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Incrementally Interpreting Presuppositions

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1 The Project Pursued in this Paper

1.1 Data: Immediate vs. Delayed Interpretation of Presupposition

Evidence from processing indicates that presuppositions (PSPs) can be interpreted very quickly (e.g. Sedivy et al., 1999). We put together a body of evidence centering around the online processing of German *wieder* 'again' (for detailed information on the reading time studies discussed here, we refer the reader to Tiemann, 2014).

In some experimental settings, this PSP trigger is processed immediately. In a self-paced reading study, we found early significant reading time increases for sentences with *wieder* 'again' in a neutral context (PSP not explicitly supported) in contrast to when these sentences were presented in a positive context (PSP is explicitly given).

(1) **Neutral Context:** Inge went skiing last week.
Positive Context: Susanne went skiing last week.
PSP: *Gestern war Susanne* ***wieder*** *skifahren …*
Yesterday was Susanne **again** skiing …

The reading times came apart on the PSP trigger itself—before the whole content of the PSP was revealed to the reader (see Figure 1). This finding is strongly indicative of incremental interpretation, up to and including the point at which the PSP is evaluated against the context.

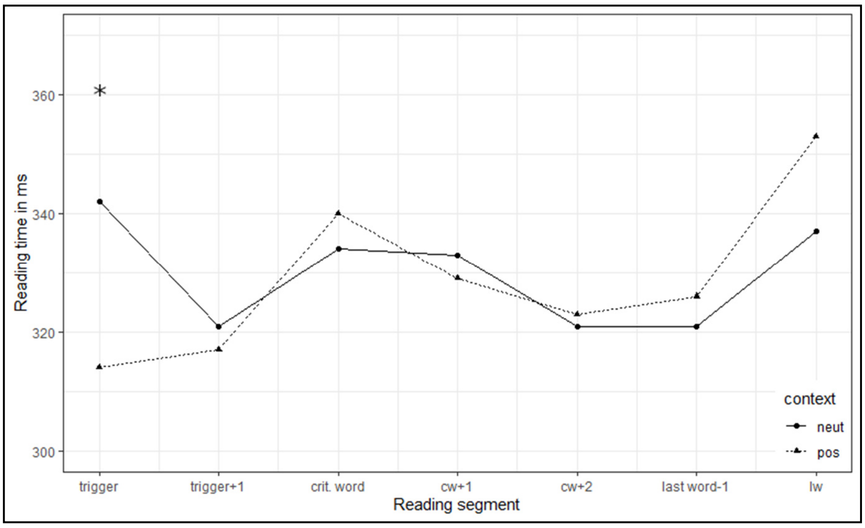


Figure 1. Reading times in ms for sentences with 'again'—asterisks mark significant differences between the positive and neutral condition

However, further data indicate that processing of PSPs does not always proceed quite so quickly. In another reading experiment, reading times for sentences whose PSP was not supported by the context were significantly longer only after the whole PSP content was known ("received" / "given.away" in (2)—the 'critical word') in contrast to sentences which were supported by the context. That is, in (2) the PSP is processed **late**.

(2) **Context:** *Letzte Woche hat Linda Judith eine rosa Lampe für ein Zimmer gekauft*
Last week has Linda Judith a pink lamp for a room bought

PSP neutral: *Vor zwei Tagen hat Linda wieder eine rosa Lampe* ***erhalten*** […]
ago two days has Linda again a pink lamp **received** […]

PSP positive: *Vor zwei Tagen hat Linda wieder eine rosa Lampe* ***verschenkt*** […]
ago two days has Linda again a pink lamp given.away […]

Of the two findings, (1) is the more surprising because the context is checked before the content of the PSP is determined by the sentence.

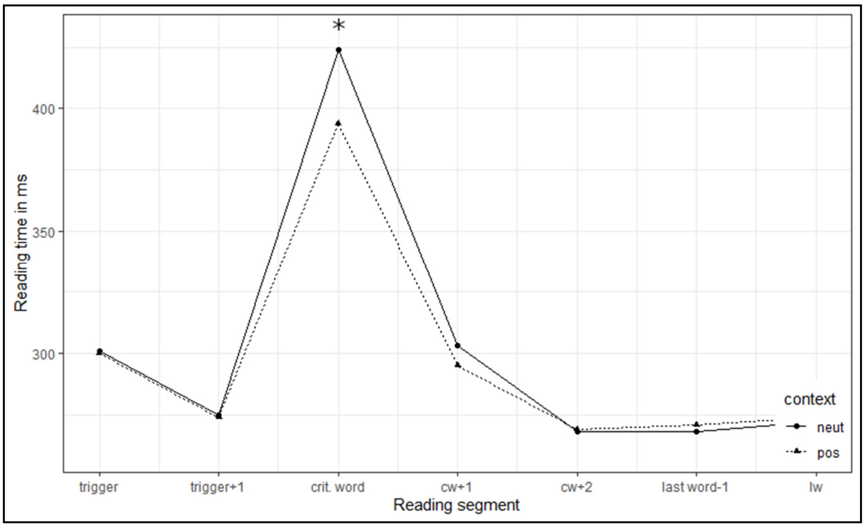


Figure 2. Reading times in ms for sentences with 'again'—asterisks mark significant differences between the positive and neutral condition

Our explanation of the contrast between (1) and (2) is based on the observation that the status of the information still missing when *again* is processed differs between the two. In (1), no matter what information is still to come, checking the experimental context reveals whether the PSP triggered by *again* is supported or not (that is, when "Susanne again" is read, no matter what property is still to come, the context doesn't support that Susanne had that property earlier). This is not the case in (2), where the missing material decides whether or not the PSP is true in the context.

1.2 Plot of the Paper

A prerequisite of this explanation is that "Susanne again" is composed into a meaningful unit, and that this unit can be checked against the context. A formal implementation of the explanation therefore requires the following:

As our starting point we need a model of incremental semantic processing, which we introduce in Section 2. Next, we require an incremental semantics and pragmatics for the PSP trigger, developed in Section 3. These proposals implement our explanation of the contrast of (1) vs. (2).

We extend the empirical domain and analysis in Section 4 to further PSP data: to another trigger, the definite determiner in Subsection 4.1; to PSPs in the scope of a quantifier in Subsection 4.2.; and to embedding under negation in Subsection 4.3. Section 5 concludes.

2 Enlightened Incrementality (Beck & Tiemann, 2018)

This section introduces our model of incremental semantic composition. We present a short review of Beck & Tiemann (2018): the general setup, a couple of motivating examples, and the incremental semantics proposed there including the Enlightened Incrementality Conjecture. We refer the reader to Beck & Tiemann (2018) for more comprehensive discussion of further empirical (e.g. Bott & Schlotterbeck; 2013; Hackl et al., 2012; Kamide et al., 2003, Kim & Osterhout, 2005, Knoeferle et al., 2005) as well as theoretical work (e.g. Steedman, 2000; Bott & Sternefeld, 2017; Demberg, 2012) that went into our proposals.

Incremental Composition (preliminary):
A model of semantic composition that incorporates processing results indicating that compositional interpretation has incremental properties.

2.1 General Setup

In (3), (4) and (5) we introduce the basic concepts used by Beck & Tiemann's incremental semantics.

