Language comprehension

Michael Thomas
Birkbeck College

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

(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

(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 dog is chased by the white horse

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
- comprehension deficits on reversibles – worse on passives than actives
  => working memory problem?
Some of our own data...

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)

(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)

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

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, & Linzberger, 1996)
- Mapping between grammatical and thematic roles (Braun & Martin, 1996)
- Working memory (Martin & Romani, 1994)
- Differential loss of syntactic operations (Caplan & Hildesheim, 1987)

Semantic vs. syntactic knowledge

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 Prose:* He said the BUS always left on time and he didn't want to miss it.

*Assessment Prose:* It said the BUS always left on time, and he didn't want to miss it.

**Late Target Position**

*Normal Prose:* Apparently, in the middle of the night some thief broke into the CHURCH and stole a golden crucifix.

*Assessment Prose:* Apparently, at the distance of the wind some went through the CHURCH and stole a new item.

*Assessment Prose:* Of middle apparently the same the into the broke night in thieves CHURCH and crucifix stole a golden.
Semantic vs. syntactic knowledge

- Ostrin and Tyler (1994): case JG marked disruption to all syntactic abilities + relatively preserved lexical-semantic abilities
- 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!
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

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
Task: 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]
  (anomalous sentences not shown)
- 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]

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?

- 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 deflection
- ELAN but no N400 when both syntactic and semantic violation
- Conclusion: syntactic violation prevents semantic stage, so it precedes 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 used in subtraction method

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)
- Sentences have syntax + semantic coherence, word lists have neither. Need non-semantic sentences to compare to word lists
- **Jabberwocky**
  - The mumph folofel fonged the apole trecon
- **Syntactic prose**
  - The infuriated water grabbed the justified dream
- Compare syntactic (no semantics) sentence to word lists (no syntax, no semantics)

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
vs
Trees can fly

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 (complexity)
  - (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 (1)

- 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
  - though must identify words as nouns, verbs, etc. first!

Overall conclusions (2)

- PET/IMRI – syntax comprehension involves network of areas, none entirely dedicated to syntax
- Functional modules realised by underlying distributed networks of neural areas
  - Cognitive modularity ≠ Substrate modularity
- Potential tension between cognitive neuropsychology, syndrome, and imaging approaches

Note on methodology

- Examples of tasks used to assess comprehension (potentially in the absence of production)
  - 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)