

Psycholinguistic Background on Incremental Processing

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Why should we care about psycholinguistic modelling?

- Learn about human cognition
- Computational models allow to observe effect of specific processing assumptions
- Can make predictions which can then be tested experimentally

And even if you're only interested in NLP applications:

- Language generation more effective if the computer understands what the human can comprehend, what constructions are difficult
- Readability assessment
- Language teaching

Early Evidence for Incremental Processing

Human sentence processing is incremental

- **Shadowing task**: repeat spoken sentence; 250ms delay
- Type of errors / corrections show that people had processed the sentence up to the most recent word at **syntactic and semantic** level.
- *Incompatible* with processing models which assume that syntactic / semantic processing can only happen once the whole constituent is available.

[Marslen-Wilson 1973]

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- 2 Eye-tracking in Reading
 - C-command
 - Faster Reading Time through Prediction
- 3 Evidence from ERPs
- 4 Incrementality and Prediction beyond the sentence
 - Reading Time Experiment

The visual world paradigm

- Look at screen displaying scene while listening to language stimulus
- People tend to fixate at objects they are thinking about → mentioned in speech
- Useful to find out about people's interpretation and anticipations
- Use scene to set up a small world
 - + controllable
 - unnatural scenes
 - must look at something in the scene

Empirical Evidence for Incrementality and Prediction

Visual world experiment:

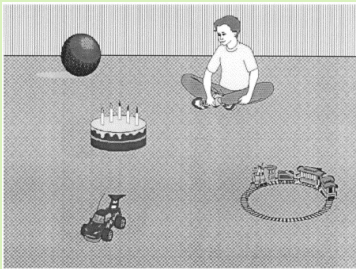
anticipatory eye-movements show that people predict subsequent input

Experiment on Incrementality and Prediction

[Altmann and Kamide, 1999]

“The boy will eat the cake.”

“The boy will move the cake.”



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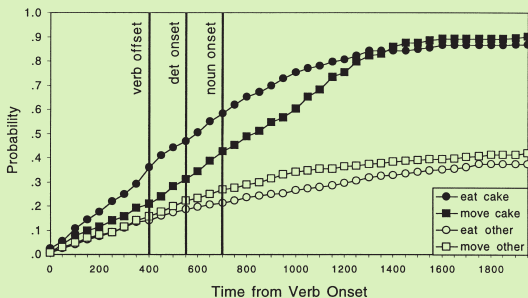
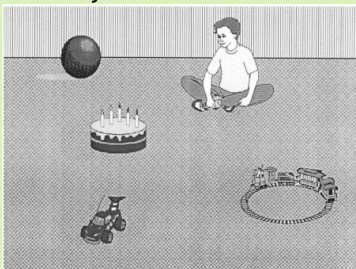
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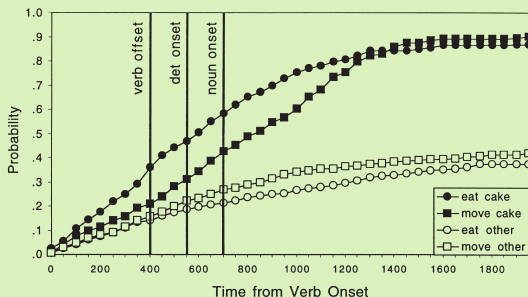
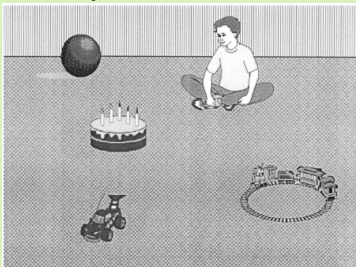
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Critique:

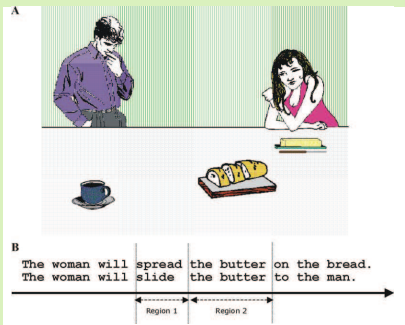
- only need “eat” to anticipate cake
- what else to look at?