(3) a. Let Θ be the set of syntactic structures produced by the human parser.
Each $T_i \in \Theta$ is a possibly partial syntax tree.
b. Let Σ be the set of interpretations produced by the corresponding human interpretive processor. The elements of Σ are sets of meanings, i.e. each $S_i \in \Sigma$ is a set whose members are elements of $\cup D\tau$ (τ a semantic type).
c. A pair $<T_i, S_i>$ is a stage reached in sentence processing.

(4) Incremental processing is a series of mappings $<T_i,S_i> \rightarrow <T_{i+1},S_{i+1}>$ ($1 \leq i \leq n$) such that
(i) T_n is an LF tree;
(ii) each mapping $T_i \rightarrow T_{i+1}$ is a matter of parsing (not our concern here);
(iii) each S_i is a set of meanings from $\cup D\tau$;
(iv) $card(S_n) = 1$ (i.e. everything is composed into one meaning in the end);
(v) $<T_n,S_n> \in [[.]]$ (the standard interpretation function).

(5) Incremental composition is the derivation of S_{i+1} from S_i.
Define a function $[[.]]_h$ ('heuristic interpretation'):
Suppose at stage i, the processor receives the structure σ as input, leading to T_{i+1}.
$[[.]]_h$ defines a mapping $<T_{i+1}, S_i, [[\sigma]]> \rightarrow S_{i+1}$.
On the basis of the new tree, the available set of meanings plus the new meaning, a new semantic stage is reached.

We can think of the function $[[.]]_h$ as interpretive heuristics. It makes predictions about the meaning of partial trees, yielding a projected or anticipated meaning (which could be proven wrong by further input). Each tree T_i is a (partial) LF structure (the input to compositional interpretation). The terminal nodes (atoms) in T_i include the words heard so far (in their proper places in the tree). T_i is the projected LF syntax at stage i.

Incremental Composition:
A model of incremental composition is a recursive definition of the function $[[.]]_h$.
For each stage that the parser may reach, $[[.]]_h$ defines the accompanying stage of the interpreter.

2.2 Illustrating Examples

The available evidence indicates that semantic composition is sometimes incremental and sometimes delayed. We phrase this preliminarily as in (6). The next two subsections give an illustrating example of each strategy of interpretation, immediate vs. delayed.

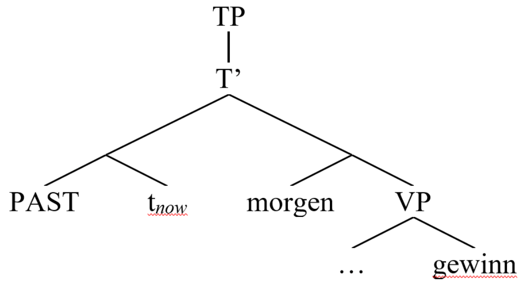
(6) **Enlightened Incrementality (preliminary):**
Meanings are composed in a type-driven fashion within LF domains, resulting in composition that is sometimes immediate and sometimes delayed.

2.2.1 Temporal adverb + tense: immediate composition

Bott (2010) found that participants respond immediately to a mismatch between verbal tense and the meaning of an adverb, as in (7). Beck & Tiemann's analysis is given in (8)-(11).

(7) *Morgen* *gewann …*
tomorrow won …
|
\# mismatch detected—immediate composition

(8) a. projected parse tree contains:



b. projected meaning:
$\lambda P_{<i,t>}.[[PAST\ t_{now}]](\lambda t'.t' \subseteq tomorrow\ \&\ P(t')) =$
$\lambda P_{<i,t>}.\exists t'[t' < t_{now}\ \&\ t' \subseteq tomorrow\ \&\ P(t')]$

(9) Temporal adverb—Tense Heuristics:
If $\alpha = [\beta_{Tense}\ [\ \gamma_{adverb}\ \ldots]]$ and γ is of type <it>,
then $[[\alpha]] = \lambda P_{<i,t>}.[[\beta]](\lambda t'[[\gamma]](t')\ \&\ P(t'))$

(10) Temporal adverb—Tense Heuristics (type shifted):
If $\alpha = [\beta_{Tense}\ [\ \gamma_{adverb}\ \ldots]]$ and γ is of type <it,it>,
then $[[\alpha]] = \lambda P_{<i,t>}.[[\beta]]([[\gamma]](P))$

The Temporal adverb-Tense Heuristics (type shifted) defines $[[\ \beta]]\bullet[[\ \gamma]]$

(11) Function composition:
If g is a function: $A \rightarrow B$ and f is a function: $B \rightarrow C$ then
$f\bullet g : A \rightarrow C$ is the composition of f and g with $f\bullet g = \lambda x.f(g(x))$

With this example, we have identified circumstances that showcase immediate composition of two semantic units that do not form a constituent in the LF tree of a sentence.

2.2.2 German Aspect: Delayed Composition

Bott (2013) and Bott & Gattnar (2015) show that aspectual mismatch in German is only processed when the verb has received its full argument structure, suggesting that the meaning of an adverbial ('for two hours') is not immediately combined with the meaning of a verb ('won'). Composition in German only happens later (in contrast to Russian).

(12) *Zwei Stunden lang gewann der Boxer den Kampf.*
Two hours for won the boxer the fight
|
no composition here

Thus, we have evidence that semantic units are not always composed immediately. Predictive composition does not seem to be explored to exhaustion to calculate a meaning under all circumstances.

Taken together, the evidence indicates that composition in semantic processing has incremental properties, but it also seems to require certain units to be built before composition proceeds. The required model needs to employ '**Enlightened Incrementality' EI**. What would be a useful hypothesis about that?

2.3 The Mechanisms and When to Apply Which

2.3.1 Delayed Composition

We first consider cases in which interpretation seems to be delayed. An example suggestive of this strategy is German aspect, (12). We suggest that no composition occurs, i.e. from stage (14) the processor moves to stage (15) in line with (13).

(13) **Wait and See**
Given $\langle T,S \rangle$ and input σ, map to $\langle T',S' \rangle$,
where T' is the modification of T derived by the syntactic parser and S' is defined by:
$[[.]]_h: \langle T', S, [[\sigma]] \rangle \rightarrow S \cup \{[[\sigma]]\}$

(14) T = [CP [PP zwei Stunden lang] …]]
S = {[[for 2h]]}

(15) T' = [CP [PP zwei Stunden lang] [C' [TP PAST …]]]]
S' = {[[for 2h]], [[PAST]]}

Another, more radical instance of delayed composition are garden path sentences (Bever, 1970) like (17). Assumptions about meaning are revised along with assumptions about structure, cf. (16): what was already composed is tossed out again.

(16) **Revision of LF**
Given $\langle T,S \rangle$ and input σ, map to $\langle T',S' \rangle$,
where T' is the revision of T derived by the syntactic parser, and S' is defined by:
$[[.]]_h: \langle T', S, [[\sigma]] \rangle \rightarrow \{[[\sigma]]\} \cup \{x: x \text{ is the meaning of an atom in } T\}$

(17) *While Anna dressed the baby spat up on the bed.*

2.3.2 Immediate Composition

Next we turn to genuine incremental composition. We conjecture that (18) is available.

