Language comprehension

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Outline
- Words vs. sentences
- Sentence comprehension
  - What's involved?
  - Difficulties with the syndrome approach
  - Syndromes not homogeneous with regard to syntactic deficits
- Theoretical models of sentence comprehension
- How patterns of breakdown inform these models
- Neural substrate revealed by brain imaging

Comprehension
- Individual words
  - Sounds (Pure word deafness)
  - Meanings (Wernicke's aphasia)
- Sentences (Broca's aphasia)
- Intended meaning (right hemisphere)
- In this lecture we will focus on sentence comprehension

Sentence comprehension
- Use syntactic information to understand meaning
  - Structure building
  - Checking agreement
  - Mapping thematic roles
  - Complexity

Sentence Comprehension
(1) Structure building
- Combining words into larger units based on word-category information + grammatical rules
  - E.g. 'cat' + 'the' + rule [det-noun=legal noun phrase] => "the cat" (and not 'cat the')

Sentence Comprehension
(2) Checking agreement
- E.g. marking for number, case, gender
  - The daughters of the colonel who were killed
  - The daughters of the colonel who was killed
**Sentence Comprehension**

- (3) Mapping thematic roles
  - map roles such as agent ('do-er') and patient ('do-ee') onto certain positions in the sentence
  - John loves Mary ≠ Mary loves John
  - Not always easy: agent does not always precede patient
    - The dog was chased by the cat

- (4) Complexity
  - Sentence is more complex if order of noun phrases that receive thematic roles deviates from usual agent-before-patient order
  - Patient-first imposes larger burden on working memory
    - Simpler: the reporter who attacked the senator
    - Complex: the reporter who the senator attacked

**Comprehension and aphasia**

- Broca's aphasics - difficulty comprehending syntax-driven meaning
  - E.g. reversible passive sentences
    - The brown horse is chased by the white dog

**The Wernicke-Geschwind model**

- Broca's area = seat of syntax?

**Problems with the syndrome approach**

- Broca's aphasics don't show uniform syntactic problems
  - Degree of agrammatic speech not correlated with degree of asyntactic comprehension
  - Double dissociation between agrammatism and asyntactism
  - Comprehension deficits on reversibles – worse on passives than actives
  - => Working memory problem?
Problems with the syndrome approach

- Grammaticality judgement preserved in patients with agrammatic speech and asyntactic comprehension
- Morphological deficits dissociate from word order problems
- Morphological deficits associated with damage to anterior temporal lobe, not Broca’s area

Problems with the syndrome approach

- Attempt to tie some type of syntactic processing deficit to clinical category of Broca’s aphasia has not proved fruitful
- Case studies showing dissociations have proved more useful

Main findings from behavioural and imaging work

- Behavioural: Semantics and syntax are independent, dissociable systems
- Behavioural: Semantic and syntactic systems interact
- Behavioural: Operation of combining semantic constraints (thematic roles) and syntactic structure may be selectively impaired
- Behavioural: There may be separate working memories for phonological information, lexical-semantic information, and syntactic information
- Behavioural: No clean loss of specific syntactic operations. Specific syntactic rules/operations may be differentially impaired, but parsing theory not well enough advanced to explain current data - Better cognitive level theory required
- Imaging: Temporally, syntax processing is initially autonomous (modular?) but later interacts with semantic processing
- Imaging: No syntax processing module (for comprehension) is apparent in the substrate. Network of areas, different areas recruited for different tasks

Sentence processing theories

1. Serial / syntax-first model
   - Syntactic structure derived autonomously based on word-class information, prior to semantic information (e.g., Frazier, 1987)

2. Interactive / constraint satisfaction model
   - All types of information interact at each stage of language comprehension (e.g., Marslen-Wilson & Tyler, 1980)

Sentence processing theories

- Interactivity does not rule out independent structures for different types of knowledge

Boland’s concurrent model (1997)
Sentence processing theories

Spivey and Tanenhaus's (1998) constraint-based model of comprehension

The evidence examined by...

