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

DEFICITS?

- 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

adj. _noun_ _verb_ _noun_ _prep. phrase_

- Newspaper headline:

ENRAGED COW INJURES FARMER WITH AXE

_____ COW _____ FARMER WITH AXE

ENRAGED __ INJURES ____ WITH AXE

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

noun determiner

- 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

P (S) A

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

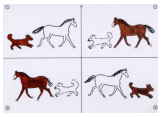
Simpler: the reporter ~~who attacked~~ the senator
Complex: the reporter who the senator attacked

the reporter

Comprehension and aphasia

- Broca's aphasics - difficulty comprehending syntax-driven meaning
  - E.g. reversible passive sentences

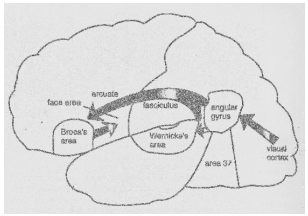
The brown dog is chased by the white horse

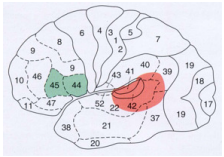


Taken from Test of Receptive Grammar (TROG)

The Wernicke-Geschwind model

- Broca's area = seat of syntax?



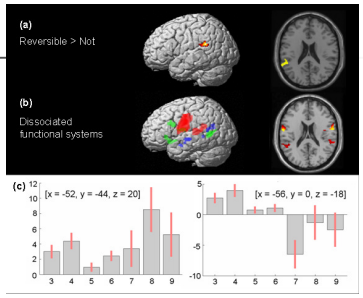


Problems with the syndrome approach

- 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…



Activation for (a) reversible vs. non-reversible sentences (b) syntactic and semantic sentence processing, amodal semantics and articulation (c) plots of contrast estimates

x-axis: (3) auditory sentences, (4) visual sentences, (5) auditory words, (6) visual words, (7) object action retrieval, (8) articulation, and (9) mouth movements.

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

methods

- 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

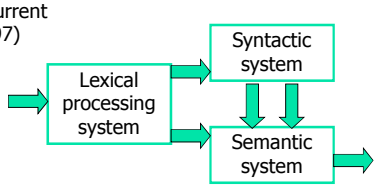
Sentence processing theories

- (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

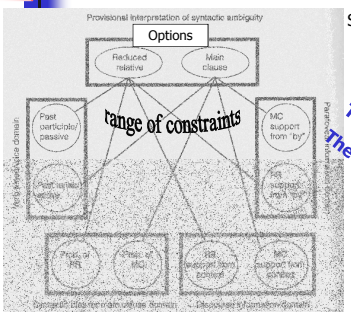
- Interactivity does not rule out independent structures for different types of knowledge

Boland's concurrent model (1997)



Interactivity

Interactivity



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

The evidence examined...
The woman examined...
The horse examined by...

(NB importance of frequency)

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

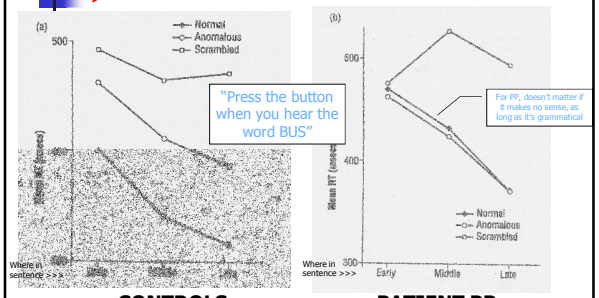
~~Semantic~~ vs. syntactic knowledge

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

Early Target Position
Normal Prose. He said the BUS always left on time and he didn't want to miss it.
Anomalous Prose. It said the BUS always tells in space, and he didn't hope to guess it.
Scrambled Prose. The said he BUS and want left always he on didn't it time miss to.

