

The Neuropsychology of Sentence Comprehension: Where do We Stand?

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Dolomite Alps

Broca's Aphasia

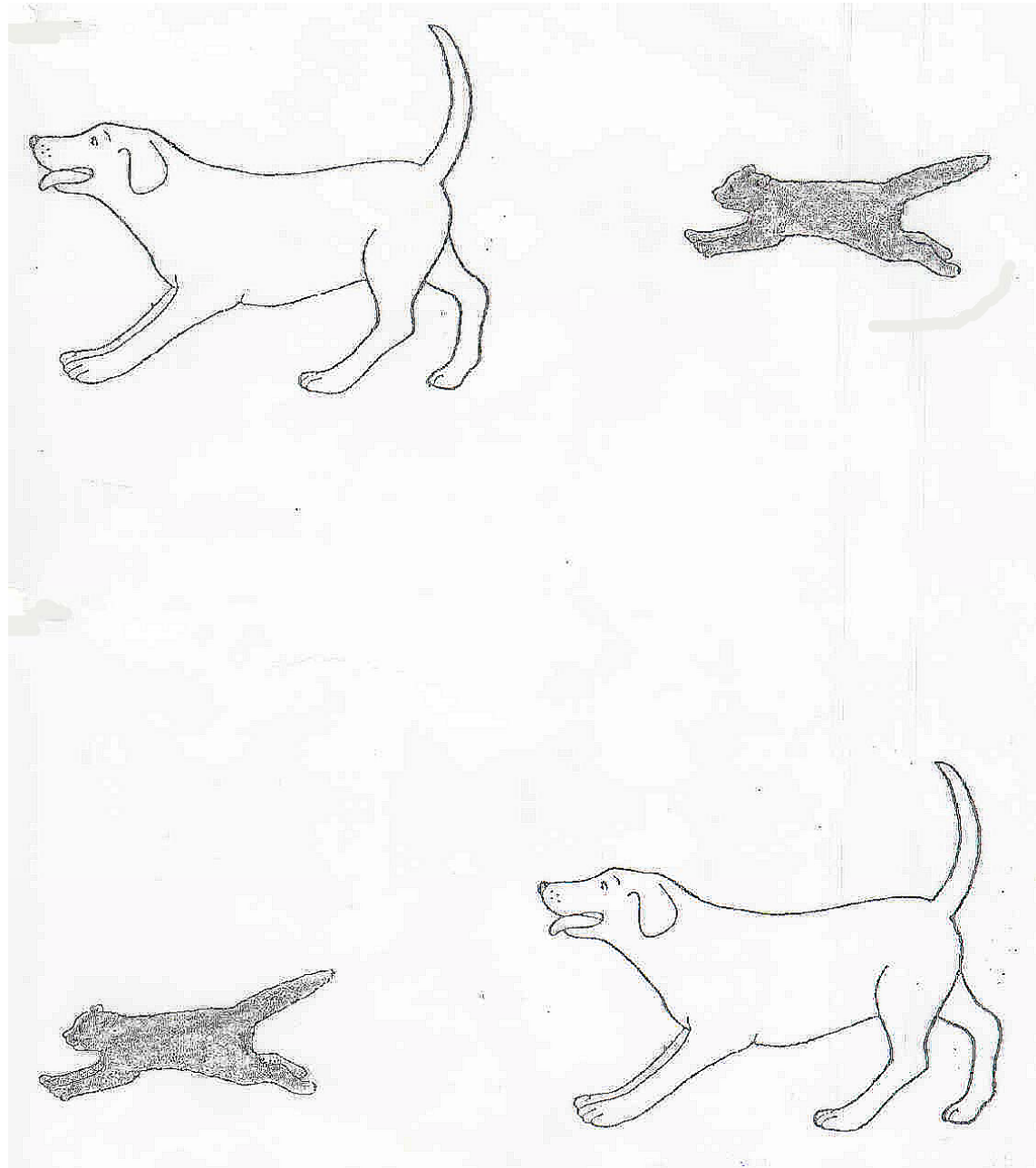
- Wernicke-Lichtheim model: Broca's aphasia
 - Motor word image deficit
 - Poor production
 - Good comprehension
- Reformulation of nature of deficit in 1970s
- Agrammatism in speech
 - Omission of function words and grammatical markers
 - Simplified sentence structureexamples describing Cookie Theft picture from BDAE:

LS: “A mothera dish...drying...” “Plate....a faucet...running..”

AT: “The boy is falling on the....almost falling floor. The mother is running...faucet floor...The sister is passing cookie.”

The cat that the
dog chased
was black.

