The Computation of Telicity

E. Matthew Husband
Michigan State University
What’s in an Event?

run

run a race

cross the river

roam the course

splash

run a race

chase her competitors
- for an hour / in an hour

- Run: ok weird
- Chase her competitors: ok weird
- Roam the course: ok weird
- Run a race: incomp ok
- Cross the river: incomp ok

Atelic Telic
Big Picture Question

• What are the principles and representations used by the parser to arrive at meaning?

• Parser makes use of the grammar in making interpretative commitments.
Outline

• Linguistic ingredients of event meanings
• Processing issues
• Examine several studies
• Some conclusions
Outline

• Linguistic ingredients of event meanings

• Processing issues

• Examine several studies

• Some conclusions
A Focus on Telicity

• Inherently bounded and unbounded verbs
  • *Win* (the race), *Tagged* his teammate
  • *Chase* her competitors, *Roam* (the trail)

• Verbs which depend on their argument
  • *Run*
  • *Run* the race
  • *Run* races
Ingredients of Telicity

• Verbal Boundedness (Verb Type)
  • +Bounded: Win, Tag
  • –Bounded: Chase, Roam
  • Unspecified: Run

• Argument Countability (NP Type)
  • Count: a race, her teammate, the course
  • Non-count: races, water
## Calculus of Events

<table>
<thead>
<tr>
<th>Verb Type</th>
<th>NP Type</th>
<th>Telicity</th>
<th>VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>+Bounded</td>
<td>Count</td>
<td>Telic</td>
<td>Win the race</td>
</tr>
<tr>
<td>+Bounded</td>
<td>Non-count</td>
<td>Telic</td>
<td>Win races</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Count</td>
<td>Telic</td>
<td>Run the race</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Run races</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Count</td>
<td>Atelic</td>
<td>Roam the trail</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Roam trails</td>
</tr>
</tbody>
</table>
Semantics of Telicity

• Quantized vs. Homogeneous

• For Entities:
  • Non-count (mass) entities are homogeneous
    • water ⊕ water → water
    • a water ⊕ a water ⊕/→ a water

• For Events:
  • Atelic events are homogeneous
    • run races ⊕ run races → run races
    • run a race ⊕ run a race ⊕/→ run a race
Semantics of Telicity

• Cumulative
  • P is cumulative iff there is an x and y (x distinct from y) with property P such that the sum of x and y also have property P.
    • $\exists x, y \ [P(x) \land P(y) \land \neg x = y] \land \forall x, y \ [P(x) \land P(y) \rightarrow P(x \oplus y)]$

• Quantized
  • P is quantized iff for all x and y with property P, y is not a proper part of x.
    • $\forall x, y \ [P(x) \land P(y) \rightarrow \neg y <_P x]$
Semantics of Telicity

• Non-quantized representations are treated differently by cognition in general.
  • Representing “uncountable” numbers of objects
  • Tracking substances vs. objects
  • Processing standards for scalar adjectives

• Representation of atelic events arguably has the same processing difficulty.
Syntax of Telicity

• Dowty’s Correlation: Relationship between telicity and argument structure
  • Agentive and atelic, definitely unergative
  • Non-agentive and telic, definitely unaccusative

• Aspectual projection (AspP) which:
  • Licenses the internal argument
  • Licenses telic interpretation
  • Derivation of the calculus of events
Telic Structures

[Diagram showing the structure of telic sentences with nodes labeled AspP, Asp_{+bound}, VP, V, tag_{+bound}, DP_{i}, and DP ±bound.]
Telic Structures

Diagram:

```
AspP

\(\text{Asp}_{+\text{bound}}\)

VP

\(\text{run}\)

\(\text{DP}_i\)

\(\text{DP}_i\)
```

+bound
Structures for Atelicity?

• Atelic VPs are generally thought to be syntactically more simple.
  • Internal argument receives default case assignment, or
  • Raises to a functional projection that has no event properties.
Representational Complexity

- Semantic
  - Atelic  >  Telic

```
<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
</table>
```

Diagram:

![Diagram showing atelic and telic relationships](image)
Representational Complexity

- Syntactic
  - Atelic
  - Telic
Outline

• Linguistic ingredients of event meanings
• Processing issues
• Examine several studies
• Some conclusions
Parsing Telicity

• What is the domain over which the parser interprets telicity?

