

On Concepts, Words and Syntax:

*The Featural and Unitary Semantic Space
Hypothesis and Beyond*

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I apologize for this latest entry. I can't find a chimp making a face as dumb as this one. -Rich



- *Part I: On Words' meanings and Concepts: The Featural and Unitary Semantic Space (FUSS) Hypothesis*
- *Part II: On Words' meanings and Grammatical Class: how far can we go without syntax?*

- Mechanistic meaning construction hypothesis
- does not go beyond the skin
- only looks at language use: performance
- only looks at unconscious processes of language use
- it is reductionist: brain
- representations: relation between brain and reality (or: stored information for easier use)

Part I:
On Words' Meanings
and Concepts

Featural and Unitary Semantic Space (FUSS)

Hypothesis: Assumptions

FUSS

- The same principles underlie the semantic representation of words from different domains (objects & events)
- Same representations are consulted during production and comprehension of language.

Words' meanings are grounded in conceptual knowledge...

Words' meanings binding of conceptual features to interface with syntactic, phonological and orthographic information.

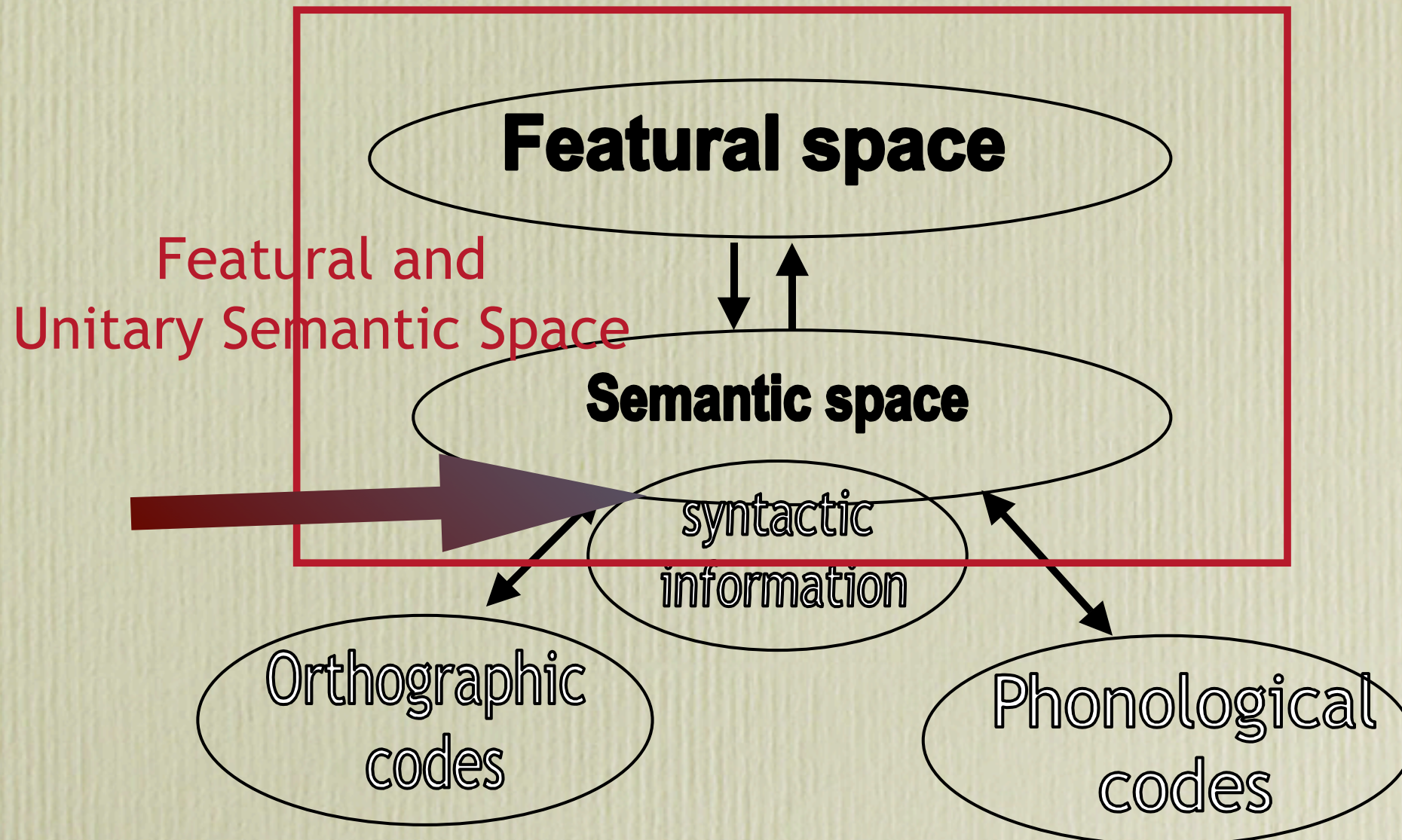
This interface is necessary to: Allow for cross-linguistic variability in what is lexicalized (*universality* of conceptual knowledge, but *language specificity* of semantic representations for words