(18) **Predictive Function Application**
Given $\langle T,S \rangle$ and input σ, map to $\langle T',S' \rangle$,
where T' is derived by the syntactic parser and
if there is a $\delta \in S$ such that (a) $[[\sigma]](\delta)$ or
(b) $\delta([[\sigma]])$ is defined, then,
(a) $S' = S \backslash \delta \cup \{[[\sigma]](\delta)\}$ or
(b) $S' = S \backslash \delta \cup \{\delta([[\sigma]])\}$ (whichever is defined).

A potential example would be immediate compositional interpretation in the DP as in (19), (20). (21) would be an interesting test case: (21b) should lead to a garden path effect if (20) is right.

(19) *Every dog …*

(20) a. S = {[[every]]}
b. S' = {[[every]]([[dog]])}

(21) a. *Every dog that greeted its master was fed.*
b. *Every dog was fed that greeted its master.*

The incremental composition principle in (22) is our core mechanism. An example from above is (23), the temporal adverb in combination with tense information.

(22) **Predictive Function Composition**
Given <T,S> and input σ, map to <T',S'>,
where T' is derived by the syntactic parser and
if there is a δ∈S such that (a) δ•[[σ]] or
(b) [[σ]]•δ is defined, then,
(a) S' = S\δ ∪ {δ•[[σ]]} or
(b) S' = S\δ ∪ {[[σ]]•δ} (whichever is defined).

(7) *Morgen gewann …* (tense—temporal adverb
tomorrow won …

2.3.3 When is Composition "Immediate" and when "Delayed"—a Possible Generalization

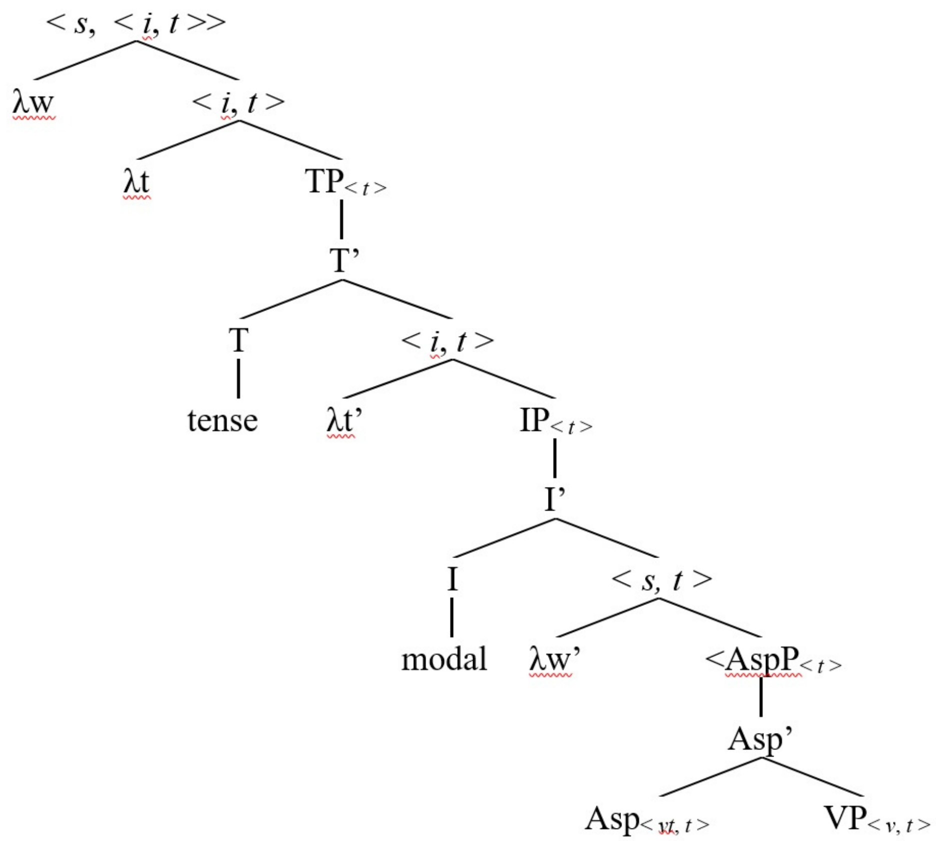
A model of (enlightened) incremental interpretation should be an optimal compromise regarding two conflicting demands: (a) a low load on working memory: it is unrealistic that we carry around a large number of separate meanings until the end of an utterance; (b) reliable predictions: it is undesirable to randomly compose word meanings when the confidence that this is the actual interpretation is low. EI is Beck & Tiemann's central proposal for how this compromise may be reached:

Enlightened Incrementality Conjecture: Units in the same LF domain (DP, VP, TP, AspP) are composed incrementally.

– "**immediate**": there is incremental composition, but it is limited to a local LF domain. E.g., we predictively combine the verb with its arguments within the VP <e,t>. We predictively combine tense with temporal adverbials within the TP layer <i,t> ('Morgen gewann …'). It appears that predictive composition occurs in layers. (This does not mean that you have to finish a layer before you start the next one, as the case 'Morgen gewann …' shows.) The LF tree below shows the (simplified) type domains.

– "**delayed**": German aspect /Aktionsart ('Zwei Stunden lang gewann …') concerns material that in the LF is scattered across several domains (TP and type <i>, AspP and <v>, VP and <e>). See Beck & Tiemann (2018) for further examples of both delayed and immediate semantic processing, their analyses in terms of EI and references.

In sum, late composition facts show us that Predictive FA and Predictive FC cannot always apply. We conjecture with Beck & Tiemann (2018) that predictive composition happens in local LF domains (identifiable by semantic type), where the confidence that this is the correct composition is high. The ideas that we have formulated towards a definition of a heuristic interpretation function $[[.]]_h$ model incremental composition. This offers the beginnings of a framework for theories of semantic parsing.



3 Incorporating PSP into Enlightened Incrementality EI

The option of incremental checking of PSPs against the context is now to be incorporated into EI. Our presentation proceeds in three steps: (i) we introduce an incremental semantics for the PSP trigger *again*; (ii) we implement a shift from a proposition to a context change potential ccp—the 'pragmatic step'; (iii) the ccp is applied to the actual context—'context check and update'.

The intellectual starting point of this project is our intuitive explanation of immediate PSP checking in Subsection 1.1: that very early processing of PSP as in (24a) requires that an incremental ccp (24b) be composed; and that this ccp be checked immediately against the context.

(24) a. *Susanne was again …*
b. $\lambda P.\lambda c$: $\forall w[w \in c \rightarrow \exists e'[\tau(e') < t_{topic} \;\&\; P(w)(e')(Susanne)]]$.
$c \cap \{w: \exists e[\tau(e) \subseteq t_{topic} \;\&\; P(w)(e)(Susanne)]\}$

3.1 Extending the Semantics

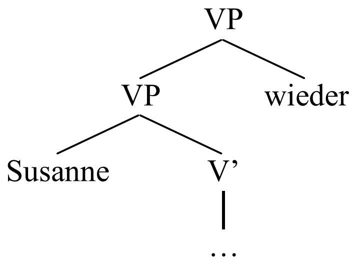
We begin with a standard semantics for the PSP trigger *wieder* / *again*. The analysis is illustrated in (25c,d) for example (25a) (see Beck & Tiemann, 2018, for further references). We adopt a background theory according to which the output of compositional interpretation are type <s,t> propositions and PSPs as definedness conditions yield partial functions of type <s,t>.