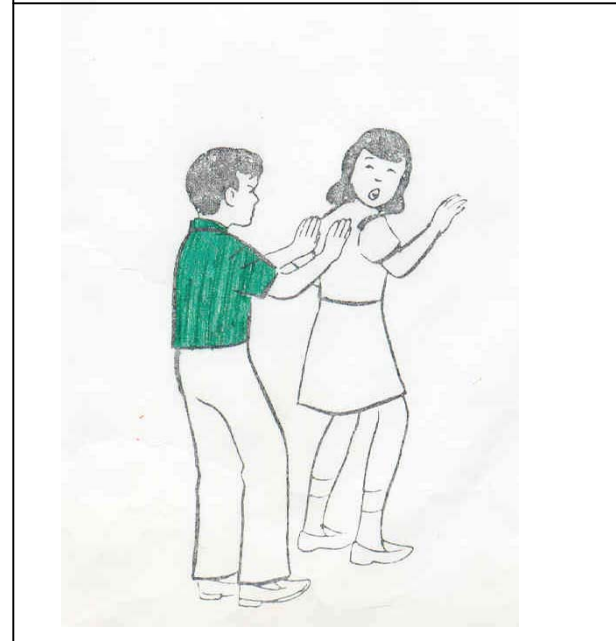
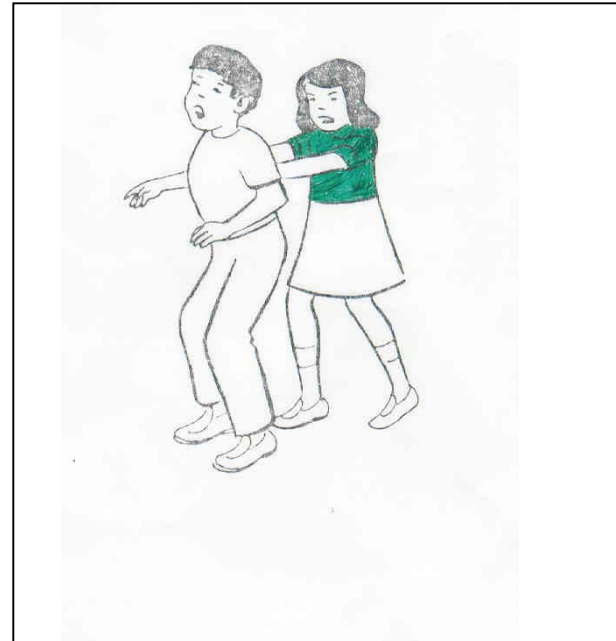
Caramazza &
Zurif (1976)



Reversible sentence
comprehension deficit
even with simple actives
and passives (Schwartz,
Saffran, & Marin, 1980)

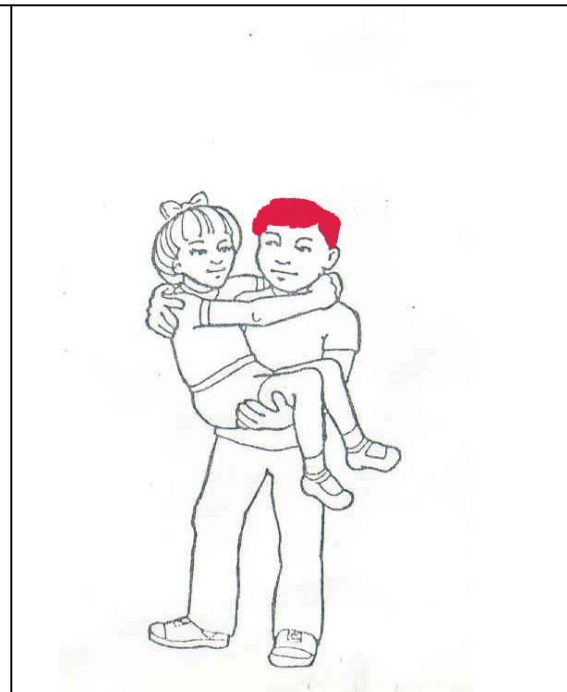
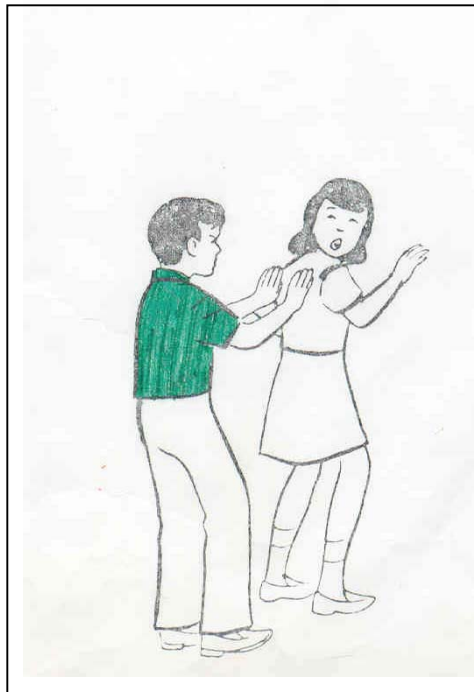
The boy pushed the girl.

The boy was pushed by the girl.



Preserved
performance with
lexical distractor

The girl was carried by the boy



Syntactic Deficit Hypothesis

- Berndt & Caramazza (1980)
 - Disruption of syntactic knowledge underlies production and comprehension deficit
 - Evidence for independence of syntax and semantics
 - Components of syntactic processing potentially affected
 - Knowledge of function words (i.e., prepositions, determiners, auxiliaries, etc) in determining structure
 - Knowledge of phrase structure, transformations

Conduction aphasia problematic

- Not agrammatic speakers
- Sentence comprehension deficit like that of Broca's aphasics (Caramazza & Zurif, 1976)
- Leads to hypothesis of STM deficit underlying comprehension deficit

Wernicke's Aphasia

- Single word comprehension deficit
- Sentence comprehension deficit derives from single word problem

