Sentence comprehension in a wider discourse

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When do listeners and readers use discourse context?
lots of ERP data

Well, yes, but how do they do it?
more ERP data

Where to go from here?
No brains in this talk...
Only **EEG** (and **ERPs**, average bits of EEG timelocked to some event X)
Event-related brain potentials

Gazzaniga, Ivry, and Mangun (1998)
Sentence comprehension proceeds incrementally

Snowwhite kissed a dwarf before she left.
The N400 reflects normal processes in integration.

Snowwhite kissed a dwarf before she left.

The amplitude of the N400 indexes the ease of semantic integration.
Once upon a time, a bunch of dwarfs stumbled across...

Snowwhite kissed a dwarf before she left.
Once upon a time, a bunch of dwarfs stumbled across…

Snowwhite kissed a dwarf before she left.

When does the brain use discourse context?
Two kinds of answers

Common sense:

"Right away, of course!"

Many cognitive scientists:

"Sentence-internal processing is fast...

*but* discourse-level processing *is slow*"
Listening

Cutler & Clifton, 1999

ZAP!

a linguistic reflex

slow inferencing
Once upon a time, a bunch of dwarfs stumbled across...

When does the brain use discourse context?

When do people relate a word’s meaning to discourse context?

Snowwhite kissed a dwarf before she left.
Study 1: Discourse-dependent semantic anomalies

Jane told her brother that he was exceptionally ...

slow

quick
As agreed upon, Jane was to wake her brother and sister at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed. Jane told her brother that he was exceptionally ...
As agreed upon, Jane was to wake her brother and sister at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed. Jane told her brother that he was exceptionally …

**Study 1: Discourse-dependent semantic anomalies**

People just listen (or read through) a bunch of stories, without any additional task.
A discourse-dependent N400 effect while listening

As agreed upon, Jane was to wake her brother and sister at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed. Jane told her brother that he was exceptionally ...
As agreed upon, Jane was to wake her brother and sister at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed. Jane told her brother that he was exceptionally ...
...regardless of where the word is in the sentence
...and regardless of word length

[Graph showing EEG waveform for short and long words, with labels for words 1, 2, word, 40, 51, 52, ..., 80.]

- Red dashed line: anomalous in discourse
- Black line: coherent in discourse
Discourse kicks in well before acoustic word offset

As agreed upon, Jane was to wake her brother and sister at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed. Jane told her brother that he was exceptionally ...
Really a discourse effect?

As agreed upon, Jane was to wake her brother and sister at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed. Jane told her brother that he was exceptionally …

van Berkum, Zwitserlood, Hagoort & Brown (2003), *Cognitive Brain Research*

van Berkum, Hagoort & Brown (1999), *Journal of Cognitive Neuroscience*
Control: taking the discourse context away

Jane told her brother that he was exceptionally …
So this really is a discourse-dependent effect

As agreed upon, Jane was to wake her brother and sister at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed. Jane told her brother that he was exceptionally ...
As agreed upon, Jane was to wake her brother and sister at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed. Jane told her brother that he was exceptionally...
The N400 reflects normal processes in integration.

The amplitude of the N400 component indexes the ease of semantic integration.

Snowwhite kissed a dwarf before she left.
Study 2: Discourse-dependent subtle differences in fit

The brave knight saw that the dragon threatened the benevolent sorcerer. Quickly he reached for a ...
Study 2: Discourse-dependent subtle differences in fit

The brave knight saw that the dragon threatened the benevolent sorcerer. Quickly he reached for a ...

What aspect of prior discourse is responsible for these discourse-dependent N400 effects???
Is it really the precise combinatorial message that does it?

1. Precise combinatorial message (& the bag of words) prefers “sword”

   The brave knight saw that the dragon threatened the benevolent sorcerer.
   Quickly he reached for a…
   
   sword
   lance

2. Only the bag of words prefers “sword”

   The benevolent sorcerer saw that the dragon threatened the brave knight.
   Quickly he reached for a…
   
   sword
   lance
Study 2: Support from precise message & bag of words

The brave knight saw that the dragon threatened the benevolent sorcerer. Quickly he reached for a ...
Study 2: Support from the bag of words only

The benevolent sorcerer saw that the dragon threatened the brave knight. Quickly he reached for a ...
Study 2: Difference waves for “lance” - “sword”

Precise message support

Bag-of-words support only

N400 effect
Study 3: Discourse against ‘local semantics’

Can discourse context neutralize this local lexical-semantic animacy violation?