(25) a. *It is raining again.*
b. PSP: It rained earlier.
Assertion: It is raining.
c. $[[again]] = \lambda P.\lambda t.\lambda w{:}\exists e'[\tau(e') < t \;\&\; P(e')(w)].\exists e[\tau(e) \supseteq t \;\&\; P(e)(w)]$
d. $\lambda w{:}\exists e'[\tau(e') < t_{now} \;\&\; rain(e')(w)].\exists e[\tau(e) \supseteq t_{now} \;\&\; rain(e)(w)]$

This semantic analysis is integrated into incremental composition next. The evidence indicates that subject and adverb are combined incrementally. That is, the processor anticipates that the adverb will modify some property attributed to the subject (26b). (26b) can be constructed via (27) or (28) by the heuristic interpretation function.

(24) a. *Susanne was again ...*

(26) a. projected parse tree contains:



b. projected meaning:
$\lambda P_{<e,vt>}$. [[wieder]](λe.P(e)(Susanne))

(27) <v,t>-Adverb-Subject Heuristics:
If α = [[β_{subj} …] γ_{adverb}] and γ is of type <vt,vt>,
then $[[\alpha]]_h = \lambda P_{<e,vt>}.[[\gamma]]_h(P([[\beta]]_h))$

(28) <v,t>-Adverb-Subject Heuristics (type shifted subject):
If α = [[β_{subj} …] γ_{adverb}] and γ is of type <vt,vt>,
then $[[\alpha]]_h = \lambda P_{<e,vt>}.[[\gamma]]_h([[\beta]]_h(P))$
(The Adverb-Subject Heuristics (type shifted) defines $[[\gamma]]_h \bullet [[\beta]]_h$)

There is no evidence available to us as to when Tense and Aspect are identified and how the layers are integrated. One possible assumption is to postulate PAST and PFV and compose everything. This is the assumption we adopt in (29) for the sake of concreteness (other assumptions would work equally well). (29) is a partial proposition with a property gap corresponding to the predicate (yet to be filled incrementally).

(29) $\lambda P.\lambda w$: $\exists e'[\tau(e') < t_{topic}$ & P(w)(e')(Susanne)]. $\exists e[\tau(e) \subseteq t_{topic}$ & P(w)(e)(Susanne)]

3.2 The Pragmatic Step

3.2.1 ASSERT Relates Semantics to Context

Next we lay out our assumptions about the pragmatic step. By this we mean the shift from propositions to context change potentials (or context updates, as in Dynamic Semantics (Heim, 1982)). The latter, we take to be of type <c,c>, functions from contexts to contexts. For present purposes, we take a context to simply be a set of possible worlds (see Stalnaker, 1973, a. m. o.). We illustrate this with the ccp of (25a) = (30a), derived from the semantics (25d); the corresponding ccp is given in (30b).

(30) a. *It is raining again.*
b. ccp:
$\lambda c:\forall w[w\in c \rightarrow \exists e'[\tau(e') < t_{now}$ & rain(e')(w)]].$c\cap\{w:\exists e[\tau(e) \supseteq t_{now}$ & rain(e)(w)]}

The proposal incorporates Stalnaker's Bridge for PSPs: the partial proposition must be defined in all worlds in the context for the update to be felicitous. Getting from the proposition to the ccp requires the shift in (31):

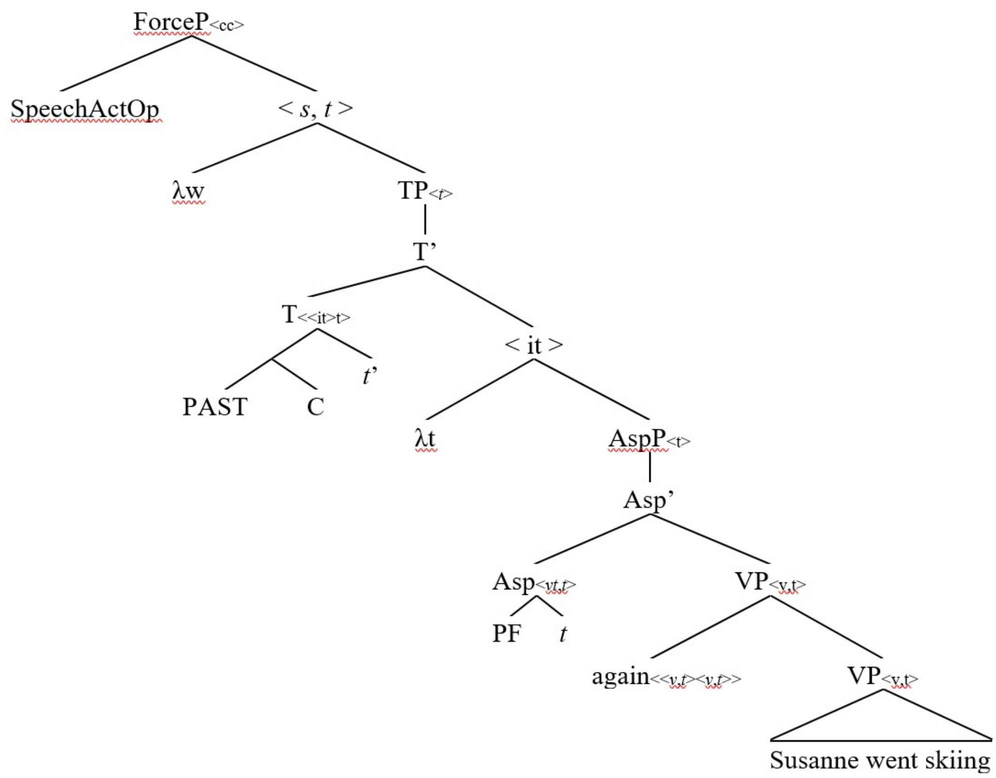
(31) $\lambda p.\lambda c{:}\forall w[w \in c \rightarrow p(w)$ is defined$].c \cap \{w: p(w) = 1\}$

The operator that realizes this shift can be seen as part of the action of uttering / asserting a sentence. For transparency of presentation, we will locate it in a (simplified) ASSERT operator which is part of the LF (Krifka, 2014). (30b) is derived via the LF in (32a) with this operator, (32b), as indicated in (32c).

(32) a. [ForceP ASSERT [CP [C' [TP t_{now} [VP again [rain]]]]]]
b. [[ASSERT]] = $\lambda p.\lambda c{:}\forall w[w \in c \rightarrow p(w)$ is defined$].c \cap \{w: p(w) = 1\}$
c. [[(32a)]] = $\lambda c{:}\ \forall w[w \in c \rightarrow \exists e'[\tau(e') < t_{now}\ \&\ rain(e')(w)]].$
$c \cap \{w{:}\exists e[\tau(e) \supseteq t_{now}\ \&\ rain(e)(w)]\}$

3.2.2 Incremental Ccps

Next, this analysis needs to go incremental. Constructing the LF with the ForceP layer is part of the job of the parser. Enlightened Incrementality will have to work for these "larger" LFs the same way as it did for the LFs without the ForceP layer. We expect that the ForceP layer is postulated when an utterance is recognized as (e.g.) an assertion (for instance, in a German V2 structure without a *wh*-phrase, like (1)). It participates in a cascading type driven incremental composition like the other layers. It constitutes its own type domain, the <c> domain, illustrated in the tree below.



