Psycholinguistic Studies into Event Semantics

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Structure of the talk

- Two kinds of theories of aspectual coercion
  - Operator based accounts
  - Planning accounts
- Event calculus
  - The language of the event calculus
  - Axiomatization
  - Reification
- Three types of coercion
- ERP Study "Additive Coercion"
- Processing Difficulty in "Abstract Type Shift"
- Predictions for an ERP study on "Abstract Type Shift"
- Conclusions
Examples of aspectual coercion

1. John reached the top in **two** hours.
2. John built a house for **two** years.
3. John sneezed for **two** hours.
4. John dived through the pool for **two** hours.
Theories of aspectual coercion I: Operator based accounts

Given expression $A$ of type $\langle \beta, \gamma \rangle$ and expression $B$ of type $\alpha \neq \beta$.

**Result:** Type mismatch for $A(B)$

**Resolve** type mismatch by introducing an operator $OP$ of type $\langle \alpha, \beta \rangle$.

No type mismatch occurs in $A(OP(B))$. 
The computation of the temporal profile of a discourse is viewed as coming up with a plan that permits a (non-monotonic) derivation of a goal from a given initial state.

Coercion is characterized by shifts in meaning that result from the update of a plan when integrating new information.
Event calculus I: The language of the event calculus

- Ontology: eventtypes, fluents (time-dependent properties, such as activities), real numbers, individuals.
- Terms include fluent-valued and eventtype-valued functions.

1. Momentaneous change
- Initially($f$)
- Happens($e,t$)
- Initiates($e,f,t$)
- Terminates($e,f,t$)
2. Continuous change
- $Releases(e, f, t)$
- $Trajectory(f_1, t, f_2, d)$

3. No $f$-relevant events between $t_1$ and $t_2$
- $Clipped(t_1, f, t_2)$

4. Truth predicate
- $HoldsAt(f, t)$
Event calculus II: Axiomatization

An informal example

If a fluent holds initially or has been initiated by some event occurring at time $t$ and no event terminating $f$ has occurred between $t$ and $t' < t'$, then $f$ holds at $t'$.

Axiom

$$\text{Initially}(f) \rightarrow \text{HoldsAt}(f, 0)$$

Axiom

$$\text{HoldsAt}(f, r) \land r < t \land \neg \exists s < r \text{HoldsAt}(f, s) \land \neg \text{Clipped}(r, f, t) \rightarrow \text{HoldsAt}(f, t)$$
It was hot. Jean took off his sweater.

World knowledge contains no link to the effect that taking off one’s sweater changes the temperature. Since it is hot at some time before now, the state hot must either hold initially or have been initiated. The latter requires an event, which is however not given by the discourse. Therefore hot holds initially. Similarly no terminating event is mentioned, so that hot extends indefinitely, and it follows that the event described by the second sentence must be positioned inside hot.
Event calculus III: Reification

Given a predicate like

\[ burn(x, y, t) \]

there are two possibilities to construct terms:

1. **Event types**: John’s burning of the house
   \[ \exists t. burn[j, h, t] \]

2. **Fluents**: John’s burning the house
   \[ burn[j, h, \hat{t}] \]

\[ \text{HoldsAt}(burn[j, h, \hat{t}], s) \leftrightarrow burn(j, h, s) \]
Special case

There is a mapping from eventtypes to fluents $e \rightarrow f$ via

$$e \rightarrow \text{Happens}[e, \hat{t}] = f$$
Scenario for the accomplishment *building a house*

1. *build* is an activity fluent, derived by nominalization from the corresponding verb
2. *house(x)* is a parametrised fluent representing the construction stage *x* of a house
3. *c* is a real constant indicating a construction stage at which the house is considered finished; thus *house(c)* is the fluent representing the consequent state.
4. Similarly, *a* is a real constant indicating the stage at which the building starts.
5. *start* is any event initiating building.
6. *finish* is the canonical event terminating building, namely when the house is finished.
7. *g* is a monotone increasing real-valued function relating the building activity to the construction stage.
1. Initially($house(a)$)
2. Initiates($start$, $build$, $t$)
3. Initiates($finish$, $house(c)$, $t$)
4. Terminates($finish$, $build$, $t$)
5. $HoldsAt(build, t) \land HoldsAt(house(c), t) \rightarrow Happens(finish, t)$
6. Releases($start$, $house(x)$, $t$)
7. $HoldsAt(house(x), t) \rightarrow Trajectory(build, t, house(x + g(d)), d)$
Three types of coercion (Bott 2008)

Additive coercion

1. John reached the top in two hours.
2. Johann fand den Schlüssel in fünf Minuten.
   John found the key in five minutes

The adverbial *in tow hours* requires an accomplishment. Therefore the scenario for achievements has to be updated to a scenario for accomplishments by introducing a *climbing* or *searching* activity.