Late Target Position
Normal Prose. Apparently in the middle of the night some thieves broke into the CHURCH and stole a golden crucifix.
Anomalous Prose. Apparently at the distance of the wind some ants pushed around the CHURCH and forced a new item.
Scrambled Prose. Of middle apparently the some the into the broke night in thieves CHURCH and crucifix stole a golden.

~~Semantic~~ vs. syntactic knowledge



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: 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)

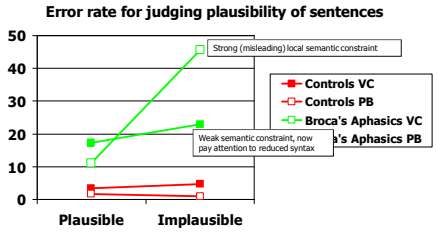
		Plausible	Implausible
STRONG SEMANTICS	Verb-constrained		
	Active	The audience was watching the performance.	The cat barked at the puppy.
	Passive	My car was demolished by the tornado.	The movie was frightened by the child.
	Cleft Subject	It was the artist that disliked the painting.	It was the cheese that ate the mouse.
	Cleft Object	It was the children that the crash frightened.	It was the idea that the professor surprised.
WEAKER SEMANTICS	Proposition-based		
	Active	The robin ate the insect.	The insect ate the robin.
	Passive	The rat was squashed by the truck.	The frog was swallowed by the fish.
	Cleft Subject	It was the boys who caught the turtle.	It was the worm that swallowed the bird.
	Cleft Object	It was the boy whom the doctor lifted up.	It is the cat that the mouse is carrying.

Note. From "Semantic Influences on Thematic Role Assignments: Evidence from Normals and Aphasics," by E. Saffran, M. Schwartz, and M. Linebarger, 1998, *Brain and Language, 62*, pp. 282–284.

Patients: 'Plausible!' (E) - relying on semantics and not syntax

Patients: 'Implausible!' (C) - now using syntax

Saffran, Schwartz and Linebarger (1998)



Interim conclusion 2

- Semantics and syntax interact!

Mapping between grammatical and thematic roles

- Breedin and Martin (1996): patient LK, verb problem
  - 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?

BORROW

(a)

LEND

(b)

DISTRIBUTE

(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
- 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]
- 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

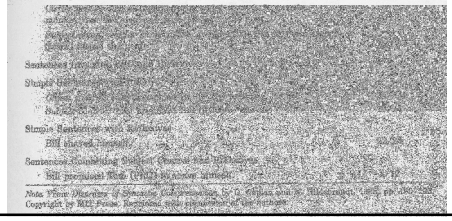
Can you lose specific syntactic operations?

- 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?

Proportion Correct for Patient KG on Enactment Task from Caplan and Hildebrandt, 1988.

Sentences with Moved Elements	Proportion Correct
Simple Sentences	
Cleft object sentences with 2 nouns. It was the monkey that the elephant (trace) kicked.	11/12
More Complex Sentences	



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

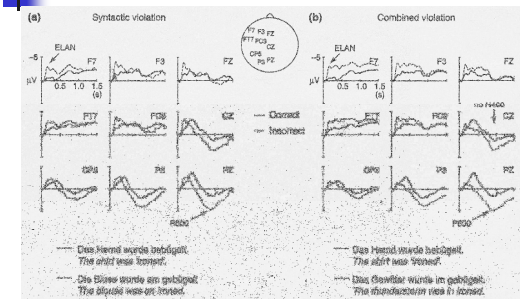
Interim conclusion 5

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

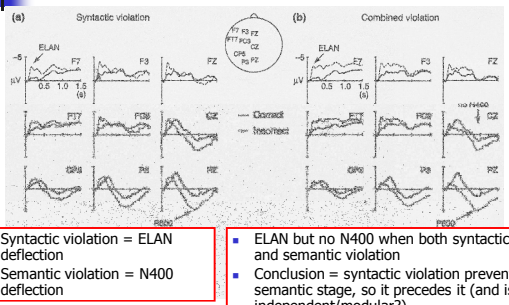
Neural substrate: Friederici (2002)