• What factors guide the parser in telicity interpretations online?

• Does the parser immediately commit to a telicity interpretation?
Immediate Full Interpretation

• “A reader tries to interpret each content word of a text as it is encountered, even at the expense of making guesses that sometimes turn out to be wrong… interpretations at all levels of processing are not deferred; they occur as soon as possible.”

Just & Carpenter (1980)
Immediate Partial Interpretation

• “Perceivers much 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.”

  Frazier (1999)
Immediate Partial Interpretation

• What are incompatible meanings?
  • Different model-theoretic interpretations count as distinct and incompatible meanings
• What kinds of underspecification does the grammar permit?
  • Distinct LFs cannot be underspecified. (Dicky 2001)
Predictions

• Immediate Full Interpretation
  • The parser will make a commitment to telicity immediately upon parsing any word or constituent with aspectual features.
    • In particular, Vs themselves should have event interpretations.

• Immediate Partial Interpretation
  • The parser will delay commitment to telicity until parsing the VP.
    • When the grammar must posit an AspP and an event interpretation.
Outline

- Linguistic ingredients of event meanings
- Processing issues
- Examine several studies
- Some conclusions
Parsing Verbs

• Evidence for lexical semantics of events online
  • Gennari & Poeppel (2003)
  • Events vs. states
• McKoon & MacFarland (2002)
  • Internally caused vs. externally caused
Events vs. States

(1) a. The retired musician built his second house from scratch. (event)
b. The retired musician loved his second child very much. (state)

Fig. 1. Verb reading times as a function of word position and verb class in Experiment 1. Error bars indicate standard error.
Aspectual Coercion

- John tagged his teammate…
  - after a minute. (one tagging)
  - for a minute. (iterative taggings)

- Coercion effects, driven by an aspectual mismatch, provide evidence to a commitment to telicity.
Aspectual Coercion of Modifiers

- Pinango et al. (1999, 2006)
  - $+_\text{Bounded}/-\text{bounded}$ verb followed by durative/neutral modifier
  - Cross-modal lexical decision task

<table>
<thead>
<tr>
<th>Verb Type</th>
<th>NP Type</th>
<th>Telicity</th>
<th>VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>$+_\text{Bounded}$</td>
<td>Count</td>
<td>Telic</td>
<td>Win the race</td>
</tr>
<tr>
<td>$+_\text{Bounded}$</td>
<td>Non-count</td>
<td>Telic</td>
<td>Win races</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Count</td>
<td>Telic</td>
<td>Run the race</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Run races</td>
</tr>
<tr>
<td>$-_\text{Bounded}$</td>
<td>Count</td>
<td>Atelic</td>
<td>Roam the trail</td>
</tr>
<tr>
<td>$-_\text{Bounded}$</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Roam trails</td>
</tr>
</tbody>
</table>
(5) a. The insect [glided effortlessly until \(^\) it reached the far end of the garden that was hidden in the shade]
b. The insect [hopped effortlessly until \(^\) it reached the far end of the garden that was hidden in the shade]

<table>
<thead>
<tr>
<th>Table I. Mean and Standard Deviation for Each Experimental Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Standard deviation</td>
</tr>
</tbody>
</table>
## Aspectual Coercion of Verbs

- Brennan & Pylkkanen (2008)
  - **Durative**/neutral modifier followed by +bounded verb
  - Self-paced reading & MEG

<table>
<thead>
<tr>
<th>Verb Type</th>
<th>NP Type</th>
<th>Telicity</th>
<th>VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>+Bounded</td>
<td>Count</td>
<td>Telic</td>
<td>Win the race</td>
</tr>
<tr>
<td>+Bounded</td>
<td>Non-count</td>
<td>Telic</td>
<td>Win races</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Count</td>
<td>Telic</td>
<td>Run the race</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Run races</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Count</td>
<td>Atelic</td>
<td>Roam the trail</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Roam trails</td>
</tr>
</tbody>
</table>
4. a. Coercion: Throughout the day the student sneezed in the back of the classroom.
b. Control: After twenty minutes the student sneezed in the back of the classroom.
• MEG also shows increased neural activity in response to Coercion compared to Control conditions.
Summary

• The aspectual information contained in (+bounded) verbs affects online processing.
  • Affects processing of a durative modifier downstream from a +bounded verb.
  • Affects processing of a +bounded verb downstream from a durative modifier.