Status in 1984 - 1987

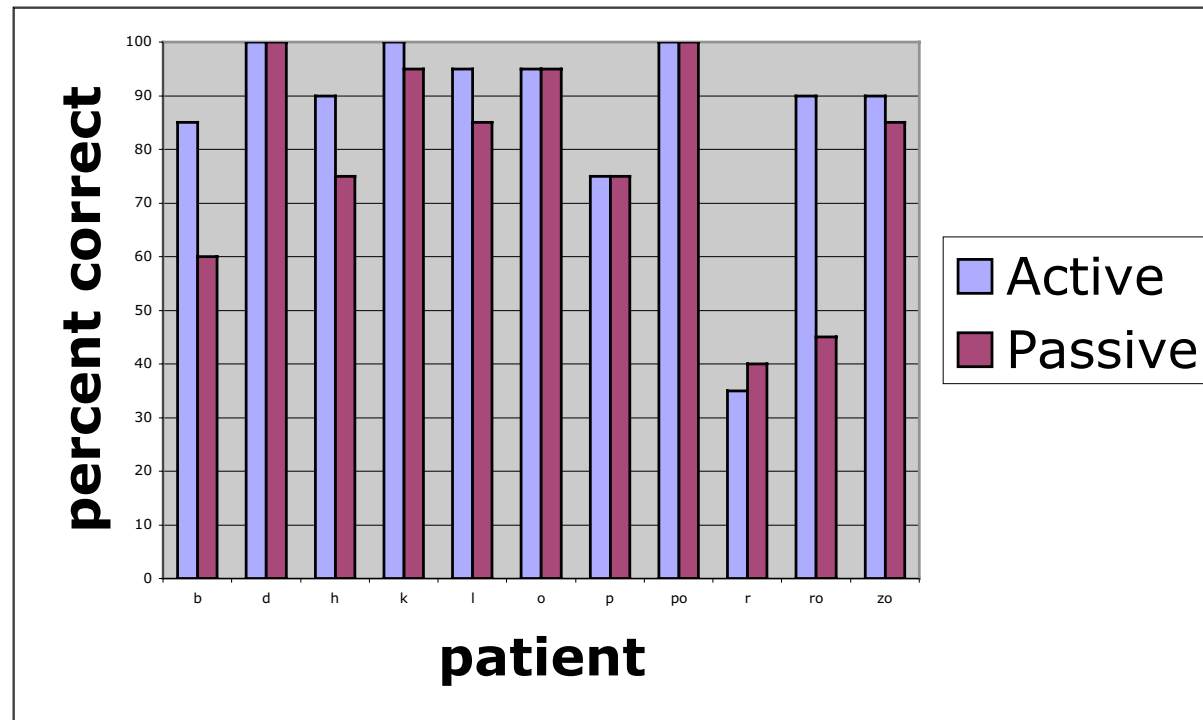
- Evidence building up against syntactic deficit hypothesis
- Evidence building up against STM hypothesis
- General problems with group study approach

Evidence against syntactic deficit hypothesis

- Dissociations between production and comprehension
 - Agrammatism without asyntactic comprehension (Miceli, Mazzucchi, Menn & Goodglass, 1983; Kolk, van Grunsven & Keyser, 1985)
 - No match in degree of deficit (Martin, Wetzel, Blossom-Stach, & Feher, 1987)
 - Note: Reports of dissociations pre-date hypothesis (see De Bleser, 1987; Howard, 1985, for reviews of early German aphasiologists' writings)

- Continuous variation in degree of comprehension deficit

E.g., Kolk & van Grunsven (1985) 11 agrammatic speakers varied in comprehension on reversible passives from 40% correct to 100% correct.



- Difficulties with reversible sentences not restricted to agrammatic speakers
 - Martin & Blossom-Stach (1986)
 - Fluent patient - mild Wernicke's, temporo-parietal lesion
 - Sentence-picture matching:
 - reversible actives - 67%
 - reversible passives - 59%
 - lexical substitutions - 97%