Empirical Evidence for Incrementality and Prediction

Variant: time-course for prediction with goal PP

Experiment on Incrementality and Prediction

[Kamide et al, 2003]

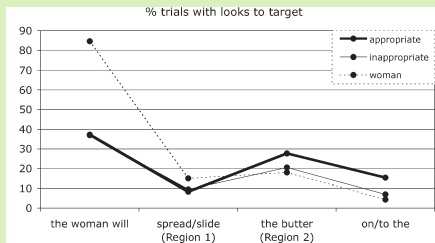
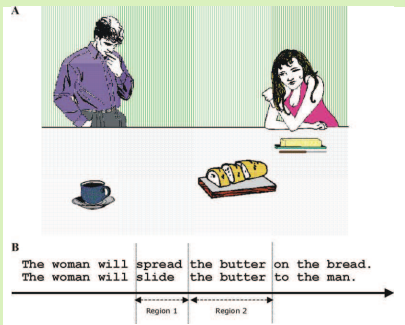


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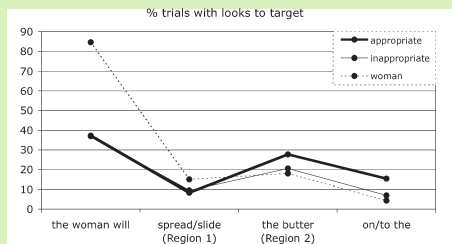
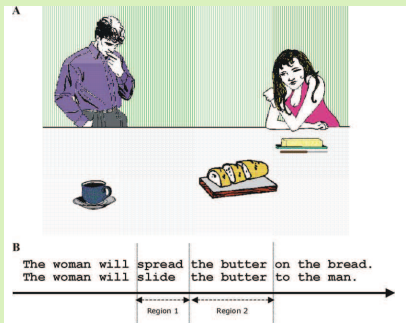


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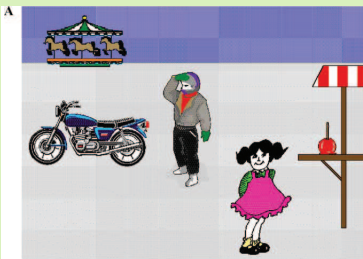
- only need “spread” / “slide” to anticipate goal

Empirical Evidence for Incrementality and Prediction

Variant: need combination of noun and verb

Experiment on Incrementality and Prediction

[Kamide et al, 2003]



B

The man will	ride	the motorbike.
The girl will	ride	the carousel.
The man will	taste	the beer.
The girl will	taste	the sweets.

Critique:

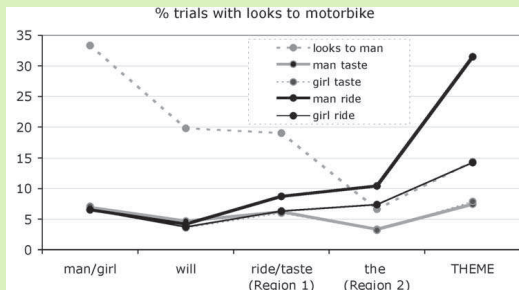
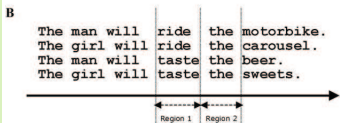
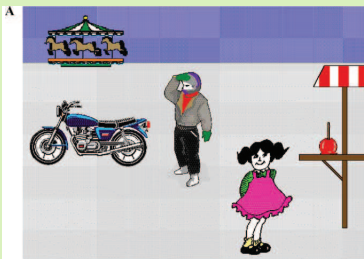
- Full connection / role assignment necessary?

Empirical Evidence for Incrementality and Prediction

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Critique:

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Empirical Evidence for Incrementality and Prediction

Visual world experiment:

anticipatory eye-movements show that people predict subsequent input

Experimental Findings: Incrementality and Prediction

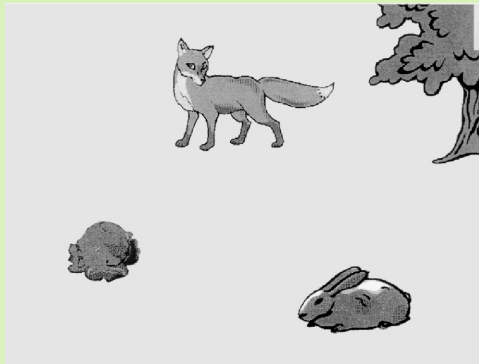
[Kamide et al. 2003]

“Der Hase frisst gleich den Kohl.”

