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

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

Deafness?

Newspaper headline:
ENRAGED COW INJURES FARMER WITH AXE

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

Sentence Comprehension

(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?

- 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

1. Behavioural: Semantics and syntax are independent, dissociable systems
2. Behavioural: Semantic and syntactic systems interact
3. Behavioural: Operation of combining semantic constraints (thematic roles) and syntactic structure may be selectively impaired
4. Behavioural: There may be separate working memories for phonological information, lexical-semantic information, and syntactic information
5. 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
6. Imaging ERP: Temporally, syntax processing is initially autonomous (modular?) but later interacts with semantic processing
7. Imaging FMRI/PET: 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)

Derive word-class info ▶ Compute syntactic structure ▶ Integrate lexical-semantic information

(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)

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

Evidence 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 & Romani, 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

Exemplars of word monitoring materials used by Tyler and colleagues (from Hodges et al., 1994 and Tyler, 1992) with sentences worded in capitals:

<table>
<thead>
<tr>
<th>Early Target Position</th>
<th>Late Target Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Probe:</td>
<td>Normal Probe:</td>
</tr>
<tr>
<td>He said the BUS always left on time and he didn’t need to queue.</td>
<td>He said the BUS always left on time and he didn’t need to queue.</td>
</tr>
<tr>
<td>Anomalous Probe:</td>
<td>Anomalous Probe:</td>
</tr>
<tr>
<td>It said the BUS always left on time, but he didn’t have to queue.</td>
<td>It said the BUS always left on time, but he didn’t have to queue.</td>
</tr>
<tr>
<td>Normal Probe:</td>
<td>Normal Probe:</td>
</tr>
<tr>
<td>This was his BUS and went left always on time and he didn’t need to queue.</td>
<td>This was his BUS and went left always on time and he didn’t need to queue.</td>
</tr>
<tr>
<td>Late Target Position</td>
<td>Late Target Position</td>
</tr>
<tr>
<td>Normal Probe:</td>
<td>Normal Probe:</td>
</tr>
<tr>
<td>Apparently in the middle of the night some thieves broke into the CHURCH and stole a gold cross.</td>
<td>Apparently in the middle of the night some thieves broke into the CHURCH and stole a gold cross.</td>
</tr>
<tr>
<td>Anomalous Probe:</td>
<td>Anomalous Probe:</td>
</tr>
<tr>
<td>Apparently at the distance of the wind some trees pushed around the CHURCH and threw a saw beam.</td>
<td>Apparently at the distance of the wind some trees pushed around the CHURCH and threw a saw beam.</td>
</tr>
<tr>
<td>Normal Probe:</td>
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</tr>
</tbody>
</table>
Semantic vs. syntactic knowledge

For PP, doesn’t matter if it makes no sense, as long as it’s grammatical.
“Press the button when you hear the word BUS.”

Sentence-picture matching: asyntactic 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!
Saffran, Schwartz, and Linebarger (1998)

**Task:** "Is this sentence plausible?"

**Examples of Sentence Types From Saffran, Schwartz, and Linebarger (1998):**

- **Nouns**
  - Implausible
  - Plausible!

- **Verb**
  - Implausible!
  - Plausible!

**Patients:**

- **Implausible!** (E)
- **Plausible!** (E)

**STRONG SEMANTICS**

- Implausible!
- Plausible!

**WEAKER SEMANTICS**

- Implausible!
- Plausible!

**Error rate for judging plausibility of sentences**

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**Interpretation**

- Controls find it harder to detect implausible sentences when there are stronger semantic constraints.
  - Implies 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.
  - Relatively preserved performance on sentences with weaker semantic constraints implies patients not completely insensitive to syntactic structure.

**Interim conclusion 2**

- Semantics and syntax interact!

**Mapping between grammatical and thematic roles**

  - Sentence picture matching.
  - Difficulty discriminating between verbs that have similar semantic representations but different mapping between grammatical and thematic roles.
- Could discriminate e.g. lend from distribute.
- But not lend from borrow.

**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) LEND
(b) DISTRIBUT
(c) BORROW
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
- Martin and Romani (1994): dissociations can be found between
  - phonological working memory deficits (nonword repetition)
  - lexical working memory deficits (nouns + adjectives)
  - syntactic working memory deficits (grammaticality judgements)

Lexical working memory: Plausibility judgement

- 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

Interim conclusion 4

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

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

Can you lose specific syntactic operations?

| Preposition Correct for Patient KG in Enquiry Task from Caplan and Hildebrandt (1988) |
|-----------------------------------|---------------------------------|
| Subject + Object + Verb + Preposition | Correct/Incorrect |
| Single sentences with PHV | 49/51 |
| Single sentences with PHV | 49/51 |
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| Single sentences with PHV | 49/51 |
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| Single sentences with PHV | 49/51 |
| Single sentences with PHV | 49/51 |
Can you lose specific syntactic operations?

- KG’s performance broke down when several (linguistically defined) syntactic capacity demands were combined
- 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

Interim conclusion 5

- 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?

Time course: three phase theory

- Syntactic violation = ELAN deflection
- Semantic violation = N400
- Conclusion = syntactic violation prevents semantic stage, so is preceding it (and is independent/modular?)

Friederici & Kotz (2003)

1. Initial structure building
   - ERP: ELAN
   - Independent of semantic processes
   - fMRI, MEG: Left anterior temporal region (superior temporal gyrus) and left inferior frontal region
   - Damage to these areas = loss of ELAN
2. Semantic integration
   - ERP: N400
3. Late syntactic integration
   - ERP: P600 (patients can lose ELAN but still show P600)
   - Patients: Basal ganglia (sub-cortical) involved in late syntactic integration
   - BG and posterior regions of STG dissociation from areas for phase 1
Interim conclusion 6

- Temporally, syntax processing is initially autonomous (modular?) but later interacts with semantic processing.
- Does modular imply a special brain area...?

Neural substrate: Kaan & Swaab (2002)

- Sounds like there’s a part of the brain dedicated to syntax processing?
- Broca’s area?
- Kaan & Swaab (2002) summarise PET / fMRI data
- Results depends on contrasts

Area for syntax

- Lots of pictures coming up.
- Watch Broca’s area
- Is it (and it alone) more activated when syntax is involved?

Activation differences: (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
Activation differences:
(2) Sentences vs. word lists (no syntax)

Activation differences:
(3) Jabberwocky or syntactic prose vs. word lists (no syntax)
- 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

Activation differences:
(3) Jabberwocky or syntactic prose vs. word lists (no syntax)

Activation differences:
(4) Syntactic violations
- Syntactic violations vs. correct or semantic violations or spelling errors [black blue green]
- Semantic violations vs. correct [red]
  Trees can grew
  Vs
  Trees can grow / Trees can eat / Trees can graw

Activation differences:
(4) Syntactic violations

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
  - Cognitive modularity \( \Leftrightarrow \) Substrate modularity

Note on methodology

- Examples 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 materials (imaging)