Similar pattern of sentence difficulty across groups

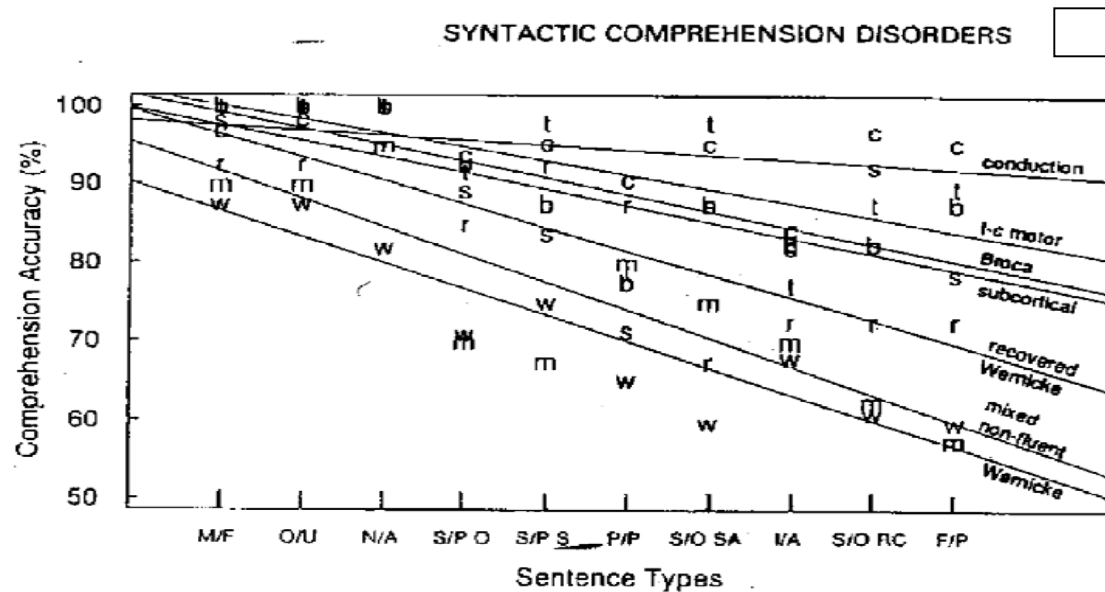
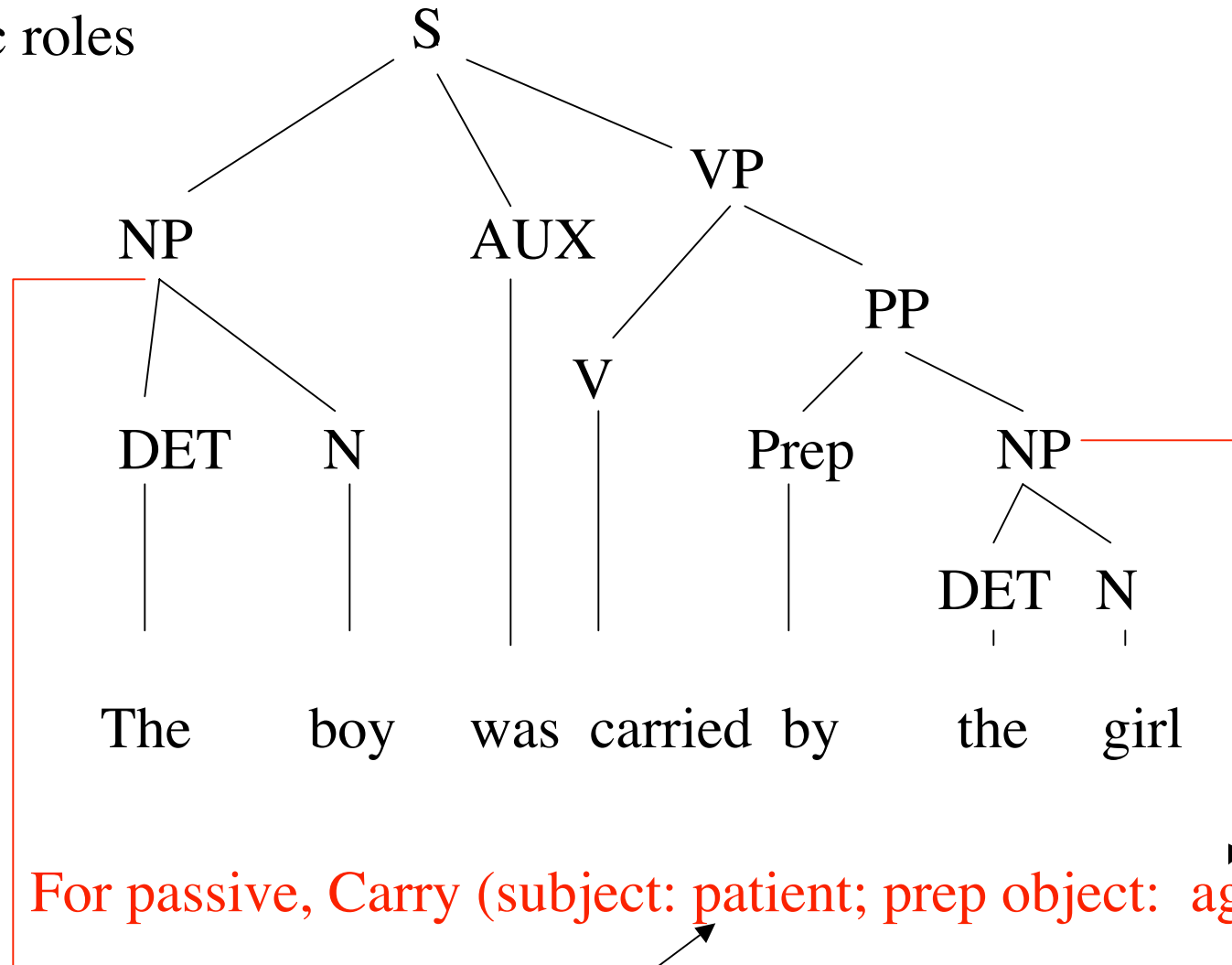


FIG. 2 Comprehension performance of 7 clinical syndrome groups of aphasic patients with different degrees of severity for 10 different syntactic and morphological contrasts: Male/Female (M/F), On/Under (O/U), Negative/Affirmative (N/A), Singular/Plural Object (S/P O), Singular/Plural Subject (S/P S), Past/Present Progressive Tense (P/P), Subject/Object in Simple Active Sentences (S/O SA), Is/Are (I/A), Subject/Object Relative Clause (S/O RC), and Future/Present Progressive Tense (F/P). The straight lines are the best-fitting linear regressions, which treat the difficulty ordering of the 10 sentence types as though it were a ratio scale. As the diverging lines suggest, all groups are able to comprehend the easiest syntactic items, whereas the groups with more severe deficits have numerous errors as the difficulty level of the sentence types increases. The difficulty ordering of the sentences, however, is generally preserved under various levels of severity. The graph is based on the data reported in Naeser et al., 1987; Table III, p. 368.