The woman examined...

(NB importance of frequency)

Insights from cognitive neuropsychological approach (patient case studies)

- Dissociation between semantic and syntactic knowledge (Hodges et al., 1994; Ostrin & Tyler, 1995)
- Interactions between syntax and semantics (Saffran, Schwartz, & Linebarger, 1998)
- Mapping between grammatical and thematic roles (Breedin & Martin, 1996)
- Working memory (Martin & Roman, 1994)
- Differential loss of syntactic operations (Caplan & Hildebrandt, 1987)

Semantic vs. syntactic knowledge

- Selective preservation of syntax in presence of semantic disruptions in Alzheimer's dementia & progressive aphasia
- Patient PP (Hodges et al., 1994): no sensitivity to semantic violations in word monitoring

Examples of Word Monitoring Materials Used by Tyler and Colleagues (from Hodges et al., 1994 and Tyler, 1992) with target word in capitals

Early Target Position
Normal: He said the BUS always left on time and he didn't want to miss it. Anomalous: He said the BUS always left late, and he didn't have time to go.

Repeated Target Position
Normal: The man always wears his glasses. Anomalous: The man always wears his glasses.

Semantic vs. syntactic knowledge

- Despite semantic deficit, preserved access to syntactic properties of individual words (e.g., word class) + may be able to process phrase structure
- Breedin & Saffran (1999) – sentence picture matching task: such patients may also have access to thematic roles (agent, patient) but not lexical semantics of words

CONTROLs PATIENT PP
Semantic vs. **syntactic** knowledge

- Ostrin and Tyler (1994): case JG marked disruption to all syntactic abilities + relatively preserved lexical-semantic abilities
- Sentence-picture matching: asynchronous comprehension (fails if agent and object are reversed, succeeds if distracter is a lexical substitution)
- Word monitoring: insensitive to grammatical violations
- Normal semantic priming in lexical decision task

Interim conclusion 1

- Semantics and syntax are independent, dissociable systems

Interactions between syntax and semantics

- Pit constraints of syntax against those of semantics
- After damage to syntax, patient may show stronger effects of semantic constraints
- When no strong semantic constraints, effects of weakened syntax should still emerge
- Saffran, Schwartz, and Linebarger (1998) => evidence for such an interaction between syntax and semantics

Saffran, Schwartz, and Linebarger (1998)

- Verb constrained sentences (strong semantic constraint)
  The cat barked at the puppy
- Proposition based sentences (weaker semantic constraint)
  The insect ate the robin

Saffran, Schwartz, and Linebarger (1998)

- Subjects: five Broca’s aphasics, one conduction aphasic, one transcortical motor aphasic
- Task: Detect implausible sentences!

<table>
<thead>
<tr>
<th>Strong Semantics</th>
<th>Weak Semantics</th>
</tr>
</thead>
<tbody>
<tr>
<td>The cat barked at the puppy</td>
<td>The insect ate the robin</td>
</tr>
<tr>
<td>The audience was watching the painting</td>
<td>The bee was watching the painting</td>
</tr>
<tr>
<td>The cat was watching the painting</td>
<td>The bee was watching the painting</td>
</tr>
<tr>
<td>The cat was watching the bee</td>
<td>The bee was watching the bee</td>
</tr>
</tbody>
</table>

Patients: Implausible (C)

Saffran, Schwartz, and Linebarger (1998)

- Examples of Sentence Types From Saffran, Schwartz, and Linebarger (1998): Parallel Implausible
  - Parallel: The cat barked at the puppy
  - Implausible: The insect ate the robin
Saffran, Schwartz and Linebarger (1998)

Results for 6 Control Subjects and 6 Aphasics Patient on Sentence Plausibility Judgments From Saffran, Schwartz, and Linebarger, 1998

<table>
<thead>
<tr>
<th>Controls Patient</th>
<th>Action</th>
<th>Passive</th>
<th>Subject Only</th>
<th>Main Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plausible</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Implausible</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>

Controls: harder to detect implausible sentences in verb-constrained than proposition constrained

=> tendency to interpret nouns not according to syntax but by the roles that they normally play (semantics)

Patients show exaggeration of this effect

=> larger effect of thematic role plausibility, weaker role of syntax

However, relatively preserved performance on proposition based sentences implies patients not completely insensitive to syntactic structure

Interim conclusion 2

Semantics and syntax interact!