↓

Additive coercion
Subtractive coercion

John baute das Haus zwei Wochen lang (bis der Kredit gekündigt wurde).
John built the house for two weeks (until the credit was canceled)

The adverbial *for two weeks* requires an activity. Therefore the scenario for accomplishments has to be stripped of all clauses referring to the culminating event.

↓

Subtractive coercion
Abstract type shift

1. Johann nieste fünf Minuten lang.
   John sneezed for five minutes.
2. John dived through the pool for two hours

The adverbial *for two weeks* requires an activity. Therefore the semelfactive *sneeze* and the accomplishment *dive through the pool* have to be transformed to an iterative process. This is achieved via the canonical map:

\[ e \rightarrow \text{Happens}[e, \hat{t}] \]
Combinations of Coercions

Peter durchtauchte das Becken *den ganzen Vormittag*. Peter through-dived the pool *the whole morning*.

There are two possible derivations:

- **Subtractive coercion**: one diving event lasting the whole morning
- **Abstract type shift**: a series of diving events

Is this example more difficult to process than abstract type shift of semelfactives?
Outline

1. Semantic Theories on Aspectual Coercion
2. Processing Additive Coercion
3. Abstract Type Shift
   - Pretesting the Readings
   - Reading Time Study
4. A Planned ERP Study
Additive Coercion

Operator Based Accounts: Reject and Recompute

"Coercion operators are only inserted when they are triggered by a mismatch. [...] The interpretation in terms of coercion is fully compositional, but the value of the hidden operator is dependent on linguistic context and world knowledge." (De Swart, 2003, p. 8)

Event Calculus: Smooth Update

Additive coercion consists in elaborating a scenario. The coercing stimulus adds an eventuality that has to be substituted with a concrete event from discourse context or world knowledge.
Additive Coercion

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Semantic Theories on Aspectual Coercion
Processing Additive Coercion
Abstract Type Shift
A Planned ERP Study

Reject-and-Recompute vs. Smooth-Update

- mismatch. The mountaineer reached the top for three hours ...
- coerc. The mountaineer reached the top in three hours ...

Reject-and-Recompute

- ERPs indicate two processes
  - Mismatch detection
  - Insert coercion operator
- Early on, aspectual mismatch and coercion elicit the same effects

Smooth-Update

- ERPs indicate only one process
  - Update the model with a preparatory process
- Mismatch and coercion elicit qualitatively different ERP effects

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Aspectual Coercion
An ERP Study on Additive Coercion – the Design

- **Adverbial**: mismatch vs. coercion vs. control
- **Critical segment**: participle (*entdeckt*)
- Apart from the first word physically identical stimuli
- Processing differences must be due to semantic context
An ERP Study on Additive Coercion – the Design

- **Mismatch**: Gänze 5 Min. hatte der Förster die Falle entdeckt, obwohl ...
  
  - For 5 min. had the ranger the trap discovered although ...

- **Coercion**: In 5 Min. hatte der Förster die Falle entdeckt, obwohl ...
  
  - In 5 min. had the ranger the trap discovered although ...

- **Control**: Vor 5 Min. hatte der Förster die Falle entdeckt, obwohl ...
  
  - 5 min. ago had the ranger the trap discovered although ...

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<table>
<thead>
<tr>
<th>mismatch</th>
<th>Coercion</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ganze 5 Min.</td>
<td>hatte der Förster die Falle entdeckt, obwohl ...</td>
<td></td>
</tr>
<tr>
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</tr>
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An ERP Study on Additive Coercion – the Design

- **Adverbial**: mismatch vs. coercion vs. control

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ERP Study *Additive Coercion* - Methods

- Sentences presented word by word (800 ms per word)
- *Did the sentence make sense?* judgment after each trial (time limit 4s)
- 120 experimental items in three conditions + 180 distractor sentences
- Latin square design
- 24 participants

- EEG continuously recorded using a standard montage with 29 scalp electrodes
- Referenced to linked mastoids
- Only artefact free trials
ERP Study *Additive Coercion* – EEG recordings
Additive Coercion – Judgments

- Mism. < coerc. < contr.
- Coercion accepted in more than 75%
- No differences in answer time

Subjects computed coerced meanings during reading

![Bar chart showing percent 'yes, makes sense' judgements]

- Mismatch
- Coercion
- Control

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Semantic Theories on Aspectual Coercion
Processing Additive Coercion
Abstract Type Shift
A Planned ERP Study
Mismatch elicits a P600