Caplan & Hildebrandt (1988) similar result in group data

- Good performance on grammaticality judgments co-occurring with poor sentence comprehension (Linebarger, Schwartz & Saffran, 1983)
 - Example sentences
 - I hope you to go to the store now.
 - I want you will go to the store now.
 - Is the boy is having a good time?
 - This job was expected Frank to get.

Mapping Deficit
Hypothesis:
Thematic roles



For active, Carry (subject: agent; direct object: patient)

Implications

- At least some different components involved in syntactic aspects of sentence production and comprehension
- Assigning syntactic structure to sentence is different from interpreting that structure to assign thematic roles
- Account needed for continuous variation in degree of deficit. Not all or none loss of syntactic knowledge.

Short-term memory and sentence comprehension

- Saffran & Marin (1976)
 - STM deficit and role reversals in repetition
- Caramazza, Basili, Koller & Berndt (1981)
 - STM deficit and difficulties comprehending reversible passives

Vallar & Baddeley (1984)

- Relatively pure STM deficit
- No difficulty with reversible passives on sentence-picture matching
- Difficulty on sentence acceptability for long sentences where order reversed:
“One could reasonably claim that sailors are often lived on by ships of various kind.”
(Apparently not tested on short sentences of this kind - e.g., “sailors are often lived on by ships”)

Evidence against connection between STM - sentence comprehension

- Butterworth, Campbell, & Howard (1986)
“The bus is preceded by the train which the triangle is below.”
- Caplan, Vanier, & Baker (1986), Waters, Caplan & Hildebrandt (1991)
- Martin (1987)
- More recent:
 - Caplan & Waters (1999)
 - Friedmann & Givion (2002)
 - Martin et al. (1995), Hanten & Martin (2001)

Implications

- Working memory capacity for sentence comprehension separate from phonological capacity for list recall
- Phonological capacity needed when verbatim recall needed

Current Status of Issues

Clear view?



Lost in a fog?



(Fog Skiing by Allan Wafkowksi)

Current Issues

- Syntactic deficits
 - Continuing studies of agrammatism
 - Dissociations of syntax and semantics
 - Interactions of lexical, semantic, and syntactic factors
- Working memory and comprehension
 - Specific or general WM for syntax
 - Phonological vs. semantic components
- Localization of syntactic processing with functional neuroimaging

Berndt, Mitchum & Haendiges (1996)

- Review of comprehension for agrammatic patients reported in the literature
 - 16 show above chance performance on actives at chance on passives
 - 15 show above chance performance on both
 - 16 show at chance performance on actives and similar or better performance on passives

Perseveration on Agrammatism: Deficit in syntactic knowledge

- Moved elements deficit (Grodzinsky, 1986,1990; but see Druks & Marshall, 1991, 1995)
- Double dependency hypothesis (Mauner, Fromkin, & Cornell, 1993)
- Mapping deficit (Schwartz, Linebarger, Saffran & Pate, 1987; but see Martin & Blossom-Stach, 1986; Carmazza & Miceli, 1991)
- Closed class vocabulary deficit (Jarema & Friederici, 1994; Friederici & Gorell, 1998)

Perseveration on Agrammatism: Processing Deficit

- Slowed syntactic parsing (Haarmann & Kolk, 1991; Kolk & Weijts, 1996)
- Slowed reactivation of NPs (Swinney, Zurif & Nicol, 1989)
- Delay in integration of lexical information (Swaab, Brown, & Hagoort, 1997)
- WM deficit specific to syntactic parsing (Caplan & Waters, 1999)

**Number of published studies
on sentence comprehension 1997-2003**

- *Brain and Language* - 21
- *Cognitive Neuropsychology* - **1**

Comments

- Many interesting ideas and experimental procedures - why apply conclusions to a syndrome?
- Case studies difficult to do
 - Host of methodological, strategy issues (Cupples & Inglis)
 - On-line measures require RT effects for single subject

Case Studies

- Syntax vs. semantics dissociations

Syntax without semantics

Semantic dementia cases

1) Hodges, Patterson & Tyler (1994)

word-monitoring paradigm - sensitive to syntactic but not semantic anomalies

2) Schwartz & Chawluk (1990); Breedin & Saffran (1999)

assign thematic roles based on sentence structure despite inability to distinguish Ns

Schwartz & Chawluk (1990)

Breedin & Saffran (1999)