Mapping between grammatical and thematic roles


Sentence picture matching

Could discriminate e.g.

lend from distribute

but not

lend from borrow

Difficulty discriminating between verbs that have similar semantic representations but where mapping between grammatical and thematic roles differs

Mapping between grammatical and thematic roles

Elisabeth is in white top with white hair band

Which of (a) and (b) is Elisabeth lending?

Which of (b) and (c) is Elisabeth distributing?

(a) (b) (c)
Interim conclusion 3

- Operation of combining semantic constraints (thematic roles) and syntactic structure may be selectively impaired

Working memory

- Phonological working deficit does not cause difficulties in processing syntactically complex sentences
- Syntactic + semantic info abstracted as you go, words not kept in mind
- Some memory deficits are problematic: keeping in mind lexical-semantic info
- Martin and Romani (1994)
- Task: Anomaly judgement

Working memory

- The rusty pail was lying on the beach [Distance 1]
- The rusty, old, red, pail was lying on the beach [Distance 3]
- The rusty, old, red swimsuit was lying on the beach
  (adjectives BEFORE noun - HARD)
- The pail was old, red, and rusty but she took it to the beach anyhow [Distance 3]
- The swimsuit was old, red, and rusty but she took it to the beach anyway
  (adjectives AFTER noun - EASY)
- For BEFORE condition, you have to keep adjective meanings in mind until noun arrives and can be modified

Working memory

- Patients AB and ML have semantic STM deficit
- Patient EA shows a phonological STM deficit

Graph: Delayed vs. Immediate Integration

Interim conclusion 4

- There may be separate working memories for phonological information, lexical-semantic information, and syntactic information

Table: Comparison of Semantic Anomaly and Grammaticality Judgements for Patients AB, ML, and MW (Normal Control)

<table>
<thead>
<tr>
<th></th>
<th>AN 19</th>
<th>AN 31</th>
<th>AN 33</th>
<th>AN 34</th>
<th>AN 35</th>
<th>AN 37</th>
<th>AN 39</th>
<th>AN 41</th>
<th>AN 42</th>
<th>AN 43</th>
<th>AN 45</th>
<th>AN 47</th>
<th>AN 49</th>
<th>AN 51</th>
<th>AN 53</th>
<th>AN 55</th>
<th>AN 57</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>87</td>
<td>91</td>
<td>64</td>
<td>66</td>
<td>91</td>
<td>77</td>
<td>86</td>
<td>86</td>
<td>91</td>
<td>86</td>
<td>91</td>
<td>86</td>
<td>91</td>
<td>86</td>
<td>91</td>
<td>86</td>
<td>91</td>
</tr>
<tr>
<td><strong>Response time</strong></td>
<td>4 (ms)</td>
<td>3 (ms)</td>
<td>4 (ms)</td>
<td>3 (ms)</td>
<td>3 (ms)</td>
<td>3 (ms)</td>
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</tr>
</tbody>
</table>
Can you lose specific syntactic operations?