The peanut was ...

Journal of Cognitive Neuroscience

Mante Nieuwland
A woman saw a dancing peanut who had a big smile on his face. The peanut was singing about a girl he had just met. And judging from the song, the peanut was totally crazy about her. The woman thought it was really cute to see the peanut singing and dancing like that.

The peanut was ...

and by the sound of it, this was definitely mutual. He was seeing a little almond.
When does the brain use discourse context?

Once upon a time, a bunch of dwarfs stumbled across…

"Right away, of course!"

Word meaning is immediately related to discourse context

Snowwhite kissed a dwarf before she left.
When does the brain use discourse context?

How about establishing reference i.e., finding out to what or whom particular expressions refer?

Snowwhite kissed a dwarf before she left.
Study 4: Discourse-dependent referential ambiguity

2-ref: David had asked the two girls to clean up their room before lunchtime. But one of the girls had stayed in bed all morning, and the other had been on the phone all the time. David told the girl ...

1-ref: David had asked the boy and the girl to clean up their room before lunchtime. But the boy had stayed in bed all morning, and the girl had been on the phone all the time. David told the girl ...
Study 4: Discourse-dependent referential ambiguity

2-ref: David had asked the two girls to clean up their room before lunchtime. But one of the girls had stayed in bed all morning, and the other had been on the phone all the time. David told the...

1-ref: David had asked the boy and the girl to clean up their room before lunchtime. But the boy had stayed in bed all morning, and the girl had been on the phone all the time. David told the...


Study 5: Discourse-model referential ambiguity

The Nref effect only emerges when there is true discourse-model referential ambiguity.

David had asked the two girls to clean up their room before lunchtime. But one of the girls had been sunbathing in the front yard all morning, and the other had actually just driven off in his car for some serious downtown shopping. As he gazed at the empty driveway, David told the …
Reference and word meaning

Problems with reference and problems with word meaning recruit (at least partially) non-overlapping neuronal ensembles

Mante Nieuwland

Nieuwland, Petersson & Van Berkum (in press)

Karl Magnus Petersson
When does the brain use discourse context?

People immediately look for suitable discourse referents.

Snowwhite kissed a dwarf before she left.
When does the brain use discourse context?

How about constraints on parsing i.e., can discourse-referential ambiguity affect ongoing syntactic analysis?

Snowwhite kissed a dwarf before she left.
Study 6: Can discourse context guide syntactic analysis?

*David told the girl that...*

**complement clause**

\[ \text{there would be some visitors soon} \]_{cc}

**relative clause**

\[ \text{had been on the phone} \]_{rc} to hang up

van Berkum, Brown, & Hagoort (1999) *Journal of Memory and Language*
Without any context, the parser chooses a CC analysis.

David told the girl that...

David vertelde het meisje dat...
...which it can maintain at “there”

David told the girl that...

[there would be some visitors soon]_{cc}

David vertelde het meisje dat...

[er visite kwam]_{cc}
…but with which it runs into a dead end at “had”

David told the girl that...

[there would be some visitors soon]_{CC}

[had been on the phone]_{RC} to hang up

David vertelde het meisje dat...

[er visite kwam]_{CC}

[had zitten bellen]_{RC} op te hangen
...where it has to abandon its preferred CC analysis

David told the girl that...

[there would be some visitors soon]$_{CC}$

[had been on the phone]$_{RC}$ to hang up

P600 effect

David vertelde het meisje dat...

[er visite kwam]$_{CC}$

[had zitten bellen]$_{RC}$ op te hangen
One girl in the discourse context: no change

David told the girl that...

[there would be some visitors soon]$_{CC}$
[had been on the phone]$_{RC}$ to hang up

P600 effect

David vertelde het meisje dat...

[er visite kwam]$_{CC}$
[had zitten bellen]$_{RC}$ op te hangen
Two girls in the discourse context: preference is changed!!

David told the girl that…

[there would be some visitors soon]$_{CC}$

[had been on the phone]$_{RC}$ to hang up

P600 effect

David vertelde het meisje dat…

[er visite kwam]$_{CC}$

[had zitten bellen]$_{RC}$ op te hangen
Discourse-referential modulation of syntactic analysis

David had asked the boy and the girl / the two girls ...

David told the girl that [there …]_{CC}

David told the girl that [had …]_{RC} ...

\textbf{P600}
When does the brain use discourse context?