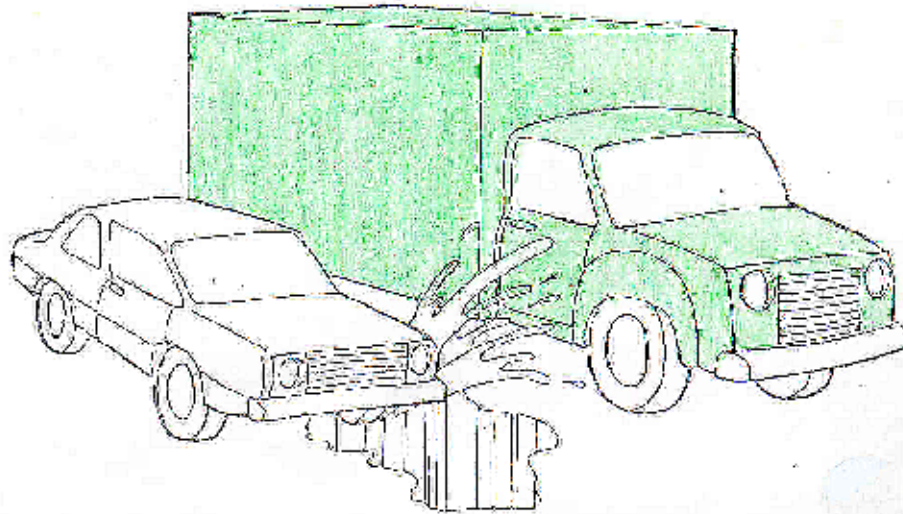
Matching

The truck was splashed by the car..

Show me car.

Non-matching

The car was splashed by the truck. Show me car.



Semantics without syntax

- Ostrin & Tyler (1995)
 - Left temporo-parietal CVA
 - Sentence-picture matching impairment for reversals (not lexical distractors) **and** poor performance on grammaticality judgments
 - Semantic priming in lexical decision
 - No sensitivity to grammatical violations in word monitoring paradigm

Influence of semantics and lexical biases on syntactic processing

Recent literature on sentence comprehension in normal individuals. During ambiguity resolution, parsing decisions affected by:

1) Lexical biases

e.g., Spivey-Knowlton & Sedivy (1995)

She *saw* the boy with binoculars. (NP attachment)

She *hit* the boy with the stick. (VP attachment)

2) Plausibility of nouns in thematic roles

e.g. Trueswell, Tanenhaus, Garnsey (1994)

The defendant examined by the prosecutor was...

The evidence examined by the prosecutor was...

2) Plausibility of thematic roles (cont.)

Ferriera (2003) Identifying agents and patients in implausible sentences for undergraduate subjects

Active: The man bit the dog. 5% errors

Passive: The dog was bitten by the man. 20% errors

3) Nonlinguistic context

Spivey, Tanenhouse, Eberhard & Sedivy (2002)

Put the mouse on the mat on the table.

No garden path if scene has a mouse on a mat and one not on a mat

Relevance to patient studies??

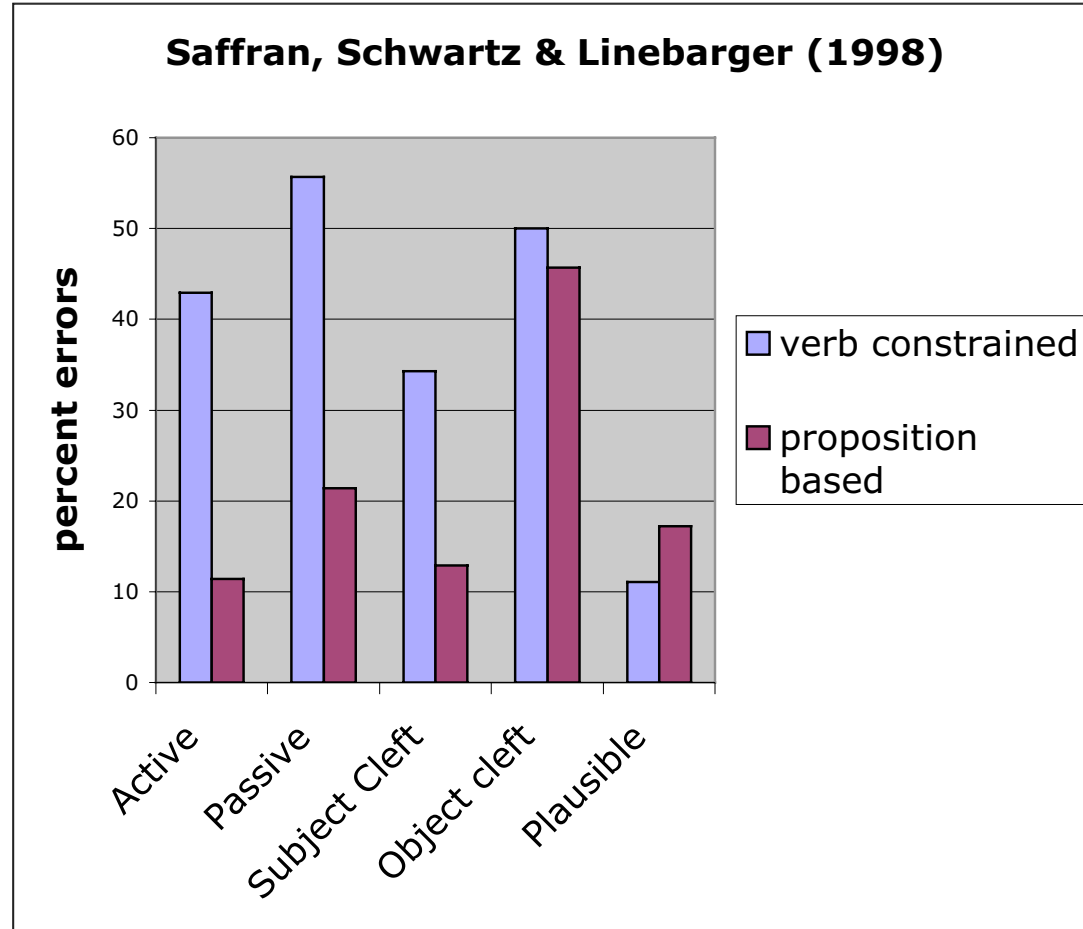
Lexical bias influences

- Gahl, Menn, Ramsberger, Jurafsky, Elder, Rewega & Holland (2003)