- Most studies of agrammatism use linguistic theory to generate hypotheses about locus of existing deficit
- Few studies of aphasia seek dissociations of specific linguistic rules based on existing theory
- Exception: Caplan & Hildebrandt (1987, & Evans, 1988): patient KG
  - Analysed in terms of Chomskian theory
  - Surface vs. Deep structure of sentence

KG's performance broke down when several syntactic (linguistically defined) capacity demands combined
- But not related to verbal memory span (in normal range)
- Some evidence that comprehension of linguistic constructions may be differentially affected by brain damage
- However, theories of parsing not well enough developed to explain findings

Specific syntactic rules/operations may be differentially impaired, but parsing theory not well enough advanced to explain current data
- Better cognitive level theory required

Neural substrate: Friederici (2002)

- Postulates areas of brain involved in auditory sentence processing based on imaging work
- Autonomy of syntax assessed using ERP components
- claim => initial phase of syntactic processing is autonomous – modularity?
Friederici (2002)

- **Process**
- **Neural structure**
- **ERP waveform component**

Associated ERP waveform components

- **N400** – sensitive to words that can’t be semantically integrated into preceding semantic context
- **LAN** (left anterior negativity):
  - Early (ELAN) – sensitive to rapidly detectable word-category errors;
  - Late LAN – sensitive to morphosyntactic errors
- **P600** – sensitive to outright syntactic violations / garden-path revisions / processing increasingly complex sentences
Time course: three phase theory

- Phase 1: (100-300ms): initial syntactic structure formed based on word-category information ELAN
- Phase 2: (300-500ms): lexical-semantic and morphosyntactic processes take place with goal of thematic role assignment LAN N400
- Phase 3: (500-1000ms): different types of information are integrated P600

Question: how do processes interact over time?

Time course: three phase theory

**Word-category violation**
- Should produce deflection of ELAN (phase 1, syntax) and later N400 (phase 2, semantics)
- Result: No N400! Target word rejected by syntax processor is not lexically integrated – syntax building precedes semantics

**Morphosyntactic violation**
- Should produce deflection in LAN (phase 2, morphosyntax) and N400 (phase 2, semantics)
- Result: Both components present P600 (phase 3) varies as function of both syntactic and semantic violation – interaction of information in final phase

Interim conclusion 6

- Temporally, syntax processing is initially autonomous (modular?) but later interacts with semantic processing

Neural substrate: Kaan & Swaab (2002)

- Okay, is there evidence for a part of the brain dedicated to syntax processing?
- Broca’s area?
- Kaan & Swaab (2002) summarise PET / fMRI data
- Results depends on contrasts
(1) Complex vs. simple sentences
- Syntactically simple
  The reporter who attacked the senator admitted the error
- Syntactically complex
  The reporter who the senator attacked admitted the error

(2) Sentences vs. word lists
- Jabberwocky
  The mumphy folofel fonged the apole trecon
- Syntactic prose
  The infuriated water grabbed the justified dream
  J/S removes semantic content but leaves syntactic
  Word lists lack both syntactic and semantic coherence

(3) Jabberwocky / syntactic prose vs. word lists
- Syntactic violations vs. correct / semantic violations / spelling
  errors [black blue green]
- Semantic violations vs. correct [red]
  Trees can grew
  Vs
  Trees can grow / Trees can eat / Trees can graw
Neural substrate: Kaan & Swaab (2002)

- Conclusion:
  - No one part of the brain is exclusively involved in syntax
  - Network of areas, different areas recruited for different tasks
  - In comprehension, Broca’s area appears to underlie something like working-memory-for-syntax
  - Production is generally more anterior and also involves Broca’s area

Interim conclusion 7

- No syntax processing module (for comprehension) is apparent in the substrate

Overall conclusions

- Syndrome approach less useful than cog-neuro approach in using deficits to inform models of sentence comprehension
- Semantics and syntax appear to be dissociable but interacting functional systems
- Time course of interaction revealed by ERP work – suggests syntax initially autonomous
- PET/fMRI suggests syntax comprehension involves network of areas, none entirely dedicated to syntax
- Functional modules realised by underlying distributed networks of neural areas

Note on methodology

- Types of tasks used to assess comprehension
  - Sentence-to-picture matching
  - Grammaticality judgement
  - Plausibility judgement
  - Anomaly detection
  - Enactment
  - Word monitoring
  - Priming (e.g., in lexical decision task)
  - Passive listening to different material (imaging)