The evidence indicates that incremental ccps with "gaps" like (33) = (24) are constructed:

(33) a. *Susanne was again …*
b. $\lambda P.\lambda c{:}\quad \forall w[w \in c \rightarrow \exists e'[\tau(e') < t_{topic}\ \&\ P(w)(e')(Susanne)]].$
$c \cap \{w{:}\ \exists e[\tau(e) \subseteq t_{topic}\ \&\ P(w)(e)(Susanne)]\}$

(33) can be derived by combining the result of the incremental semantics in (29) with the ASSERT operator, as shown in (34).

(29) $\lambda P.\lambda w{:}\ \exists e'[\tau(e') < t_{topic}\ \&\ P(w)(e')(Susanne)].\ \exists e[\tau(e) \subseteq t_{topic}\ \&\ P(w)(e)(Susanne)]$

(34) Composition of ForceP layer and ASSERT via Predictive FC:
[[ASSERT]] • (29) = (24):
$\lambda P.\lambda c$: $\forall w[w \in c \rightarrow \exists e'[\tau(e') < t_{topic}$ & P(w)(e')(Susanne)]].
$c \cap \{w: \exists e[\tau(e) \subseteq t_{topic}$ & P(w)(e)(Susanne)]}
(context change potential with a property gap)

To sum up, we have integrated an analysis of how propositional meaning can be turned into dynamic meaning in the incremental semantic framework started in Beck & Tiemann (2018). The proposal includes a treatment of PSPs in which they start their compositional existence as partial functions. This projects to the level of context change potentials, where they require that all worlds in the context make the PSP true.

3.3 Context Check: Application of Ccp to Context

We now turn to the third step anticipated in the beginning of this section, applying the ccp to the context. A ccp like (35b) in example (35a) must be related to the actual context. That is, the processor has to check whether the actual context $c_@$ is such that the definedness condition holds; if so, $c_@$ is updated with the propositional content. We call (36) below—applying a ccp to $c_@$—"carrying out the context check and update".

(35) a. *It is raining again*.
b. ccp: $\lambda c{:}\forall w[w \in c \rightarrow \exists e'[\tau(e') < t_{now}$ & rain(e')(w)]].$c \cap \{w{:}\exists e[\tau(e) \supseteq t_{now}$ & rain(e)(w)]}

(36) **Context check and update**:
$[\lambda c{:}\forall w[w \in c \rightarrow \phi(w)].c \cap \{w: \psi(w)\}](c_@)$

The context check and update for 'it is raining again' might apply its ccp to a context containing worlds w_1-w_{15} in which Thilo and I agree, for the purposes of the conversation, that we are talking about the weather in Pfrondorf, that it rained there earlier this morning, that "rain" is anything that leaves a residue in our new pluviometer etc. So $\{w_1, \ldots, w_{15}\} = c_@$. In this case, the check would be positive and the update performed.

What about (24)? It still contains an incremental gap for the predicate.

(24) a. *Susanne was again ...*
b. $\lambda P.\lambda c$: $\forall w[w \in c \rightarrow \exists e'[\tau(e') < t_{topic}$ & P(w)(e')(Susanne)]].
$c \cap \{w: \exists e[\tau(e) \subseteq t_{topic}$ & P(w)(e)(Susanne)]}

Here we come back to our initial hypothesis: in the experimental context c, there is no P such that $\forall w[w \in c \rightarrow \exists e'[\tau(e') < t_{topic}$ & P(w)(e')(Susanne)]]. Hence, before knowing what P is, it is clear that the context check will fail. A hearer is able to predict this, so we get very early processing of PSP. **Hypothesis ECC** gives rise to very **early** PSP processing effects as in (1).

(37) **Hypothesis Early Context Check ECC**:
In an input $\phi(P)$, if for all incremental "gaps" P, $c \geq \phi(P)$ or for all P: $c \geq \neg\phi(P)$, then context check is carried out immediately.

In (38), which corresponds to (2), the late effect, there is also an incremental gap for the predicate at the point the PSP trigger is encountered.

(38) a. *Linda has again …*
b. $\lambda P.\lambda c$: $\forall w[w \in c \rightarrow \exists e'[\tau(e') < t_{topic}$ & P(w)(e')(Linda)]].
$c \cap \{w: \exists e[\tau(e) \subseteq t_{topic}$ & P(w)(e)(Linda)]}

The context in this experiment, however, was constructed in such a way that it could only be determined whether $c_@$ entails the PSP after P is incrementally filled. **Hypothesis DCC** gives rise to **late** PSP processing effects as in (2).

(39) **Hypothesis Delayed Context Check DCC**:
In an input $\phi(P)$, if it is not the case that for all incremental "gaps" P: $c \geq \phi(P)$ or $c \geq \neg\phi(P)$, then delay context check until P is known.

Hypothesis DCC predicts effects of PSaP processing at the end of a sentence. What about more complex predicates? In (40), for example, information on the predicate can be added in a stepwise fashion.

(40) **Context:** *Letzte Woche hat Linda Judith eine rosa Lampe gekauft*
Last week has Lind Judith a pink lamp bought

PSP: *Vor zwei Tagen hat Linda wieder eine rosa Lampe für Marie gekauft.*
ago two days has Linda again a pink lamp for Marie bought

Hypothesis DCC, as it is formulated above, would lead us to expect that effects occur only at *gekauft*—when the whole VP is incorporated.

Enlightened Incrementality tells us that composition within the VP layer proceeds incrementally. After both objects are known, there is still a gap for the predicate:

(41) Linda hat wieder eine rosa Lampe für Marie …
$\lambda P.\lambda c$: $\forall w[w \in c \rightarrow \exists e'[\tau(e') < t_{topic}$ & $P(w)(e')(Marie)(pink\ lamp)(Linda)]]$.
$c \cap \{w: \exists e[\tau(e) \subseteq t_{topic}$ & $P(w)(e)(Marie)(pink\ lamp)(Linda)]\}$

This would lead us to expect earlier PSP related effects (e.g. on *Marie*). Hypothesis DCC could thus be re-formulated to Hypothesis DCC':

(42) **Hypothesis Delayed Context Check DCC'**:
In an input $\phi(P)$, if it is not the case that for all incremental "gaps" P: $c \geq \phi(P)$ or $c \geq \neg\phi(P)$, then delay context check until P is incrementally (partially) filled.

Further research may decide between the two versions of the DCC (and might furthermore consider the possibility that a very high likelyhood may be sufficient to trigger ECC instead of requiring absolute certainty; see e.g. Kuperberg & Jaeger, 2016, for general discussion). For the present, our suggestion is, in a nutshell, that the PSP trigger signals the need for a context check and the context check is carried out as soon as enough information has been gathered incrementally. In (1), the information is already sufficient when the processor encounters the trigger, hence the early effect. This is not the case in (2), hence the late effect.[1] Crucially, it is a prerequisite for the context check that a ccp be incrementally constructed which can be applied to the context for the sentence with the PSP.