For mixed group of patients, difficulty with passives depends on whether verb is active-bias or passive-bias

Interaction of syntax and semantics - Neuropsychological findings

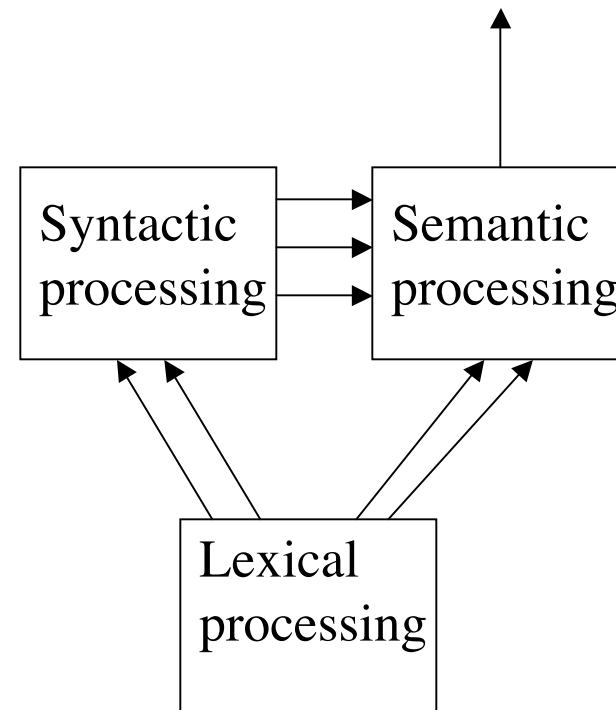
- Saffran, Schwartz & Linebarger (1998)
 - Sentence anomaly judgments
 - Mixed groups of patients - Broca's, conduction, transcortical
 - Verb - constrained:
The deer shot the hunter.
The car demolished the tornado.
 - Proposition based:
The insect ate the robin.
 - Syntactic structure:
 - Active, passive, cleft subject, cleft object
 - » Cleft subject: It was the insect that ate the robin.
 - » Cleft object: It was the robin that the insect ate.



- Poor performance for even simple actives on verb-constrained
- Much better performance on proposition based
- Inconsistent with any “moved arguments” analysis
- Similar pattern for conduction and transcortical as for Broca’s

Boland's Concurrent Model (1997)

- Multiple syntactic interpretations generated in parallel
- Different weights based on lexical factors
- Semantic interpretation generated at same time
- Semantics decides among syntactic possibilities



Interpretation

- “Strength” of syntactic analysis can vary depending on frequency
- Hypothesize that brain damage may generally reduce strength
- Greater influence of semantic, contextual factors when strength of input from syntax reduced

Do we still need working memory accounts?

- Martin, Inglis, & Kuminiak (unpublished)

Patient ML, sentence-picture matching

Simple passive:

The boy was carried by the girl. 100%

Active center-embedded relative clause:

The boy that carried the girl had red hair 75%

Passive center-embedded relative clause:

The boy that was carried by the girl had red hair 50%
(chance)

- Similar findings Caplan, Evans & Hildebrandt (1987)

- WM deficit for language comprehension (semantic, syntactic, lexical) (Miyake, Just & Carpenter, 1994)
- WM deficit specific to syntactic processing unrelated to span (Caplan & Waters, 1999)
 - Differential effects of number of propositions and syntactic complexity
 - No interaction between WM capacity and syntactic complexity

Semantic STM

- Martin, Shelton & Yaffee (1994), Martin & Romani (1994), Martin & He (in press)
 - Patients with *left inferior frontal lesions*
 - Reduced span, nonword = word span
 - Difficulty maintaining unintegrated semantic information
 - “The rusty old red swimsuit” vs.
“The swimsuit was old, red, and rusty”

 - “Rugs, mirrors and vases cracked during the move” vs.
“The movers cracked the vases, mirrors, and rugs”
 - Phonological STM case showed normal pattern

Semantic STM(cont)

- Relation to more complex sentences?
 - “The boy that the girl carried \wedge had red hair.”
- Consistent with theorizing by Gibson (1999)

Neuroimaging Studies of Sentence Comprehension

- Similar patterns of sentence comprehension difficulty across patients with left hemisphere lesions but different clinical classifications
 - Non-localizable within left hemisphere?
 - Messy lesions?
- Neuroimaging to the rescue?