Once upon a time, a bunch of dwarfs stumbled across…

Snowwhite kissed a dwarf before she left.
Words are immediately related to the wider discourse

Just as the elderly hippie had lit up a joint, he got a visit from a friend and a nephew (two friends). Even though his friend (one of his friends) had had quite a few drinks already, and the nephew (the other one) had just been smoking quite a lot already, they insisted on smoking along. The hippie warned the friend that there would be some problems/fascists soon.

referentially induced frontal negative shift

syntactic P600 effect

semantic N400 effect
When does the brain use discourse context?

Once upon a time, a bunch of dwarfs stumbled across…

"Uhhh, no!"

Can people also use discourse context to anticipate specific upcoming words ‘on the fly’?

Snowwhite kissed a
The burglar had no trouble at all to locate the secret family safe. Of course, it was situated behind a...
The burglar had no trouble at all to locate the secret family safe. Of course, it was situated behind a…

painting

neuter-gender noun
The burglar had no trouble at all to locate the secret family safe. Of course, it was situated behind a...

\[
\begin{align*}
\text{big}_{\text{neu}} & \quad (\text{groot}) & \quad \text{prediction-consistent} \\
\text{big}_{\text{com}} & \quad (\text{grote}) & \quad \text{prediction-inconsistent}
\end{align*}
\]
When does the brain use discourse context?

People use discourse context to immediately anticipate specific upcoming words ‘on the fly’.

Snowwhite kissed a dwarf.
When does the brain use discourse context?

So, textual discourse context is used immediately to make sense, to establish reference, to parse, & to predict upcoming language.

Snowwhite kissed a dwarf before she left.
What about other types of ‘discourse context’?

- **the text**
  - i.e., what has been told so far

- **the speaker**
  - i.e., who is telling it

- **currently unfolding utterance**
What about other types of ‘discourse context’?

**the speaker**

i.e., who is telling it

“I want you out!”
Study 8: When do listeners take the speaker into account?

“When I think I am pregnant”

When and how do listeners relate what’s being told to who is telling it?

When do we take into account that somebody is a compulsory liar?

a politician before elections?

a soccer referee?

“I think I am pregnant”
The standard model: 2-step interpretation

I think I am ... pregnant

Wider theoretical context

Lattner & Friederici, 2003: speaker info is used late

Compute what it really means in context after ~600 msec

~200-500 msec

Compute sentence meaning

the speaker

lexical semantics (‘linguistic word meaning’)
The alternative: immediately contextualized (‘1-step’) interpretation

Compute what it really means in context

I think I am ... pregnant
Study 8: When do listeners take the speaker into account?

(1) speaker-consistent (80 sentences)
  e.g. female voice:  “I think I am pregnant because I feel sick”

(2) speaker-inconsistent (80 sentences)
  e.g. male voice:   “I think I am pregnant because I feel sick”

Van Berkum, Van den Brink, Kos, Tesink & Hagoort (submitted)
Study 8: When do listeners take the speaker into account?

(1) speaker-consistent (80 sentences)
   e.g. female voice: “I think I am pregnant because I feel sick”

(2) speaker-inconsistent (80 sentences)
   e.g. male voice: “I think I am pregnant because I feel sick”

female voice: “I think I am pregnant because I feel sick”
male voice: “I think I am pregnant because I feel sick”

mature voice: “I always like to have a cigar after dinner”
young voice: “I always like to have a cigar after dinner”

lower-class accent: “I have a big tattoo on my back”
upper-class accent: “I have a big tattoo on my back”
Study 8: When do listeners take the speaker into account?

(1) speaker-consistent (80 sentences)
   e.g. female voice: “I think I am pregnant because I feel sick”

(2) speaker-inconsistent (80 sentences)
   e.g. male voice: “I think I am pregnant because I feel sick”

![Graph showing N400 effect](image)
The standard model: 2-step interpretation

I think I am ... pregnant

Wider theoretical context

Lattner & Friederici, 2003: speaker info is used late

The speaker

Compute what it really means in context

Compute sentence meaning

Lexical semantics (‘linguistic word meaning’)

after ~600 msec

~200-500 msec
Study 8: When do listeners take the speaker into account?

