation of aspect then proceeds by denoting event models with different semantic properties. These syntactic and semantic representations have been used in this chapter to generate predictions concerning the processing of aspect, to which we now turn.

4.1 What is the domain over which the parser interprets aspect?

Concerning the processing domain of aspect, our results argue that the domain of aspectual interpretation is the VP constituent. Evidence from self-paced reading, aspectual coercion, and garden-path recovery all point to the role of the VP as the relevant domain for aspectual interpretation. Studies showing earlier effects of aspectual processing may be attributable to recovery of aspectual features which drive the syntactic parse but do not show commitment of the parser to an aspectual interpretation. This domain also has theoretical weight in linguistic theory, suggesting that the grammar places strong constraints on the decision points at which the parser makes a commitment to interpretation. This is not unlike other interpretative de-

cisions in which the grammar constrains the timing and range of possible decisions the parser must make (Frazier, 1999; Dickey, 2001).

4.2 What factors guide the parser in aspectual interpretation online?

Having surveyed the ingredients of aspectual interpretation and their use online, we affirm the importance of both a verb's event semantics and the count/mass syntax of the internal argument. Both elements play an important role in determining telicity and both are shown here to have consequences for online processing. Much of aspectual processing relies especially on the verb's event semantics, though as demonstrated in several studies, the properties of the internal argument are rapidly composed with those of the verb to yield aspectual interpretations.

4.3 Does the parser immediately commit to an aspectual interpretation?

In response to our final question about the time course of aspectual interpretation, experimental evidence points to a parser that makes commitments to aspectual interpretation immediately upon parsing the aspectual domain, i.e. the VP. Several studies have demonstrated immediate effects of aspectual interpretation in sentence processing, and evidence for delayed or underspecified aspectual interpretation are likely due to experimental confounds. We also note that the verb constituent alone appears to be unable to license an aspectual interpretation. A highly incremental parser which performs immediate full interpretation should commit to an aspectual interpretation upon encountering an unambiguous verb (Marslen-Wilson and Tyler, 1980). However, our evidence suggests that the parser delays commitment to aspectual interpretation until it has parsed the full VP in accord with the grammar, as per the principle of immediate partial interpretation (Frazier, 1999).

The results of these studies suggest a two stage model of aspectual processing. In the first stage, verbal and nominal properties license the construction of the VP and project AspP if needed due to either verbal event features or nominal properties. Verbal semantic features alone cannot trigger the projection of AspP, though the hierarchy of functional projections requires that in the presence of tense, a verb with event semantics must project AspP, though mapping to an event model awaits parsing of a full VP. In the second stage, the parser commits to an aspectual interpretation based on the syntactic structure arrived at through the first stage and constructs an event model with the right structure. If AspP was projected either for reasons of a verb's event semantics, or because of the presence of a count NP, a non-homogeneous model is constructed. If AspP was not projected because the verb had

no event semantics and its internal argument was not a count NP, a homogeneous model in constructed.

Taken together, this research provides detailed evidence concerning the processing of aspect specifically, and the processing of compositional structures more generally. These results also have important consequences for theories of sentence processing. They continue to argue for incremental commitment to aspectual interpretation, placing the commitment point for telicity at the VP, which is the first point when all the information needed to construct an aspectual interpretation has been provided to the system (i.e., both the verb and the internal argument).

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