- 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



Time course: three phase theory

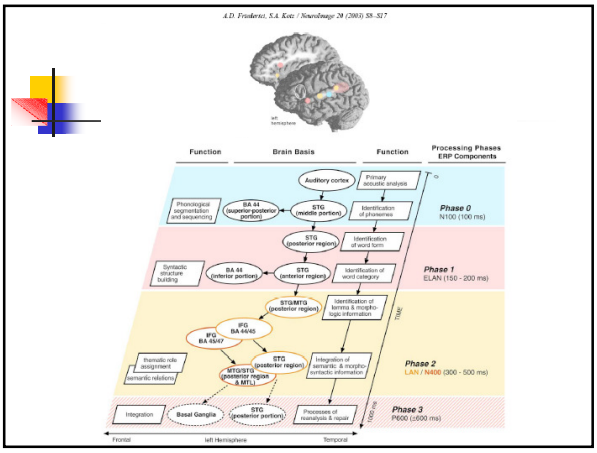


- Syntactic violation = ELAN deflection
- Semantic violation = N400 deflection

- 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

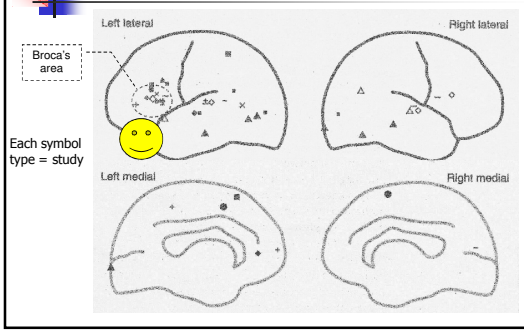
- Syntactically simple

The reporter who attacked the senator admitted the error

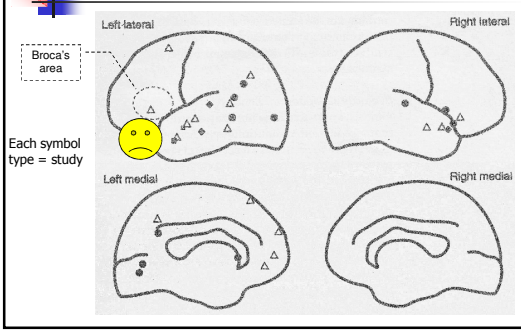
- Syntactically complex

The reporter who the senator attacked admitted the error

Activation differences: (1) Complex vs. simple sentences



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*

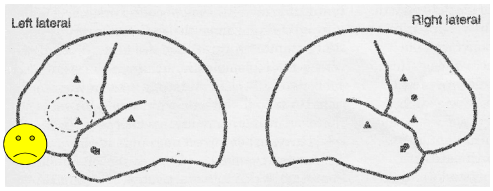
The mumphy folofel fonged the apole trecon

- *Syntactic prose*

The infuriated water grabbed the justified dream

- Compare syntactic (no semantics) sentence to word lists (no syntax, no semantics)

Activation differences:
(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

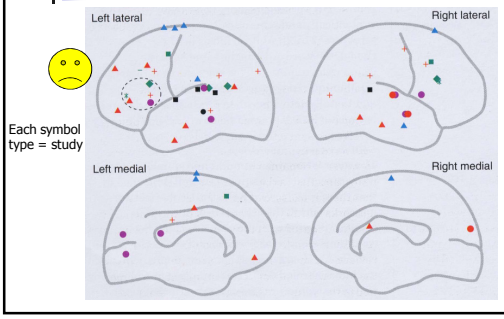
Trees can grow / **Trees can eat** / **Trees can graw**

vs

Trees can fly

(purple = pragmatic violations)

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 (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/fMRI – syntax comprehension involves network of areas, none entirely dedicated to syntax
- Functional modules realised by underlying distributed networks of neural areas
  - Cognitive modularity $\neq$ 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)