The Hare-nom will eat soon the cabbage-acc.

“Den Hasen frisst gleich der Fuchs.”

The Hare-acc will eat soon the fox-nom.



Prediction of arguments vs. adjuncts

When do people anticipate upcoming material?

Prediction of Arguments vs. Adjuncts

[Arai and Keller, 2012]

Surprisingly, the nun punished the artist.

Surprisingly, the nun disagreed with the artist.



- Artist was looked at more during transitive verb.
- For intransitive condition, people look at artist when they hear the preposition (“with”).

Summary of experiments so far

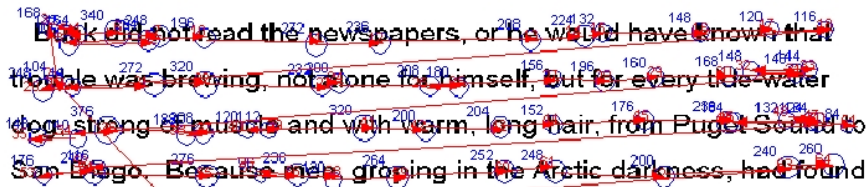
Results so far:

- Processing in general happens incrementally (syntax and semantics)
- Evidence for syntactic connectedness at specific points in the sentence (c-command relation)
- people anticipate arguments
- they do not (or at least not to a similar extent) anticipate adjuncts

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Eye-tracking in Reading



- Eyes don't move smoothly over text: fixations, saccades
- Oculomotor effects of saccade programming as well as linguistic effects
- Eye-mind link

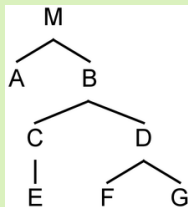
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Principal Idea: How to show incremental processing

- **Goal:** Prove that syntactic structure has been built to connect words
- Find a syntactic construction with structural constraint

C-Command



X c-commands Y iff:

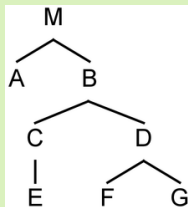
- X does not dominate Y
- Y does not dominate X
- The first branching node that dominates X also dominates Y

Notion useful for expressing some constraints in natural language.

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Empirical Evidence for Incrementality and Connectedness

Coordination processing: **structural binding** in c-command relation

Experiment on Incrementality and Connectedness [Sturt & Lombardo 2005]

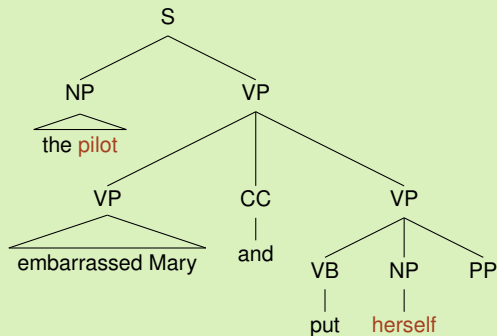
The pilot embarrassed Mary and put **herself** in an awkward situation.
himself
her

- Gender default mismatch difficulty occurred at first pass reading on pronoun “herself” (c-commanded by “pilot”).

Empirical Evidence for Incrementality and Connectedness

Coordination processing: **structural binding** in c-command relation

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Evidence for Incrementality and Connectedness

Incrementality and Connectedness (2)

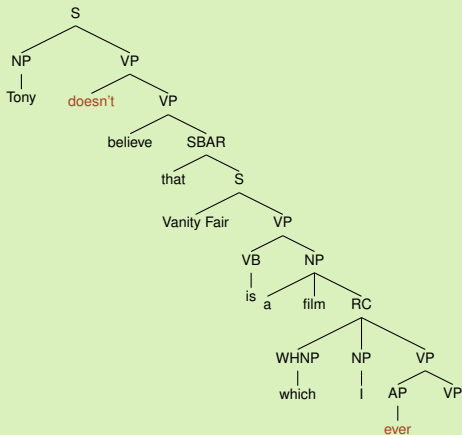
[Sturt & Yoshida, 2008]

Tony doesn't believe it, but Vanity Fair is a film which I ^{ever}_{never} really want to see.