• But what about the Argument Properties?
Parsing VPs

- Todorova et al. (2000)
  + Bounded/–bounded VP followed by durative/neutral modifier
  Self-paced stop making sense task

<table>
<thead>
<tr>
<th>Verb Type</th>
<th>NP Type</th>
<th>Telicity</th>
<th>VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>+Bounded</td>
<td>Count</td>
<td>Telic</td>
<td>Win the race</td>
</tr>
<tr>
<td>+Bounded</td>
<td>Non-count</td>
<td>Telic</td>
<td>Win races</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Count</td>
<td>Telic</td>
<td>Run the race</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Run races</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Count</td>
<td>Atelic</td>
<td>Roam the trail</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Roam trails</td>
</tr>
</tbody>
</table>
Although Howard sent a check to his daughter for years she … checks last year
Although Howard sent a check to his daughter for years she... checks last year
Summary

• Verbal boundedness is accessed online and affect sentential aspect.
  • Events take longer to process than states
    • Gennari & Poeppel (2003)
  • Verb event semantics affects interpretation of modifiers
    • Pinango et al. (1999, 2006)
    • Brennan & Pylkkanen (2008)
Summary

• Evidence that argument properties are also accessed online and affect sentential aspect.
  • Direct object can influence the interpretation of a temporal modifier
    • Todorova et al. (2000)
Counter examples

• Proctor, Dicky, & Rips (2004)
  • Marginal online effects of aspectual coercion

• Pickering et al. (2006)
  • No online effects of aspectual coercion
Proctor, Dicky, & Rips (2004)

<table>
<thead>
<tr>
<th>Segment 1</th>
<th>Segment 2</th>
<th>Segment 3</th>
<th>Segment 4</th>
<th>Segment 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Leslie consumed</td>
<td>Polar Purity’s</td>
<td>ice water</td>
<td>with zeal</td>
</tr>
<tr>
<td>b</td>
<td>Leslie consumed</td>
<td>Polar Purity’s</td>
<td>ice cube</td>
<td>with zeal</td>
</tr>
<tr>
<td>c</td>
<td>Leslie monitored</td>
<td>Polar Purity’s</td>
<td>ice water</td>
<td>with zeal</td>
</tr>
<tr>
<td>d</td>
<td>Leslie monitored</td>
<td>Polar Purity’s</td>
<td>ice cube</td>
<td>with zeal</td>
</tr>
<tr>
<td>e</td>
<td>Leslie consumed</td>
<td>Polar Purity’s</td>
<td>ice water</td>
<td>with zeal</td>
</tr>
<tr>
<td>f</td>
<td>Leslie consumed</td>
<td>Polar Purity’s</td>
<td>ice cube</td>
<td>with zeal</td>
</tr>
<tr>
<td>g</td>
<td>Leslie monitored</td>
<td>Polar Purity’s</td>
<td>ice water</td>
<td>with zeal</td>
</tr>
<tr>
<td>h</td>
<td>Leslie monitored</td>
<td>Polar Purity’s</td>
<td>ice cube</td>
<td>with zeal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adverb</th>
<th>Verb</th>
<th>Noun</th>
</tr>
</thead>
<tbody>
<tr>
<td>For</td>
<td>Telic</td>
<td>Mass</td>
</tr>
<tr>
<td>For</td>
<td>Telic</td>
<td>Count</td>
</tr>
<tr>
<td>For</td>
<td>Atelic</td>
<td>Mass</td>
</tr>
<tr>
<td>For</td>
<td>Atelic</td>
<td>Count</td>
</tr>
<tr>
<td>In</td>
<td>Telic</td>
<td>Mass</td>
</tr>
<tr>
<td>In</td>
<td>Telic</td>
<td>Count</td>
</tr>
<tr>
<td>In</td>
<td>Atelic</td>
<td>Mass</td>
</tr>
<tr>
<td>In</td>
<td>Atelic</td>
<td>Count</td>
</tr>
</tbody>
</table>
• Polar Purity’s ice water.