[1]Results from two studies presented in Brasoveanu & Dotlačil (2015) seem to offer interesting insights into how connectors like IF and AND seem to play a role in the interpeter's decision to carry out a late vs. an early context check: Whilst IF facilitates the processing of a cataphoric PSP resolution as in (1a), AND does not have the same effect in (1b). This could be due to the fact that in (1b) an ECC has already taken place before the second conjunct is parsed (and therefore the cataphoric resolution has no effect), whereas in (1a), the context check is delayed because IF signals the possibility of some kind of context adjustment coming up (which could be relevant for the PSP interpretation). However, more information about the whole experiment would be needed in order to get the full picture (only RTs after the second *argued* have been reported).

1. a. Jeffrey will argue with Diane again IF he argued with her in the courtyard last night.
   b. Jeffrey will argue with Diane again AND he argued with her in the courtyard last night.

4 Further Data

4.1 The Definite Determiner

4.1.1 Sedivy et al.'s (1999) Experimental Result

(43) *Touch the* ***tall*** *…*

In a series of experiments employing the visual world paradigm, Sedivy et al. (1999) (see also Tanenhaus et al., 1995, for similar results) explored contrasting adjectives. As soon as the participant heard "Touch the tall …" (i.e. before encountering the head noun), they shifted their gaze to the target (see Figure 3). This strongly suggests that the meaning of the determiner was already composed with the meaning of the adjective and some pragmatic reasoning is already in place (tall in contrast to small glass). The pattern is parallel to (1): surprisingly, effects occur before the content of the PSP is known (very early processing of PSP), following the ECC.

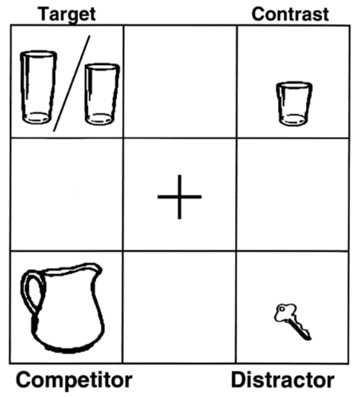


Figure 3. Experimental item from Sedivy et al. (1999)

4.1.2 Our Interpretation

The incremental semantics must yield the composition of the definite determiner with the adjective, leaving incremental gaps for the noun and the predicate, (44). The pragmatic step must furthermore yield an incremental ccp with the same gaps, (45).

(44) $[[\text{the tall} \dots]]_h = \lambda Q.\lambda P.\lambda w{:}\exists!x[\text{tall}(x)(w)\ \&\ Q(x)(w)].P(\iota x{:}\text{tall}(x)(w)\ \&\ Q(x)(w))(w)$

(45) $\lambda Q.\lambda P.\lambda c{:}\ \forall w[w\in c \rightarrow \exists!x[\text{tall}(x)(w)\ \&\ Q(x)(w)]].\ c\cap\lambda w.P(\iota x{:}\text{tall}(x)(w)\ \&\ Q(x)(w))(w)$

This incremental ccp feeds into the following pragmatic reasoning:

(46) a. For any N,c: When there is exactly one N in c, "the N" is used.
b. "the Adj" is used, which must be "the Adj N" for some N.
$\Rightarrow$ there is exactly one Adj N in c and there is more than one N in c.

The pragmatic reasoning in (46) can be justified by a version of parsimony, perhaps reducible to the maxim of manner (47a), which we phrase as in (47b) for the case at hand. The principle gives rise to a meaning component that we see as akin to an anti-presupposition (Heim, 1991). Its content is given in (47c).

(47) a. Be brief!
b. The Swabian Principle: Make your definite DP as small as possible![2]
c. Anti-PSP: $\forall w[w\in c \rightarrow \exists X[{*N}(w)(X)\ \&\ \text{card}(X)\geq 2]]$
there are at least two Ns in the context

Sedivy et al.'s results arise from immediate calculation of (47c). In order for the participants to be able to calculate (47c), they must relate an incremental semantics for the partial definite DP to the context. In other words, (45) must be available to them.

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[2] Inhabitants of the central European region of Swabia are well-known for their frugality and taciturnity. The principle is named for them and its Swabian version is given in (i).

(i) *Wenn'sch's et brauchsch, läsch's weg.*
if.2ndsg.3rdsg Neg need.2ndsg leave.2ndsg.3rdsg out
'If you don't need it, leave it out.'

4.1.3 Deriving the Incremental Ccp for the Definite DP

Next we address the question of how the processor derives (44) and (45). Let's say that (48a) is what the parser has at stage T, and (48b) what the parser has at state T'.

(48) a. T: [DP the [NP …]]
b. T': [DP the [NP AP [N' …]]]

The corresponding stages of the interpreter are given in (49a) and (49b). (49b) is identical to (44). In (49c) we provide the meaning of the modifier *tall* that we assume.

(49) a. S: $\{[[\text{the}]]\} = \{\lambda Q.\lambda P.\lambda w{:}\exists!x[Q(x)(w)].P(\iota x{:}Q(x)(w))(w)\}$
b. S': $\lambda Q.\lambda P.\lambda w{:}\exists!x[\text{tall}(x)(w) \,\&\, Q(x)(w)].P(\iota x{:}\text{tall}(x)(w) \,\&\, Q(x)(w))(w)$
c. $[[\text{tall}]] = \lambda R.\lambda x.\lambda w.\text{tall}(x)(w) \,\&\, R(x)(w)$

The heuristic interpretation function will derive (49b) from (49a) and (49c) by way of the following heuristics:

(50) $[[.]]_h$: $<T', S, [[\sigma]]> \rightarrow S'$, where S' is defined by:
$[[\ [\text{DP the [NP tall …]]}\ ]]_h = \lambda Q.[[\text{Det}]]([[\text{Adj}]](Q))$
$= [[\text{Det}]] \bullet [[\text{Adj}]]$

In other words, this is a case of predictive Function Composition. Similarly, (45) can be derived by predictively composing the ASSERT operator with (44).

(51) $[[\text{ASSERT}]] \bullet (44) =$
$\lambda Q.\lambda P.\lambda c{:}\ \forall w[w\in c \rightarrow \exists!x[\text{tall}(x)(w) \,\&\, Q(x)(w)]].\ c\cap\lambda w.P(\iota x{:}\text{tall}(x)(w) \,\&\, Q(x)(w))(w)$

We see that technically, this instance of immediate composition can be captured by the mechanisms for $[[.]]_h$ that are already in place. The most interesting aspect of this data point is that immediate composition occurs, although a case could be made that several LF layers are involved. Perhaps this teaches us about the role of DPs in the composition, *viz a viz* the clausal spine: DPs may be their own units, and definite DPs require a contextual interpretation. We come back to this point in the conclusions.

4.2 PSP in the Scope of a Quantifier

4.2.1 Facts

Next, we consider PSPs triggered in the scope of quantifiers. Tiemann (2014) reports results from eye tracking for sentences with *again* and the definite determiner in the scope of a universal quantifier as in (52) and (54) which suggest that (i) readers interpret a universal PSP (i.e. the PSP has to be fulfilled for all members of the restrictor of the universal quantifier) and (ii) there is no early context check for sentences with *again.* Finding (ii) contrasts with the findings for unembedded occurrences of *again* reportet for (1).