Tony doesn't believe that Vanity Fair is a film which I ^{ever}_{never} really want to see.

- Incremental and connected processing in an object relative clause.
- *ever* / *never* is connected to the structure **before** RC verb has been perceived.

Evidence for Incrementality and Connectedness



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Empirical Evidence for Incrementality and Prediction

Processing facilitation in *either.. or* constructions

Experimental Finding: Prediction

[Staub & Clifton, 2006]

Peter read **either** a book **or an essay** in the school magazine.

Peter read a book **or an essay** in the school magazine.

- The presence of “either” leads to shorter fixation times on “or” and the second conjunct.
- processing facilitation through **prediction**

Violation of Agreement with Anticipated Noun

- **Idea:** Create context which is sufficiently constraining to make it possible for people to anticipate a specific noun.
- **Question:** Do people really have such strong anticipations?
- **Difficulty:** Measure *before* the noun itself.

Experimental Material

De inbreker had geen enkele moeite de geheime familiekluis te vinden.
[The burglar had no trouble locating the secret family safe.] (3)

Deze bevond zich natuurlijk achter een groot_{neu} maar onopvallend schilderij_{neu}. [Of course, it was situated behind a big- \emptyset _{neu} but unobtrusive painting_{neu}.] (consistent)

Deze bevond zich natuurlijk achter een grote_{com} maar onopvallende boekenkast_{com}. [Of course, it was situated behind a big-e_{com} but unobtrusive bookcase_{com}.] (inconsistent)

Result (Self-paced reading)

Reading Time (in Milliseconds) Results Across 37 Items With Inflected 2nd Adjective at cw + 3 in Experiment 3

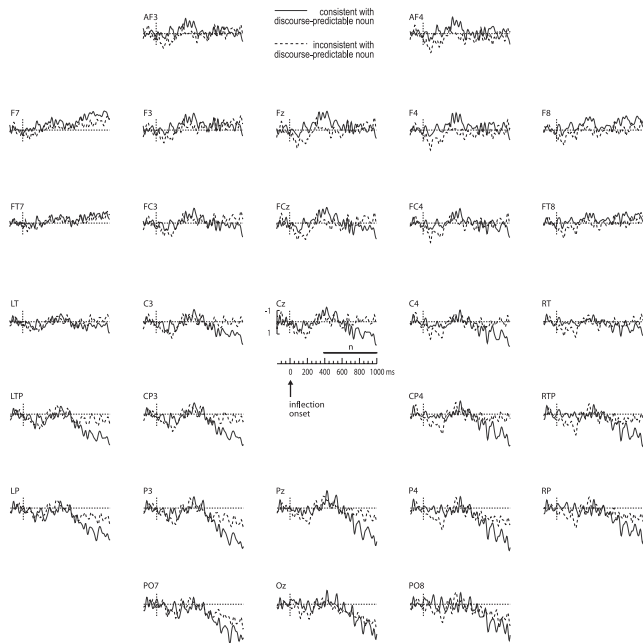
Results	Word								
	cw-4 . . .was	cw-3 situated	cw-2 behind	cw-1 a	Adj big-INFL	cw+1 but	cw+2 rather	cw+3 (adj2) unobtrusive-INFL	Noun painting/bookcase
Reading times									
Consistent	403	364	359	327	344	349	368	405	487
Inconsistent	397	362	361	336	349	353	370	426	591
Effect size	-6	-2	2	9	5	4	2	21	104
<i>F</i> test									
F_1 (1, 23)	0.66	0.31	0.13	2.46	0.81	0.26	0.08	4.50	19.08
F_2 (1, 35)	0.39	0.35	0.21	2.04	0.42	0.20	0.12	5.84	21.69
MSE_1	1431	1129	1128	828	843	1324	1230	2404	13608
MSE_2	2639	929	549	652	1089	1031	1393	1405	9211
p_1	.424	.721	.727	.130	.379	.616	.775	.045	.000
p_2	.537	.559	.651	.162	.523	.666	.727	.021	.000

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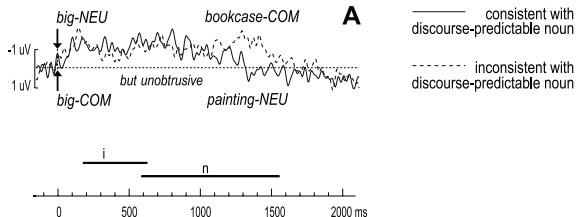
What's ERP / EEG?