Neuroimaging of Sentence Comprehension

- Variations in design
 - Passive listening vs. active judgment task
 - Grammaticality or comprehension
 - Control task (e.g., list of words vs. less complex structures)
 - Subject group (young vs. old)
- Variations in results

Examples of neuroimaging findings

- Mazoyer et al. (1993)
 - Passive listening to:
 - Word lists
 - Jabberwocky - “The blives semble on the plim”
 - Semantically anomalous - “The kitchens march on the clouds”
 - Results
 - Activation of temporal poles bilaterally for sentence but not word list conditions

- Friederici et al. (2000), Moro et al. (2001)
 - Active judgments (does this have structure? Is this grammatical?)
 - Jabberwocky sentences
 - Real word sentences
 - Results
 - Deep inferior frontal activation bilaterally for pseudoword materials
 - No frontal activation for sentences with real words

- Ni et al. (2000), Kuperberg (2000)
 - Active processing of sentences with real words
 - Semantic condition: Sentence anomaly
 - Syntactic condition: Grammaticality
 - No region selectively activated in syntactic condition
- Dapretto & Bookheimer (1999)
 - Similar design except that syntactic condition required judging whether two sentences meant the same thing
 - E.g. The teacher was outsmarted by the student vs. The student outsmarted the teacher
 - Greater activation in Broca's area for syntactic condition

Comparisons of sentences varying in syntactic complexity

- Just et al. (1996)
 - Comprehension task
 - Subject vs. object relative clauses

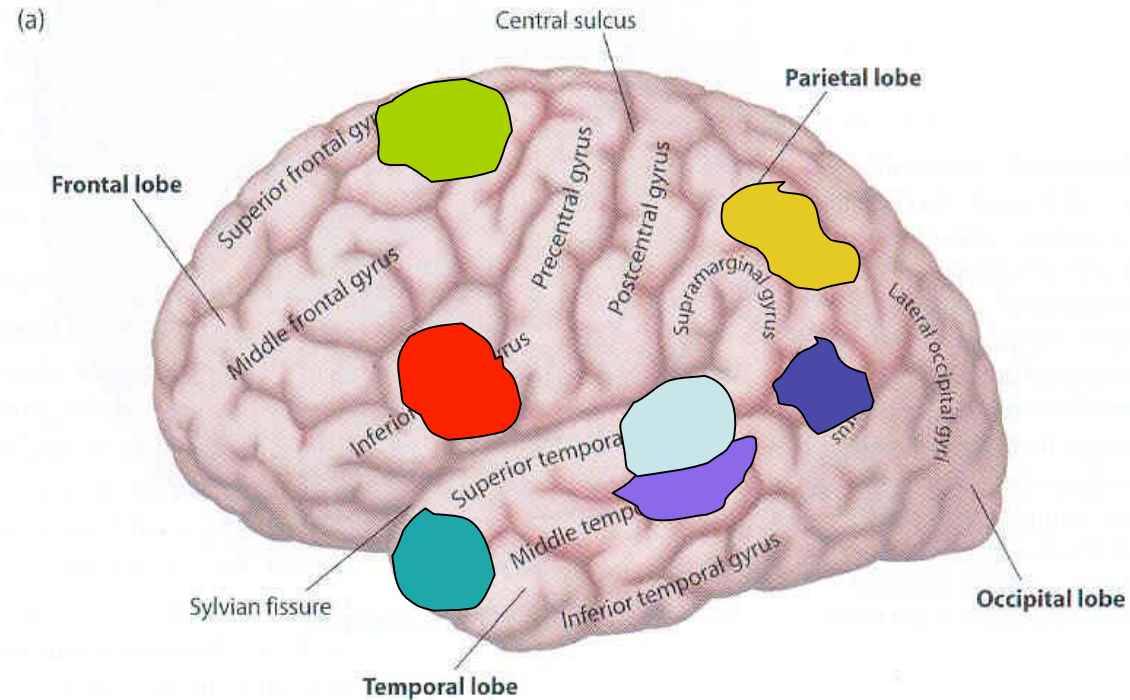
The boy that pushed the girl wore a green shirt.

The boy that the girl pushed wore a green shirt.

- Greater activation in left inferior frontal gyrus and left middle and superior temporal gyri for more complex

- Caplan & colleagues (1996, 1998, 2001)
 - Sentence anomaly task
 - Subject vs. object relative
 - Several experiments show activation only in Broca's area (or nearby)
 - With elderly subjects and young subjects matched in education, find activation in parietal and superior frontal regions (though different for two groups)
 - With event-related design and young subjects, activation only in angular gyrus and superior temporal region

Areas involved in syntactic processing of sentences



Implications of imaging studies

- Further research needs to be done
- Broca's area (or thereabouts) activated in several (but not all) that required determination of meaning based on syntactic structure
 - *Unlikely to be region dedicated to parsing, given patient findings on grammaticality judgments*

- Possibly region related to semantic reactivation (as in object relative sentences)
- Consistent with other imaging findings showing inferior frontal region involved in semantic retrieval and manipulation (Poldrack et al., 1999; Roskies et al., 2001)
- Consistent with lesion localization for semantic STM deficit patients (Romani & Martin, 1999)

Future Directions



Bressanone Trail Map

Future Directions

- Extensive case studies needed to test specific model-based hypotheses
 - A starting point: Take the hypotheses about agrammatism and apply to single cases (whether agrammatic or not). Test among competing hypotheses at the single subject level with converging tests.
 - Issue of connections between production and comprehension can be addressed
- Computational models needed to work out predictions of interactive models and WM models
- Neuroimaging studies - much is unclear regarding appropriate baseline, effects of difficulty, separating out working memory demands from syntactic processing, assigning syntactic structure vs. thematic role interpretation