• Leslie drank ice water #in 8 minutes.
• Leslie drank the ice water in 8 minutes.
• Leslie drank John’s ice water in 8 minutes.
Pickering et al. (2006)

• Attempted to replicate Pinango et al. (1999) and Todorova et al. (2000)
• Self-paced reading and eye-tracking
• Found no effects of aspectual coercion
• Used frequentive modifiers (*every year*)

(5a) Howard sent / a large check / to his daughter / *every year* / but as / usual, she refused / to accept his money. Singular object–frequency adverb (SF).

(5b) Howard sent / large checks / to his daughter / *every year* / but as / usual, she refused / to accept his money. Plural object–frequency adverb (PF).
Quantification vs. Coercion

- I met a friend every time I went to the bakery. (For every A, there is a B.)
- $M$: function from $e'$ to $e$ such that every $e'$ maps to a distinct $e$. (Rothstein, 1995)
Summary

- Aspectual coercion provides evidence that telicity is calculated online.
  - Both verbal event semantics and argument properties can affect the interpretation of aspectual modifiers.

- Does telicity affect processing when there isn’t an aspectual modifier?
Aspect and Transitivity

• Reduced relatives
  • Reanalysis of NP as an internal argument
  • Non-agentive and telic, unaccusative

• The letter *sent* by the teacher
  [obligatorily transitive; +bounded]

• The letter *studied* by the teacher
  [optionally transitive; unspecified]
Rapid access to verbal boundedness eases garden-path recovery in reduced relatives with **+bounded** verbs. (O’Bryan, 2003)

<table>
<thead>
<tr>
<th>Verb Type</th>
<th>NP Type</th>
<th>Telicity</th>
<th>VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>+Bounded</td>
<td>Count</td>
<td>Telic</td>
<td>Win the race</td>
</tr>
<tr>
<td>+Bounded</td>
<td>Non-count</td>
<td>Telic</td>
<td>Win races</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Count</td>
<td>Telic</td>
<td>Run the race</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Run races</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Count</td>
<td>Atelic</td>
<td>Roam the trail</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Roam trails</td>
</tr>
</tbody>
</table>
Aspect and Transitivity

• Frazier et al. (2006)
  • Perfective expect a telic event, thus must give up an expected semantic property in giving up its definite direct object (when the verb is unspecified).
  • Lacking this expectation, imperfective aspect may be more willing to give up its direct object.
(4) a. As John hunted the frightened deer escaped through the woods.
b. As John hunted the frightened deer it escaped through the woods.
c. As John was hunting the frightened deer escaped through the woods.
d. As John was hunting the frightened deer it escaped through the woods.

- Go-Past Reading Times
Summary

• Commitment to telicity reinforces the existence of an internal argument.
  • Quick reanalyze of a reduced relative with +bounded verb which needs an NP as an object.
  • Hinders reanalysis when the definite NP object commits the parser to a telicity that supports a perfective.
Initial Commitment to Telicity

• Unanswered: Is there a processing consequence to the initial construction of telicity itself?
### Calculus of Events

<table>
<thead>
<tr>
<th>Verb Type</th>
<th>NP Type</th>
<th>Telicity</th>
<th>VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>+Bounded</td>
<td>Count</td>
<td>Telic</td>
<td>Win the race</td>
</tr>
<tr>
<td>+Bounded</td>
<td>Non-count</td>
<td>Telic</td>
<td>Win races</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Count</td>
<td>Telic</td>
<td>Run the race</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Run races</td>
</tr>
<tr>
<td>--Bounded</td>
<td>Count</td>
<td>Atelic</td>
<td>Roam the trail</td>
</tr>
<tr>
<td>--Bounded</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Roam trails</td>
</tr>
</tbody>
</table>
Aspectual Computation

- Comparison of +bounded verbs with unspecified verbs
- Also manipulated NP Type
- Word-by-word self-paced reading