Listeners need only some 200-300 ms to relate what’s being told to who’s telling it.
Summary of findings so far

(1) The system is *incremental all the way up to the discourse*

- Words are immediately related to the wider textual discourse, in terms of their meaning and what they refer to
  - discourse kicks in at every word
  - discourse kicks in rapidly at the word (e.g., as it is still unfolding)
- Word meaning is also immediately related to the speaker

(2) Discourse can rapidly feed into parsing and prediction

- Discourse context can immediately guide the syntactic parser
- Discourse context can help people anticipate words on the fly
Cutler & Clifton, 1999

ZAP!

a linguistic reflex

Cutler & Clifton, 1999
(1) When do listeners and readers use discourse context? 
   lots of ERP data

(2) Well, yes, but how do they do it? 
   more ERP data

(3) Where to go from here?
The short answer

We don’t know yet
One additional consistent finding

(3) The system doesn’t seem to care much about where the constraints on interpretation come from

- Whether contextual constraints on *making sense* come from
  - the first few words of a single sentence
  - what the wider discourse is about
  - or who is talking

integrating the incoming word is reflected in the N400
Sentence- and discourse-dependent N400 effects

Sentence, written

Discourse, written

Sentence, spoken

Discourse, spoken
Sentence- and **speaker**-dependent N400 effects

Havana has a nice **nose**

man: I think I’m **pregnant**
One additional consistent finding

(3) The system doesn’t seem to care much about where the constraints on interpretation come from

- Whether contextual constraints on making sense come from
  - the first few words of a single sentence
  - what the wider discourse is about
  - or who is talking
  integrating the incoming word is reflected in the N400

- Whether contextual constraints on establishing reference come from
  - the first few words of a single sentence
  - what the wider discourse is about
  having too many referents elicits an Nref effect
Discourse- & sentence-dependent Nref effect

2-ref: David had asked the two girls to clean up their room before lunchtime. But one of the girls had stayed in bed all morning, and the other had been on the phone all the time. David told the...

1-ref: David had asked the boy and the girl to clean up their room before lunchtime. But the boy had stayed in bed all morning, and the girl had been on the phone all the time. David told the...

| 2-ref: David shot at John as... |
| 1-ref: David shot at Linda as... |

A

written noun

Nref effect

B

spoken noun

Nref effect

C

written pronoun

Nref effect

D

spoken pronoun

Nref effect
“Is there such a thing as text comprehension?”

Isn’t it just

- sentence-level ‘linguistic’ processing…
- + more memory demands…
- + more executive control?

Is there such a thing as sentence comprehension?

- Does it really matter whether the interpretive context for some word is defined by the first few words of a single unfolding sentence or by a prior text?
- or a visual scene…
- or an accompanying gesture…
- or what we know about the speaker…
'global' comprehension (what does it mean in context?)

Local sentence comprehension (context-free meaning)

Cutler & Clifton, 1999
Global comprehension

Integration into discourse model

Utterance interpretation
  - syntactic analysis

Recognize
  recognition
    - activation of lexical candidates
    - competition
    - retrieval of lexical information

Segment
  Exploitation of segmentation cues
    Phonetic processing (segmental and suprasegmental)

Decode
  Select speech from acoustic background
    Transform to abstract representation

Auditory input

Cutler & Clifton, 1999
Wider theoretical context

The standard model: 2-step interpretation

- the speaker
- the current situation
- the prior discourse
- lexical semantics (‘linguistic word meaning’)

Compute what it really means in context

Compute sentence meaning

I think I am ... pregnant
Wider theoretical context

The alternative: 
immediately contextualized (‘1-step’) interpretation

the speaker
the current situation
the prior discourse
lexical semantics
(‘linguistic word meaning’)

Compute what it really means in context

I think I am ... pregnant
Not necessarily simple, though!

- We’ve seen various ERP effects come out of this box...
  - Nref effect – referential ambiguity
  - N400 effect – semantic integration
  - and more...

- The interpretation system seems two-step (or ‘two-stream’) in another way
  - Precise combinatorial message
  - Bag-of-words processing (heuristic/shallow, semantic memory-based, coarse coding)
**Study 2: Differential effect for “lance” - “sword”**

1. Precise combinatorial message (& the bag of words) prefers “sword”

   The brave knight saw that the dragon threatened the benevolent sorcerer. Quickly he reached for a... 

   ![Diagram](image)

   N400 effect

2. Only the bag of words prefers “sword”

   The benevolent sorcerer saw that the dragon threatened the brave knight. Quickly he reached for a...

   ![Diagram](image)

   ???
Animacy violations in a minimal sentence context...

Coherent
The woman then told the tourist that she thought he looked really trendy...

Anomalous
The woman then told the suitcase that she thought he looked really trendy...