- ERP = event related potentials
- EEG = electroencephalogram
- uses electrodes attached to head to measure electrophysiological responses
- good time resolution, not so good spatial resolution
- N400 (semantic effect: negativity after 400 msec)
- P600 (syntactic effect: positivity after 600 msec)
- P300 unexpected event

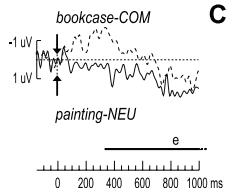
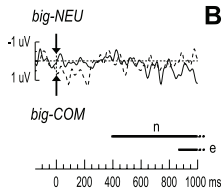


Study Results (1)

*The burglar had no trouble whatsoever
to locate the secret family safe.
Of course, it was situated behind a...*

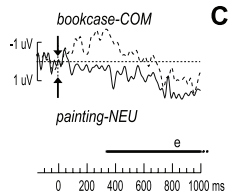
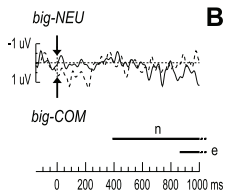


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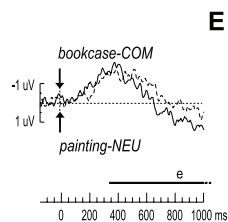
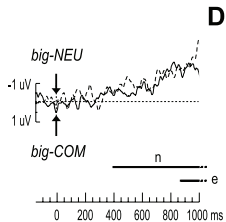
Study Results (2)

*The burglar had no trouble whatsoever
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Of course, it was situated behind a...*



[no predictive discourse context]

Of course, it was situated behind a...



Related Study for English

[DeLong et al., 2005]

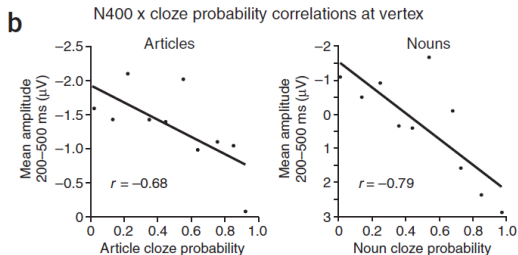
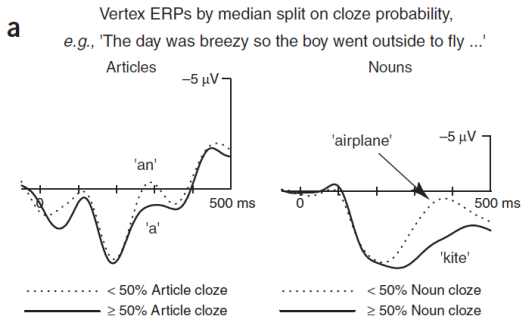


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Modelling Discourse

- Seen evidence for incremental processing and anticipation of upcoming material at syntax and semantics level
- How about discourse?
- Cristea and Webber (1997) observe that certain discourse connectors “raise expectations” (e.g. *on the one hand...on the other hand*)
- Do the underlying assumptions of incremental, eager, predictive processing also hold at discourse level?
- Start at discourse connectives (*but, although, however...*)

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Discourse Connectives and Incremental Processing

Are discourse cues processed **incrementally**?

Can people make **predictions** based on discourse cues?

- Connective Integration Model (Millis & Just, 1994): When connective encountered, preceding part buffered, integration at the end
- Incremental processing (Traxler, Bybee, & Pickering, 1997)
- Evidence for incremental processing of causals, but without connector (Kuperberg, Paczynski, & Ditman, 2011)

Experiment on time course of integration of causal and concessive connectors
(therefore / however)

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(therefore / however)

Experiment on Discourse Connectors



Steffen denkt über einen kleinen Snack nach. Er hat gerade Lust, etwas Süßes zu essen.

Daher holt er sich aus der Küche die appetitliche Waffel.

Dennoch holt er sich aus der Küche die appetitliche Brezel.