Trigger *wieder*:

(52) a. **Context 1:** *Marie, Sophie and Anna are all playing at a theatre. Last week, Sophie and Marie went ice-skating, whereas Anna has never been ice-skating yet.*
Context 2: *Marie, Sophie and Anna are all playing at a theatre. Last week, Sophie and Marie went ice-skating, whereas Anna went ice-skating two weeks ago.*
b. *Gestern war jede der drei Schauspielerinnen wieder Schlittschuhlaufen,*
yesterday was each of.the three actresses again ice-skating
weil *das Wetter so schön war*
because the weather so nice was

'Yesterday, each of the three actresses went ice skating again because the weather was so nice.'

The results show a significantly increased first pass duration on *weil* ('because') when (52b) was presented in Context 1 in contrast to when it was presented in Context 2. This effect occurs surprisingly late when compared to the results found for unembedded instances of *again* reported above. There we argued that the interpretation of sentences with *again* are an illustration of the ECC, repeated below.

(37) **Hypothesis Early Context Check ECC**:
In an input $\phi(P)$, if for all incremental "gaps" P, $c \geq \phi(P)$ or for all P: $c \geq \neg\phi(P)$, then context check is carried out immediately.

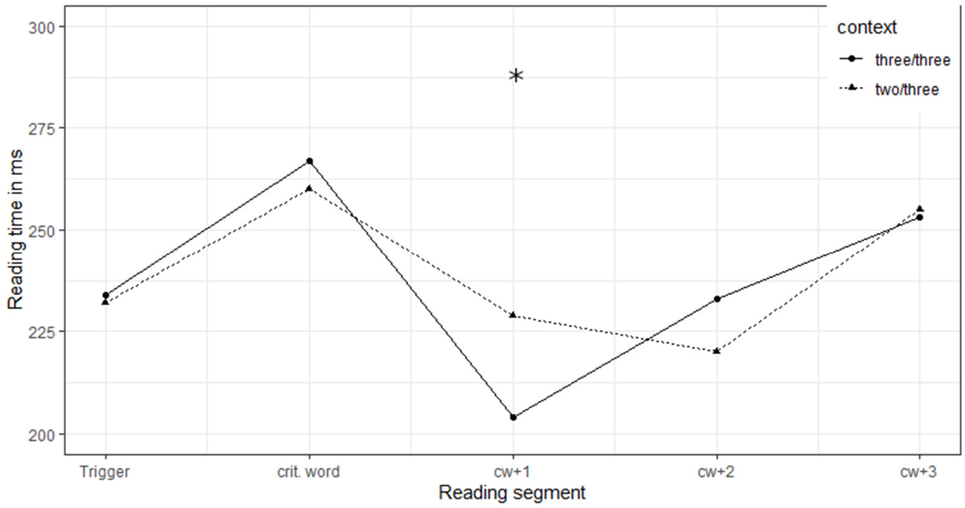

Figure 4. First pass durations in ms for sentences with 'each … again'—asterisks mark significant differences between the positive and neutral condition

Intuitively, it is not clear why there is no ECC type effect for (52), because the sentences in the experimental setting were such that as soon as (53) is encountered in Context 1, it is clear that an universal PSP of *again* cannot hold.

(53) *Gestern war jede der drei Schauspielerinnen wieder …*
Yesterday was each of.the three actresses again …

Trigger Definites:

(54) a. **Context 1:** *Sabine, Inge and Karin are at a conference. Sabine and Inge got a laptop from their employer recently, whereas Karin still has to buy a laptop.*
Context 2: *Sabine, Inge and Karin are at a conference. Sabine and Inge got a laptop from their employer recently, whereas Karin had to buy a laptop herself.*

b. *Heute hat jede der drei Konferenzteilnehmerinnen ihren Laptop*
today has each the three conference participants her laptop
***in** einer Sitzung benutzt*
in a meeting used

'Today, each of the three conference participants used her laptop in a meeting.'

Reading times came apart right after the definite DP was encountered (on *in* above). First pass times were significantly longer in Context 1 which didn't establish the PSP that each person attending the conference had a laptop, as opposed to Context 2 which established this PSP.

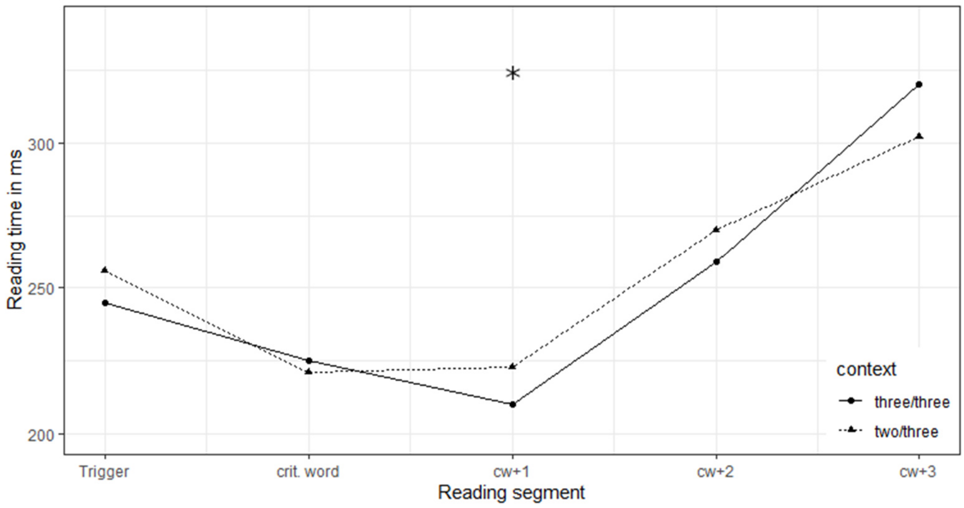

Figure 5. First pass durations in ms for sentences with 'each … definite'—asterisks mark sig. differences between the positive and neutral condition

When we compare the findings for universally quantified sentences with *again* to those with a definite determiner, it is also interesting to note that the effect for the unsupported PSP of *again* occurs **after** the quantifier and its arguments have been encountered, whilst the effect arises **within** the nuclear scope of the quantifier in sentences with the definite.

4.2.2 Towards an Explanation

Our suggestion is that the compositional calculation of the projected universal PSP causes delay in sentences with *again*.

Note that there is a potential ambiguity in (55a): the universal could outscope *again* (56a) or vice versa (56b). The two LFs lead to two different PSPs (assuming projection properties for *every* as in (55b), cf. Tiemann, 2014). The different PSPs are given in (57a) vs. (57b).

(55) a. *Every actress went ice skating again.*
b. [[every]] = $\lambda P.\lambda Q.\lambda w$: $\forall x[P(w)(x) = 1 \rightarrow Q(w)(x)$ is defined].
$\forall x[P(w)(x) = 1 \rightarrow Q(w)(x) = 1]$

(56) a. [every actress [1[again [x_1 went ice skating]]]]
b. [again [every actress [1 [x_1 went ice skating]]]]

(57) a. λw: $\forall x[actress(w)(x) \rightarrow \exists e'[\tau(e') < t_{topic}$ & $skate(w)(e')(x)]$.
$\forall x[actress(w)(x) \rightarrow \exists e[\tau(e) \subseteq t_{topic}$ & $skate(w)(e)(x)]$
PSP: 'For every actress, there is a past skating event/time.'

b. λw: $\exists e'[\tau(e') < t_{topic}$ & $\forall x[actress(w)(x) \rightarrow skate(w)(e')(x)]$.
$\forall x[actress(w)(x) \rightarrow \exists e[\tau(e) \subseteq t_{topic}$ & $skate(w)(e)(x)]$
PSP: 'There is a past event / time of all actresses skating.'