Mante Nieuwland

Nieuwland & Van Berkum (2005)
Cognitive Brain Research
...elicit a standard N400 effect

Coherent

The woman then told the **tourist** that she thought he looked really trendy…

Anomalous

The woman then told the **suitcase** that she thought he looked really trendy…

Mante Nieuwland

Nieuwland & Van Berkum (2005)
Cognitive Brain Research
Study 9: In particular types of discourse...

A tourist wanted to bring his huge suitcase onto the airplane. However, because the airplane was so heavy the woman behind the check-in counter wanted to charge the tourist extra. In response, the tourist opened his suitcase and threw some stuff out. So now the suitcase of the resourceful tourist weighed less than the maximum twenty kilos.

Coherent continuation

The woman then told the *tourist* that she thought he looked really trendy...

Anomalous continuation

The woman then told the *suitcase* that she thought he looked really trendy...

- scenario-relevant
- no focus via prosody

Mante Nieuwland

Nieuwland & Van Berkum (2005)
Cognitive Brain Research
A tourist wanted to bring his huge suitcase onto the airplane. However, because the airplane was so heavy the woman behind the check-in counter wanted to charge the tourist extra. In response, the tourist opened his suitcase and threw some stuff out. So now the suitcase of the resourceful tourist weighed less than the maximum twenty kilos.

Coherent continuation

The woman then told the tourist that she thought he looked really trendy…

Anomalous continuation

The woman then told the suitcase that she thought he looked really trendy…

... the global incoherence is temporarily overlooked!

Nieuwland & Van Berkum (2005)
Cognitive Brain Research
We’ve seen various ERP effects come out of this box…
- Nref effect – referential ambiguity
- N400 effect – semantic integration
- and more…

The interpretation system seems two-step (or ‘two-stream’) in another way
- Precise combinatorial message
- Bag-of-words processing (heuristic/shallow, semantic memory-based, coarse coding)
Overview

(1)
When do listeners and readers use discourse context?
lots of ERP data

(2)
Well, yes, but how do they do it?
more ERP data

(3)
Where to go from here?
Just as the elderly hippie had lit up a joint, he got a visit from a friend and a nephew (two friends). Even though his friend (one of his friends) had had quite a few drinks already, and the nephew (the other one) had just been smoking quite a lot already, they insisted on smoking along. The hippie warned the friend that there would be some problems/fascists soon.
Unraveling how the brain makes sense of discourse
Some doubts… for this workshop only

• OK, so discourse context kicks right in, but still, can we really do without a separate context-free “sentence meaning”?
  • Our ERP findings do not need it (parsimony), but do they rule it out?
  • There may be other – e.g. analytic – reasons that dictate it
  • Contextually enriched sentence meaning?

• OK, so ERPs allow us to selectively keep track of subprocesses in text comprehension, but
  • We don’t know all that much about what they reflect…
  • …and ‘syntax’ / ‘semantics’ / ‘reference’ are for sure too big a target
  • We’re getting some odd findings (e.g., semantic P600 effects, ‘N400-like’ but left-lateralized scenario effects)
(1) Neuro-imaging research has focussed on sentence issues

This should change!

- sentence linguistics
- sentence processing theories
- neuro-imaging of language comprehension

- text & discourse processing theories
- text & discourse linguistics
- SMF theory, resonance, search after meaning, ...

Relevance, common ground, DRT, SS, ...

What does the N400 really reflect?
(2) Mutual reluctance to combine T&D with neuroimaging

sentence linguistics

sentence processing theories

neuro-imaging of language comprehension

“relate to what’s been done before”

“I’d better keep the stimuli simple”

text & discourse theories

text & discourse processing theories

“I don’t have a lab, nor any experience”

“what’s to be gained anyway?”
Dim the lights and give simple stimuli only?
I think abortion should be forbidden categorically.

If my child were homosexual, I'd find this easy to accept.

I think the emancipation of women is a positive development.

Watching TV to relax is wrong in my eyes.
addressee (participant)

director (confederate)
Take thee, uhm, the shape with thee, uhm, thuh circle above the triangle and, uhm . . . Yeah, the dancer.

Ya mean thuh one that looks like uhm, like a dancer with a fat leg?
Take thee, uhm, the shape with thee, uhm, thuh circle above the triangle and, uhm . . .
Yeah, the dancer.

Ya mean thuh one that looks like uhm, like a dancer with a fat leg?
(3) A gap between sentence- and discourse-communities

sentence linguistics

CUNY, AMLaP

sentence processing theories

CNS, HBM

text & discourse linguistics

ST&D

text & discourse processing theories

neuro-imaging of language comprehension