- Coercion leads to a sustained anterior negativity

- But no P600

▷ Increased working memory demands in coercion

▷ But no rejection
**Additive Coercion** – Mismatch Effect

Mismatch elicits a P600
Additive Coercion – Coercion Effect

Coercion leads to a working memory LAN only
Additive Coercion – Discussion

- Semantic interpretation breakdown in aspectual mismatch indexed by P600
- Coercion elicits only a working memory LAN
- Update of the situation model with an inferred preparatory process
- The study provides evidence for a smooth update:

  Smooth-Update Hypothesis
  The already computed representation is modified without rejecting it first.
Semantic interpretation breakdown in aspectual mismatch indexed by P600

Coercion elicits only a working memory LAN

Update of the situation model with an inferred preparatory process

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**Smooth-Update Hypothesis**

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**Smooth-Update Hypothesis**

The already computed representation is modified without rejecting it first.
Further Evidence

- Sentences without context: coercion slows down RT
- Supportive context: coercion effect disappears

telic context:
For half a year now, John has been swimming two kilometers every morning. When he started, it took him almost one hour but he is becoming faster by the day.

target with *in*-adverbial:
Heute schwamm er in nur dreißig Minuten. (Today he swam in only thirty minutes).

target with *for*-adverbial:
Heute schwamm er ganze dreißig Minuten. (Today he swam for thirty minutes).
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Iterative Semelfactive:

1) John nieste *den ganzen Morgen lang*.

   John sneezed *the whole morning*.

Iterative Accomplishment:

2) John durchtauchte das Becken *den ganzen Morgen lang*.

   John dived trough the pool *the whole morning*.
Iterative Semelfactives vs. Accomplishments: Operator Based Accounts

Local Mismatch:

\[
\text{for } \text{VP}_{\text{no act.}}
\]

Insert an iterative operator:

\[
\text{for repeat } \text{VP}_{\text{no act.}}
\]

▷ (1) and (2) are predicted to be equally difficult
Iterative Semelfactives in EC

The boy sneezed

- $\text{Happens(}\text{sneeze}, t) \land t < \text{now}$

the whole morning

- $\text{Happens(}\text{stop}_p, t) \land \text{HoldsAt(}\text{time}_p(x), t) \rightarrow \text{For}(p, x)$

There is no process available in the scenario

- Abstract type shift:
  - $\text{Happens(}\text{sneeze}, t) \rightsquigarrow \text{HoldsAt[}\text{Happens(}\text{sneeze}, \hat{t}]\text{]}$

- $p$ can now be instantiated by $[\text{Happens(}\text{sneeze}, \hat{t}]\text{]$}

- ”Pure” abstract type shift
Iterative Accomplishments in EC

- e: diving through the pool
- preparatory process: diving activity
- resultant state: other side of pool
- start event
- finish event
- diving distance (c)
- diving distance (0)
- time t

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Iterative Accomplishments in EC: \textit{Subtractive Coercion}

- Implausible situation, recomputation required
Iterative Accomplishments in EC: *Abstract Type Shift*

An alternative computation has to be chosen:

![Diagram of iterative accomplishments](image-url)
Iterative Readings in EC

Semelfactives:
1. Abstract type shift

Accomplishments:
1. Subtractive coercion
2. Revision of implausible reading
3. Abstract type shift

- Iterative accomplishments should be harder to process than iterative semelfactives
- Comparing them with subtractive coercion and iterative semelfactives reveals underlying processes
Reading Time Study – Semelfactives

**iterative**

Fünf Minuten lang nieste der Junge ziemlich laut, ...
For five minutes sneezed the boy rather loudly, ...
For five minutes the boy sneezed rather loudly, ...

**single**

Vor fünf Minuten nieste der Junge ziemlich laut, ...
Five minutes ago sneezed the boy rather loudly, ...
Five minutes ago the boy sneezed rather loudly, ...

... dann verließ er das Klassenzimmer.
... then left he the classroom.

- Materials similar to Brennan & Pylkkänen (2008)
- We also tried to replicate their study using English materials
Reading Time Study – Accomplishments

**long-for**  Der Arbeiter|belud|die Karre|zwanzig Jahre lang,|...  The worker|loaded|the cart|for twenty years|...  For twenty years the worker loaded the cart.  ...|dann|ging|er|in Rente.  ...then he went into retirement.

**short-in**  Der Arbeiter|belud|die Karre|in zwanzig Minuten,|...  In twenty minutes the worker loaded the cart...  ...|dann|ging|er|in die Pause.  ...then he went into the break.

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Pretesting the Readings – Two Concerns

- Does *sneeze* denote a single event?
- Does *load the cart* also have an activity reading?
For twenty years the worker loaded the cart then he went into retirement.

Did the worker finish loading the cart?

yes  no
A "Repetition Judgment Task" – Step 2

If the answer in step 1 was "yes":

How often did he load the cart?

