Linguistic Categories in the Brain:
The case of Nouns and Verbs

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Fig. 1.

EBA: ‘Oh Lordy, she’s making a mess. She let the thing go, and it’s getting on the floor. They’re stealing something. He’s falling; he’s gonna hurt himself. She’s cleaning these things. She’s looking at him falling, and she’s gonna get some of the stuff he’s giving her.’

CH: ‘Okay, the boy is, his cookies, he is, uh, his sister is look for him cookies, but he is going to fall out of his stool because his legs are not bent that way. And his mother is, all the time her dishes are bein’…and his mother is, she has got this [k ∧ sit] and her faucet is never really on that, and then he has a tree, but he is, I don’t know.’

From Shapiro & Caramazza (2003)
• reports of selective disfunction of the grammatical classes of nouns and verbs (e.g., Miceli et al., 1984; McCarthy & Warrington, 1985; Zingeser & Bernt, 1988 -- 200+ cases on record to-date).
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Association of the behavioural double dissociation with different neuroanatomical substrates (e.g., Daniele et al., 1994)
One Theoretical Tradition

- Double dissociation between noun and verb processing in patients with focal lesions
- Distinct neural substrate for nouns and verbs (as inferred from lesion data)
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Grammatical class is a principle of lexical organisation in the brain
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Grammatical class is a principle of lexical organisation in the brain

Neural separability for networks processing nouns and processing verbs
“...the results we have reported suggest a remarkably specific organization of lexical knowledge in the brain [...]. Although we do not have clear hypotheses about the nature of the brain mechanisms that compute lexical structure, it is clear that the information computed by these mechanisms must represent [...] their grammatical class”. (Caramazza & Hillis, 1991, pg. 790)
“There must be something to talk about and something must be said about this subject of discourse [...] The subject of discourse is a noun. As the most common subject of discourse is either a person or a thing, the noun clusters about concrete concepts of that order. As the thing predicated of a subject is generally an activity [...], the form which has been set aside for the business of predicating, in other words, the verb, cluster about concepts of activity. No language wholly fails to distinguish noun and verb, though in particular cases the nature of the distinction may be an elusive one” (Sapir, 1921)
“[the Functionalist approach] seeks to equate the categories that are mapped onto surface grammar with a set of semantic-pragmatic elements, bypassing an independent, abstract and unitary set of syntactic categories or symbols” (Bates & MacWhinney, 1982)

Grammatical class is not an organisational principle of lexical knowledge in the brain while semantics is, noun/verb processing does not engage distinct neural networks
Nouns and Verbs in the Cognitive System

(e.g., Levelt, 1989; Pickering & Branigan, 1998)
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(e.g., Cheng et al., 2006; Elman, 2003)
Nouns and Verbs in the Cognitive System

Conceptual Features

Lexical Codes

Phonological/Orthographic Codes

Communicative Intentions

(e.g., Levelt, 1989; Pickering & Branigan, 1998)

(e.g., Cheng et al., 2006; Elman, 2003)
Nouns and Verbs in the Cognitive System

Other theories in between (e.g., Levelt et al., 1999; Garrett, 1975)

Communicative Intentions

(e.g., Cheng et al., 2006; Elman, 2003)
Nouns and Verbs in the Brain

Neural separability at the lexical level between nouns and verbs
Nouns and Verbs in the Brain

Neural separability at the lexical level between nouns and verbs

Neural separability at conceptual level between object and action knowledge. Common system for nouns and verbs
Nouns and Verbs in the Brain

Neural separability at the lexical level between nouns and verbs

In between: neural separability not at lexical level, but between processes that integrate nouns or verbs in morphological and/or syntactic frames

Neural separability at conceptual level between object and action knowledge. Common system for nouns and verbs
A principled look to Behavioural, Imaging and Patients’ data:
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- Objects and Actions (rather than nouns and verbs) have different neuroanatomical correlates

Vigliocco, Vinson, Druks, Barber & Cappa (2011)
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- Grammatical class is not a principle of lexical organisation in the brain however triggers integration processes that can differ depending upon task and language

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A principled look to Behavioural, Imaging and Patients’ data:

- Objects and Actions (rather than nouns and verbs) have different neuroanatomical correlates

- Grammatical class is not a principle of lexical organisation in the brain however triggers integration processes that can differ depending upon task and language

- The challenge is to capture the cognitive and neural mechanisms underscoring these integration processes

Vigliocco, Vinson, Druks, Barber & Cappa (2011)
Criteria guiding the evaluation of empirical work
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1. Noun-Verb distinction vs. Object-Event distinction
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In our work: focus on words referring to events, either nouns or verbs (e.g., “the dance”, “to dance”; “the advice”, “to advise”)
Criteria guiding the evaluation of empirical work

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Criteria guiding evaluation of empirical work

