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

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’)

DEFICITS?

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

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

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?

Taken from Test of Receptive Grammar (TROG)
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)

(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**

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

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, 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
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!
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) Borrow
(b) Lend
(c) Distribute
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 anyway [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?

- 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?)

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)

- 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 depend 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) Abberwooky 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 grow
Vs
Trees can grow / Trees can eat / Trees can graw

Activation differences:
(4) Syntactic violations

Each symbol type = study

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 = 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)