- only once
- more than once
Pretest – Methods

- We pretested the readings of our materials
  - 40 accomplishments in the three plausible conditions (long-*for*, short-*in* and short-*for*)
  - 20 semelfactives (*iterative vs. single event*)
  - Initial part: separate experiment (N=20) testing materials without adverbial modification

- + 40 fillers
- 24 participants
- Latin square design
- Questionnaire administered over the internet
Without adverbial modification, both accomplishments and semelfactives express single, complete events.
Coerced Interpretations

Did the (culminating) event happen?

- "yes" judgments

- Percentage

Adverbial modification leads to coercion
A Short Summary

Accomplishments:
- short-\textit{in}: control condition
- short-\textit{for}: subtractive coercion (accomplishment $\mapsto$ activity)
- long-\textit{for}: iterative coercion of accomplishment

Semelfactives:
- \textit{ago}: control condition
- \textit{for}: iterative coercion of semelfactive
Are iterative semelfactives difficult to process?
- Reading time study *Semelfactives*

Are iterative accomplishments difficult to process?
- Reading time study *Accomplishments*
Methods

- Self-paced reading with moving window presentation
- After each trial: Did the sentence make sense?
- Experiment *Semelfactives*
  - 20 items
  - Iterative event vs. single event
  - Critical segment: verb (+ subject)
- Experiment *Accomplishments*
  - 40 items Long-for vs. short-for, short-in (control), long-in (mismatch)
  - Critical segment: adverbials (controlled for length)

- 40 participants
- Latin square design
- 80 fillers
Judgments

- Only mismatch is judged nonsensical
- Iterative accomplishments are somewhat less acceptable

Indication of difficulty?
Semelfactives – Reading Times

- No difference between coercion and control
- Semelfactives are easy to iterate

![Reading Times - Semelfactive](image)
Semelfactives – Reading Times

Reading Times - Semelfactive

mean reading times (+ standard errors of the mean)

ms

adverbial    sneezed    the boy    rather loudly.  then  left  he  the classroom.

control

iterative
Accomplishments – Reading Times

Adverbial:

- **Short-for = control**
  - It is easy to reanalyze an accompl. as activity
- **long-for = mismatch**
  - Iteration is difficult

Next segment:

- Only mismatch is slow
  - Readers have recovered from local incompatibility
Accomplishments – Reading Times

The graph shows the reading times for different words and phrases under various conditions. The x-axis represents different words and phrases such as 'The worker', 'loaded', 'the cart', 'adverbial', 'then', and 'went', while the y-axis represents the reading time in milliseconds (ms). The error bars indicate the standard error of the mean. The graph compares reading times for short and long phrases with different prepositions, such as 'short - for', 'short - in', 'long - for', and 'long - in'.
Reading Time Studies – Discussion

- Semelfactives are easy to iterate
- Accomplishments are hard
  - Coercion costs depend on aspectual class
  - EC offers an explanation – more steps required in iterating accomplishments
  - Comparison with subtractive coercion and abstract type shift of semelfactives suggests that difficulty is due to revising the first, implausible interpretation
- A potential concern: habitual reading may be different from iterated process
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A Psycholinguistic Model of Aspectual Analysis

Semantic Theories on Aspectual Coercion
Processing Additive Coercion
Abstract Type Shift
A Planned ERP Study

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Aspectual Coercion
Semantic P600 Effects (Herten, Kolk & Chwilla 2005)

3) De vos die op de stroper joeg...
The fox that at the poacher hunted...
The fox that hunted the poacher...

- Sentence becomes implausible at *joeg*
- This was indexed by a P600

(One) interpretation of the P600
The P600 is a "monitoring component that checks upon the veridicality of ones sentence perception" (p. 241)
Iterated Accomplishments – Underlying Processes

If our model of aspectual analysis is correct, we expect reprocessing in the coercion condition.

Given the Herten, Kolk & Chwilla (2005) study, this should be reflected by a P600 effect in the coercion condition.
Additive Coercion vs. Abstract Type Shift: Predictions

Additive coercion:
- Preparatory process has to be inferred and to be added to the situation model
- No mismatch, smooth update
- Enhanced working memory demands
- only working memory LAN

Abstract type shift:
- Accomplishments: revision of an implausible model leads to a shift \( \text{event} \leadsto \text{process} \)
  - Reprocessing
- Semelfactives: immediate shift \( \text{event} \leadsto \text{process} \)
  - No reprocessing
- P600 effect in iterative accomplishments but not in semelfactives
Additive Coercion vs. Abstract Type Shift: Predictions

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Conclusions

We have demonstrated that EC allows us

- to differentiate among (cognitively) distinct coercion types
- model the processes in aspectual coercion (e.g. elaborating a scenario)
- make falsifiable claims about semantic processing

We do not claim, however,

- that comprehenders actually compute constraint logic programs when interpreting language