2. Task requirements - Ecological validity

Studies must distinguish between when grammatical class is not relevant to the task (engages only lexical retrieval processes) vs. when grammatical class is relevant to the task (engages lexical retrieval + integration processes)
Criteria guiding evaluation of empirical work
3. Processing demands for nouns and verbs differ within and *between* languages:
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English: 2 (number) vs. 5 (number, tense)
Italian: 4 vs. approx. 96!
Behavioural Studies

in collaboration with:
Noriko Iwasaki, Simona Siri, David Vinson
Behavioural Studies: Background
Effects of grammatical class have long been established in sentence comprehension and sentence production (e.g., Garrett, 1976)
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Lateralization differences between noun and verb processing with verbs showing a greater advantage for right hemifield presentation (Day, 1979; Sereno, 1999)
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- Effects of grammatical class have long been established in sentence comprehension and sentence production (e.g., Garrett, 1976)

- Lateralization differences between noun and verb processing with verbs showing a greater advantage for right hemifield presentation (Day, 1979; Sereno, 1999)

- However, these studies (1) confound semantics and grammatical class; (2) do not provide crucial evidence that grammatical class affects lexical retrieval
Italian Picture-Word Interference Experiments

Vigliocco, Vinson & Siri (2005)
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Condition 1: Bare Verb Production (citation form)

Speaker says: *Saltare* [to jump]

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Distracter Words
- Correre [to run] (sem related, same GC)
- Donare [to donate] (sem unrelat., same GC)
- Passeggiata [the walk] (sem related, diff GC)
- Richiesta [the request] (sem unrelat., diff GC)

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This is also a full sentence

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![Bar graph showing naming latencies for sem related and sem unrelated distractors. The x-axis represents the type of distractor (noun or verb), and the y-axis represents naming latencies in milliseconds (ms). The graph shows higher latencies for verb distractors compared to noun distractors.]
Japanese Picture-Word Interference Experiments

Iwasaki, Vinson, Watanabe, Arciuli & Vigliocco (2008)
Condition 1: Bare Verb Production (citation form)

Speaker says: *Moyasu [to burn]*
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- Yuderu [to boil] (sem related, same GC)
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- Hime [the scream] (sem unrelated, diff GC)

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Condition 2: Phrasal Production

Otoko
[man]
Condition 2: Phrasal Production

**Otoko**
[man]

Speaker says: “otoko-ga” [man-NOM]
Condition 2: Phrasal Production

Speaker says: moyashite-iru
“burning-PROG”

Speaker says: “otoko-ga” [man-NOM]
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Speaker says: moyashite-iru
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Behavioural Studies: Conclusions
Once semantics is controlled grammatical class does not affect lexical retrieval
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Grammatical class affects integration in phrasal contexts in some languages (Italian and English too! see Vigliocco, Vinson & Barber, 2008) but not other languages (Japanese) plausibly due to different demands on verbs.
Imaging Studies

in collaboration with:
Pasquale della Rosa, Stefano Cappa, Simona Siri, Jane Warren, David Vinson, Richard Wise
Imaging Studies: Background
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Background

- Most studies, confounding between semantics and grammatical class
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• Some studies that reduced semantic confound: Left Inferior Frontal Gyrus (IFG) or Middle Frontal Gyrus for verbs (e.g., Longe et al., 2007; Shapiro, Moo & Caramazza).
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• Large variability in activations (see Crepaldi et al., 2013)
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• Large variability in activations (see Crepaldi et al., 2013)

• Studies differ in task-specific requirements and language investigated (in addition to testing objects vs actions)
Task:
This is a sail; these are ___
This person sails; these people ___

These are wugs; this is a ___
These pigs wug; this pig ___

Shapiro, Moo & Caramazza (2006)
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6 English speakers: 
Guess what “a wug”/”many wugs”/”he wugs”/”they wug” mean (40 items)
A wug: small wiggly insect, cross between worm and bug.
Many wugs: punctuation marks.
He wugs: a crazy dance.
They wug: come to an agreement.

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Singular pseudonoun (A wug): 81% object
Plural pseudonoun (Many wugs): 87% object
Singular pseudoverb (He wugs): 89% action
Plural pseudoverb (They wug): 74% action
<table>
<thead>
<tr>
<th>Nouns</th>
<th>Motion</th>
<th>Sensory</th>
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<tbody>
<tr>
<td>Giravolta twist</td>
<td>Galoppa gallop</td>
<td>Luccia shine</td>
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<td>Tuffo dived</td>
<td>Rinoccor chase</td>
<td>Starnazza quacks</td>
</tr>
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<td>Atterraggio landing</td>
<td>Pattina skate</td>
<td>Degusta taste</td>
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<td>Lampo lightning</td>
<td>Oscurita’ darkness</td>
<td>Ronzio buzz</td>
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Nouns and Verbs in inflected form
Task: listening to blocks of words, or rotated speech (baseline)

No area of significantly greater activation for either nouns or verbs
fMRI experiment in Italian using *overt* picture naming

<table>
<thead>
<tr>
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<th>Infinitive Verb</th>
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<tr>
<td><img src="image" alt="Dancing" /></td>
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No semantic (and visual) confound: same picture
Picture naming used to establish noun-verb dissociations