1. Bounded, Definite (Telic) The expert physicist lost the files on the formation of black holes.
2. Bounded, Bare (Telic) The expert physicist lost files on the formation of black holes.
3. Unspecified, Definite (Telic) The expert physicist read the files on the formation of black holes.
4. Unspecified, Bare (Atelic) The expert physicist read files on the formation of black holes.
• Interaction due to verbal event semantics and argument properties.
  • Differences emerge upon completion of the VP
  • Atelic events > Telic events
  • Direction of our semantic model complexity

• What about the verbs themselves?
+Bounded Verbs?

tagged

TP

T
-ed

AspP

Asp

DP_i

V

tag_{+bound}

VP

DP_i
Lexical decision
Verbs were
+ Bounded vs. unspecified
Infinitival vs. past tense forms

<table>
<thead>
<tr>
<th>Verb Type</th>
<th>NP Type</th>
<th>Telicity</th>
<th>VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>+Bounded</td>
<td>Count</td>
<td>Telic</td>
<td>Win the race</td>
</tr>
<tr>
<td>+Bounded</td>
<td>Non-count</td>
<td>Telic</td>
<td>Win races</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Count</td>
<td>Telic</td>
<td>Run the race</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Run races</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Count</td>
<td>Atelic</td>
<td>Roam the trail</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Roam trails</td>
</tr>
</tbody>
</table>
• No significant differences… but…

![Bar chart showing reaction time differences between 'bounded' and 'unspecified' conditions for infinitive and tensed verb forms.](image)
MEG Response to Verb Boundedness

tagged_{+bound}

ran

A

B
Summary

• Initial evidence that parsing \texttt{+bounded} verbs is costly.
  • This could be evidence in the direction of syntactic representational complexity.

• What about \texttt{–bounded} verbs?
<table>
<thead>
<tr>
<th>Verb Type</th>
<th>NP Type</th>
<th>Telicity</th>
<th>VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>–Bounded</td>
<td>Count</td>
<td>Telic</td>
<td>Win the race</td>
</tr>
<tr>
<td>+Bounded</td>
<td>Non-count</td>
<td>Telic</td>
<td>Win races</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Count</td>
<td>Telic</td>
<td>Run the race</td>
</tr>
<tr>
<td>Unspecified</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Run races</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Count</td>
<td>Atelic</td>
<td>Roam the trail</td>
</tr>
<tr>
<td>–Bounded</td>
<td>Non-count</td>
<td>Atelic</td>
<td>Roam trails</td>
</tr>
</tbody>
</table>
• Comparison of –bounded verbs with unspecified verbs
• Also manipulated NP Type
• Word-by-word self-paced reading
Summary

• **push a cart**
  • one event
• **push a button**
  • iterative events


• The “atelicity” of –bounded verbs may arise much later in processing (or not at all!).
Summary

• The initial commitment to telicity has a processing cost.
  • **Atelic** events are more costly than **telic** events
  • Some evidence for a cost associated with retrieval of verb boundedness
  • Some evidence that –**bounded** and **unspecified** verbs are treated the same
    • **Bounded** may be a privative feature.
Outline

- Linguistic ingredients of event meanings
- Processing issues
- Examine several studies
- Some conclusions
Parsing Telicity

- What is the domain over which the parser interprets telicity?
  - Telicity is calculated over the domain of the VP
  - A highly incremental parser could take advantage of verbal boundedness (especially for +bounded verbs) to make an immediate commitment to telicity.
- However, we find a delay, suggesting that the parser waits for the full VP.
Parsing Telicity

• What factors guide the parser in telicity interpretations online?
  • Verbal event semantics
    • Evidence for $+\text{bounded}$ verbs
    • No evidence for $-\text{bounded}$ verbs being different from unspecified verbs.
  • Count/mass of the argument
Parsing Telicity

• Does the parser immediately commit to a telicity interpretation?
  • Yes, but with respect to a particular domain and certain factors:
  • The parser delays commitment to telicity until it has posited the VP.
  • The parser does not commit to telicity based on the verb itself → Against Immediate Full Interpretation
Thanks!

- Linnaea Stockall
- Alan Beretta
- Alan Munn
- Cristina Schmitt
- Marcin Morzycki
- NSF IGERT