In the experimental items, at a certain stage of processing a partial tree containing (53') is reached.

(53') … [$_{AspP}$ [$_{DP}$ jede Schauspielerin] [$_{AspP}$ Asp [VP wieder …]]

We conjecture that the two constituents "jede Schauspielerin" and "wieder" are not composed. The heurstic mechanism employed at this stage is "**wait and see**", with the result in (58) for the partial tree (ignoring for the moment tense and the temporal adverbial). Composition proceeds when the whole tree is available, which is when "weil" is processed in the example. The standard interpretation function [[.]] can apply.

(58) S' = {[[jede Schauspielerin]]}∪{[[wieder]]}

We relate this effect and our explanation of it to observations in Hackl et al. (2012) and Bott & Schlotterbeck (2013) according to which composition of quantifiers may be delayed until the scope of the quantifier is ascertained. This leads to "late" effects in processing.

Next we ask how the case of the definite description (59) is different. There is no potential for scope ambiguity in the interaction between the universal and the definite. A LF tree with a gap for the verb (still to be processed) could look like (60). Ignoring tense, incremental composition can proceed to yield (61). The processing results suggest that this is what happens.

(59) a. Every participant used her laptop.
b. [every participant [1[x_1 used the laptop of x1]]]]
c. λw: $\forall x$[participant (w)(x) $\rightarrow$ $\exists!$y[laptop(w)(y) & own(w)(y)(x)].
$\forall x$[participant (w)(x) $\rightarrow$ use(w)(ιy:laptop(w)(y) & own(w)(y)(x))(x)]

(60) [$_{TP}$ heute [$_{T'}$ PAST [$_{AspP}$ [$_{DP}$ jede NP] [1[$_{AspP}$ Asp [$_{VP}$ t_1 [$_{DP}$ x_1's Laptop] …]]]]]]

(61) $\lambda R.\lambda w$:$\forall x$[participant (w)(x) $\rightarrow$ $\exists!$y[laptop(w)(y) & own(w)(y)(x)].
$\forall x$[participant (w)(x) $\rightarrow$ R(w)(ιy:laptop(w)(y) & own(w)(y)(x))(x)]

It seems that in this case, the confidence is high that whatever the final segment with the verb is, the scope position of the quantifier is certain. (61) is the input to further incremental interpretive processes including the speech act layer (61'), which allows for the context check to occur that we see in the processing results from Tiemann (2014). We phrase our preliminary proposal as in (62) for the specific issue at hand. (62) may be an instance of a more general principle governing the interpretation of quantifiers. We offer a tentative formulation in (63) but clearly, much further research is needed to understand when the processor postulates a scope position for a quantifier.

(61') $\lambda R.\lambda c$: $\forall w$[w$\in$c $\rightarrow$ $\forall x$[participant (w)(x) $\rightarrow$ $\exists!$y[laptop(w)(y) & own(w)(y)(x)].
c$\cap\lambda w.\forall x$[participant (w)(x) $\rightarrow$ R(w)(ιy:laptop(w)(y) & own(w)(y)(x))(x)]

(62) **Hypothesis Scope and PSP:**
If a PSP is triggered in the scope of a projection environment like a quantifier, compositional calculation of the projected PSP occurs when the scope position of the quantifier has been identified.

(63) **Hypothesis Scope:**
A quantifier is incrementally composed with its environment only when its scope position is identified.

4.3 Embedding under Negation

In another eye-tracking study, Schwarz & Tiemann (2012, 2016) investigated the processing of PSPs embedded under negation. To this end, they conducted a study which compared sentences with *again* above or below negation when the respective PSP was or was not supported by the preceding context (64). Surprisingly, they found no effects of an unsupported PSP under negation, whilst an unsupported PSP above negation gave rise to reading time effects.

(64) a. **Context 1**: *Tina went ice-skating for the first time last week with Karl.*
The weather was nice and they had a great time.
Context 2: *Tina wanted to go ice-skating for the first time last week with Karl.*
But the weather was miserable and they gave up on their plan.

b. *Dieses Wochenende war Tina* {***nicht wieder*** / ***wieder nicht***} *Schlittschuhlaufen,*
This weekend was Tina {not again / again not} ice-skating
weil das Wetter so schlecht war.
because the weather so bad was

'This weekend, Tina {didn't go ice-skating again / again didn't go ice skating} because the weather was so bad.'

The results show increased reading measures for *again not* sentences in Context 1 (PSP explicitly denied) compared to Context 2 (PSP explicitly given). However, there were no such effects for sentences containing *not again*.

We suggest that resolving the scopal relation of ASSERT and negation might play a role here:

(65) a. [ForceP ASSERT [nicht [wieder [Tina Schlittschuhlaufen]]]]
speaker S_c takes responsibility for the truth of the proposition that
Tina didn't go ice skating again (and proposes to add it to c)
b. [ForceP nicht [ForceP ASSERT [wieder [Tina Schlittschuhlaufen]]]]
speaker S_c does not take responsibility for the truth of the proposition that Tina
went ice skating again (and might suggest that it **cannot** be added to c)

The reading in (65b) can be made clearer by an intonational focus on again: "Tina didn't go ice-skating AGAIN. In fact, she had never been ice-skating before." This amounts to a reading in which the PSP of *again* is denied.

Delayed effects in processing could be accounted for under EI if both possibilities in (65) are entertained, since scopal ambiguity at LF can lead to delays—(66) is reminiscent of Bott & Schlotterbeck (2013) who found late effects for doubly quantified sentences in eye-tracking studies. This seems to be another case of '**wait and see**'.

(66) **Hypothesis Scope and PSP':**
If a PSP is triggered in an embedded position, its processing (including context check) may be delayed by LF ambiguity.

5 Conclusions

We have extended the model of Enlightened Incrementality, EI, from Beck & Tiemann (2018) to PSP. In addition to an incremental semantics, this requires an incrementally integrated pragmatic step. The pragmatic step is modelled here with a speech act operator in the structure, under background assumptions following in general terms Krifka (2014). The context change potentials that are calculated incrementally in this way allow us to develop hypotheses concerning when and how the processor refers to the context of an utterance. This is important because speakers' linguistic behaviour informs us on this step of context check and update. The context check and update, however, requires that incremental interpretation including the pragmatic step has taken place. Hence the model of incremental interpretation must extend to the pragmatic step; which reveals incremental properties of the interpretive processor.

This general result is solidly supported by very early processing of PSP facts, even though the specific hypotheses we propose in order to model the particular experimental results we report need more work. As interesting topics for future research, we mention two in particular:

Definite descriptions seem to be able to be integrated immediately with the context. This is not really expected under the current formulation of EI. But on an intuitive level, it makes sense that definites directly relate to the context. We speculate that EI has to treat DPs separately from the clausal spine (VP, AspP, TP etc.). This is not formally implemented at present.

The **scope position of quantifiers** is a complex issue, to which we have added the PSP triggered by definites vs. *wieder* / *again* under a quantifier. The general question of when the processor fixes the scope position of a quantifier interacts with the data that we have looked at.

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