Siri, Tettamanti, Cappa, della Rosa, Saccuman, Scifo & Vigliocco (2008)
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## Description of Conditions

### Lexical Retrieval

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- **Lexical Retrieval**: Infinitive Verbs
- **Lexical Retrieval + Inflectional Processes**: Inflected Verbs and Action Nouns
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**Action Noun - Infinitive Verb**

(p < .05, false discovery rate type correction)

Ventral IFG (BA45/47)  
\[x=-48,y=24,z=-4\]

Dorsal IFG (60% BA44)  
\[x=-46,y=16,z=26\]
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Imaging Studies: Conclusions

- Once semantics is controlled, noun and verb processing may not engage segregable neural networks.

- Left frontal cortex is more (or less) engaged depending upon (1) extent of integration required by the task; (2) extent of engagement of processes related to selection and decision.

- Language has not been addressed properly!
Patients’ Studies

in collaboration with:
Stefano Cappa, Judit Druks, Simone Matzig
A closer look to Neuropsychological Evidence

Matzig, Druks, Materson & Vigliocco (2009)
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Review of patients’ studies (focal lesions) published between 1984-2006 (note that picture naming has been used primarily)

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- 240 patients with focal lesions have been reported in 38 papers.
- Many more patients with verb specific deficit (11% noun deficit; 75% verb deficit) suggesting greater heterogeneity in causes of verb naming deficit.
- Magnitude of the dissociation is extremely variable (2 - 81%. if we limit to large dissociations (>30% difference) only 36 cases reported (12 nouns, 24 verbs).
## Lesion Data: Noun Deficit

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<tbody>
<tr>
<td>L. Fronto-Temporal</td>
<td>1</td>
</tr>
<tr>
<td>L. Temporo-Parietal (Bilat)</td>
<td>2</td>
</tr>
<tr>
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<td>1</td>
</tr>
<tr>
<td>L. Temporo-Parietal-Occipital</td>
<td>2</td>
</tr>
<tr>
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<td>2</td>
</tr>
<tr>
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**Plausible semantic account of object/noun naming deficit**
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</tr>
<tr>
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<td>1</td>
</tr>
<tr>
<td>L. Internal Capsule, White Matter</td>
<td>1</td>
</tr>
<tr>
<td>L. Basal Ganglia</td>
<td>1</td>
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<td>L. Parietal, White Matter, External Capsule, Thalamus</td>
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</tr>
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<tr>
<td>L. Fronto-Temporal</td>
<td>4</td>
</tr>
<tr>
<td>R. Fronto-Temporal</td>
<td>1</td>
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<tr>
<td>L. Occipito-Parietal</td>
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<tr>
<td>L. Temporo-Parietal</td>
<td>3</td>
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<tr>
<td>L. Fronto-Temporo-Parietal</td>
<td>3</td>
</tr>
<tr>
<td>L. Temporal</td>
<td>1</td>
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<tr>
<td>L. Parietal</td>
<td>3</td>
</tr>
</tbody>
</table>

Different causes for action/verb naming deficits

Matzig, Druks, Materson & Vigliocco (2009)
Verb naming impairment in NfPPA, PSP and CBD

• Non fluent Primary Progressive Aphasia (NfPPA): left IFG and insular atrophy (Gorno-Tempini et al., 2004)

• Corticobasal Degeneration (CBD): asymmetric (left>right) brain atrophy involving premotor cortex, superior parietal lobes and striatum

• Progressive Supranuclear Palsy (PSP): atrophy of midbrain, pons, thalamus, and striatum with minimal involvement frontal cortex (Boxer et al., 2006)

Cotelli et al. (2006)
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• Language has not been addressed!
Behavioural data

• effects of grammatical class only when task involves integration processes

• cross-linguistic differences related to different demands on integration processes

Imaging data

• semantic differences

• common neural network for nouns and verb processing

• interactions with and language

Patients’ data

• semantic differences

• plausibly, differences in demands on integration processes for verbs can account for some action/verb naming impairments
Nouns and Verbs in the Cognitive System

Conceptual Features

Lexical Codes

Phonological/Orthographic Codes

[NP:Det+N] [VP:V+NP]
(e.g., Levelt, 1989; Pickering & Branigan, 1998)

Other theories in between

Communicative Intentions

[the+w1] [w2+the+w3]
(e.g., Cheng et al., 2006; Elman, 2003)
Nouns and Verbs in the Brain

Neural separability at the lexical level between nouns and verbs
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Neural separability at conceptual level between object and action knowledge. Common system for nouns and verbs.
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• A typological emergentist view of grammatical class (Vigliocco et al., 2011)

  • Pragmatic/semantic: universal primary building blocks for establishing grammatical class differences in development.

  • Distributional probabilistic cues that can vary across languages (syntactic and morphological) would be necessary for learning and processing non prototypical members (integration)
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• Way forward: proper principled investigations of cross-linguistic differences!