Experiment on Discourse Connectors

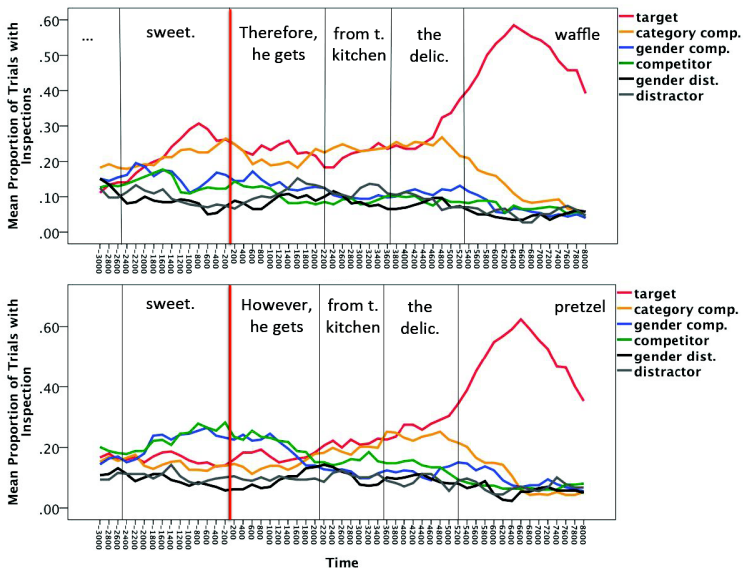


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Experiment on Discourse Connectors



Results of 1st Experiment

Results from Visual World Experiment:

- Discourse connector is integrated incrementally.
- In a strongly predictive context, people do make predictions based on discourse cue.
- In causal condition predictions rapid and stable enough to combine with grammar information to also predictively identify target referent.

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2nd Experiment: Reading

Materials

Sonja hat für das Wochenende geplant, eine schöne Schwitzkur und einen Herbstspaziergang zu machen. Sie freut sich am meisten auf die wohlige Wärme.

Causal

- **Daher** geht sie als erstes gut gelaunt in [die vermisste]_{pretarget} Sauna
- **Daher** geht sie als erstes gut gelaunt in [den vermissten]_{pretarget} Wald

Concessive

- **Dennoch** geht sie als erstes gut gelaunt in [den vermissten]_{pretarget} Wald
- **Dennoch** geht sie als erstes gut gelaunt in [die vermisste]_{pretarget} Sauna

und verbringt dort mehrere Stunden.

- 32 participants, 24 items

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und verbringt dort mehrere Stunden.

Results:

- **Causal conditions:** Significant effect on first pass, go past, total times in pre-target region
- **Concessive conditions:** Marginal effect on first pass in pre-target region

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Results:

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- **Concessive conditions:** Marginal effect on first pass in pre-target region

Results Reading Experiment

- Mismatch effect in causal condition = people are able to be predictive at this point and level of detail.
- But effect only marginal in concessive condition
- No effect = shallow interpretation? or no rapid integration of discourse connector?
- Alternative explanation: scope of concessive more variable than scope of causal?

Wider scope for concessives?

[Sonja was planning to do A and B. (She wants A the most)] Therefore A.

[Sonja was planning to do A and B. (She wants A the most)] However B / C.

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Summary for Discourse level predictions

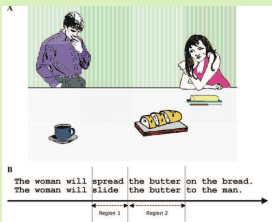
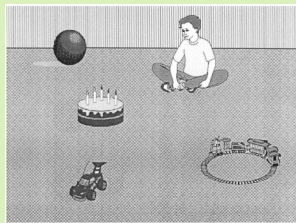
The two experiments show

- evidence for **incremental processing** of discourse connectives
- some evidence for generation of **predictions based on discourse connectives**

Overall summary and conclusions

Evidence for incremental processing and even predictive processes

- Visual World and Eye-tracking
- Eye-tracking in Reading
- ERP / EEG

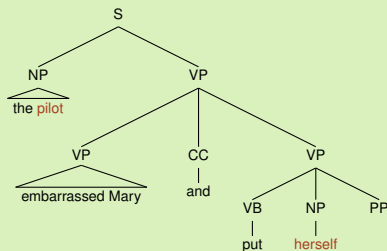


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Either..or



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- Eye-tracking in Reading
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