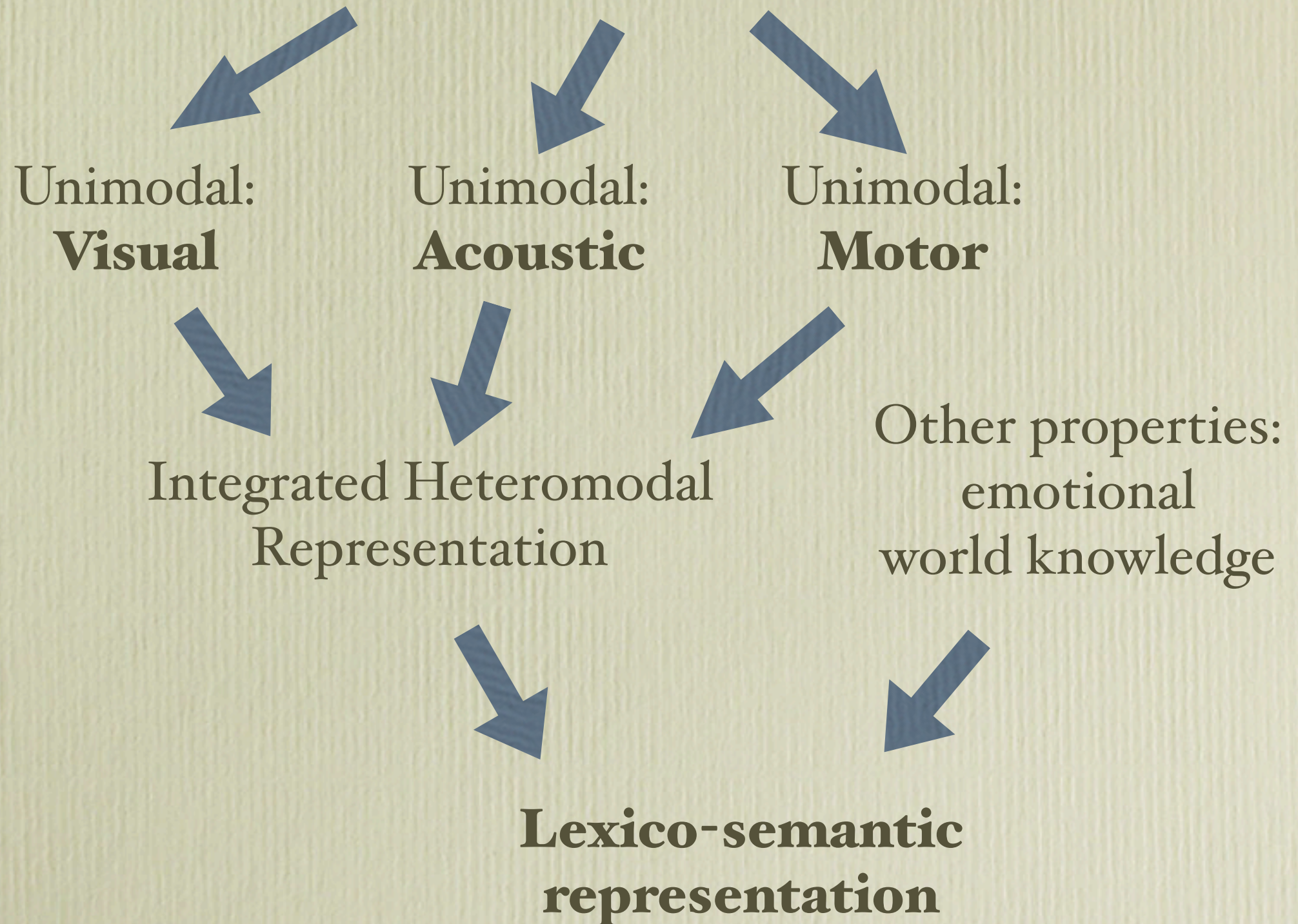
Similarity in words' meanings: similarity in featural properties of different words

Words' meanings are grounded in conceptual knowledge and concepts are grounded into our interactions with the environment

Concepts: Distributed featural representations. Some *primitive* features are distributed following the organization of sensory-motor systems

- Conceptual knowledge involves modality-specific information which is integrated across modalities in hierarchically organized sets of association areas (*convergence zones*, Barsalou *et al.*, 2003; Damasio, 1989).
- Words' meanings as one type of *convergence zone*





The logic behind

- This is not a theory of language, or languages!
- This is an attempt to explore how far we can go with a “dumb” system
 - minimal number of assumptions
 - treating words as “bags of words”

FUSS: Making the assumptions explicit

- 456 words: referring to objects & referring to events (actions, states etc)
- **Concepts:** Speakers provide features that they believe salient for given concepts
 - Provide us with the necessary data (featural space) from which to develop lexico-semantic space
 - Provide us with information concerning *modality-related* properties of words
- **Words' meanings:** Computational tools (self-organizing maps, SOMs) are used to derive a lexico-semantic space, on the basis of the distributional information provided by the features.
- We do the same in different languages...

Objects

Fruit & Veggies

Animals

Tools

Body parts

Vehicles

Clothing

...

Actions & other Events

Striking

Sounds (human, animal,
object)

Motion (manner, direction)

Light emission

Communication (type,
manner)

...

the strawberry

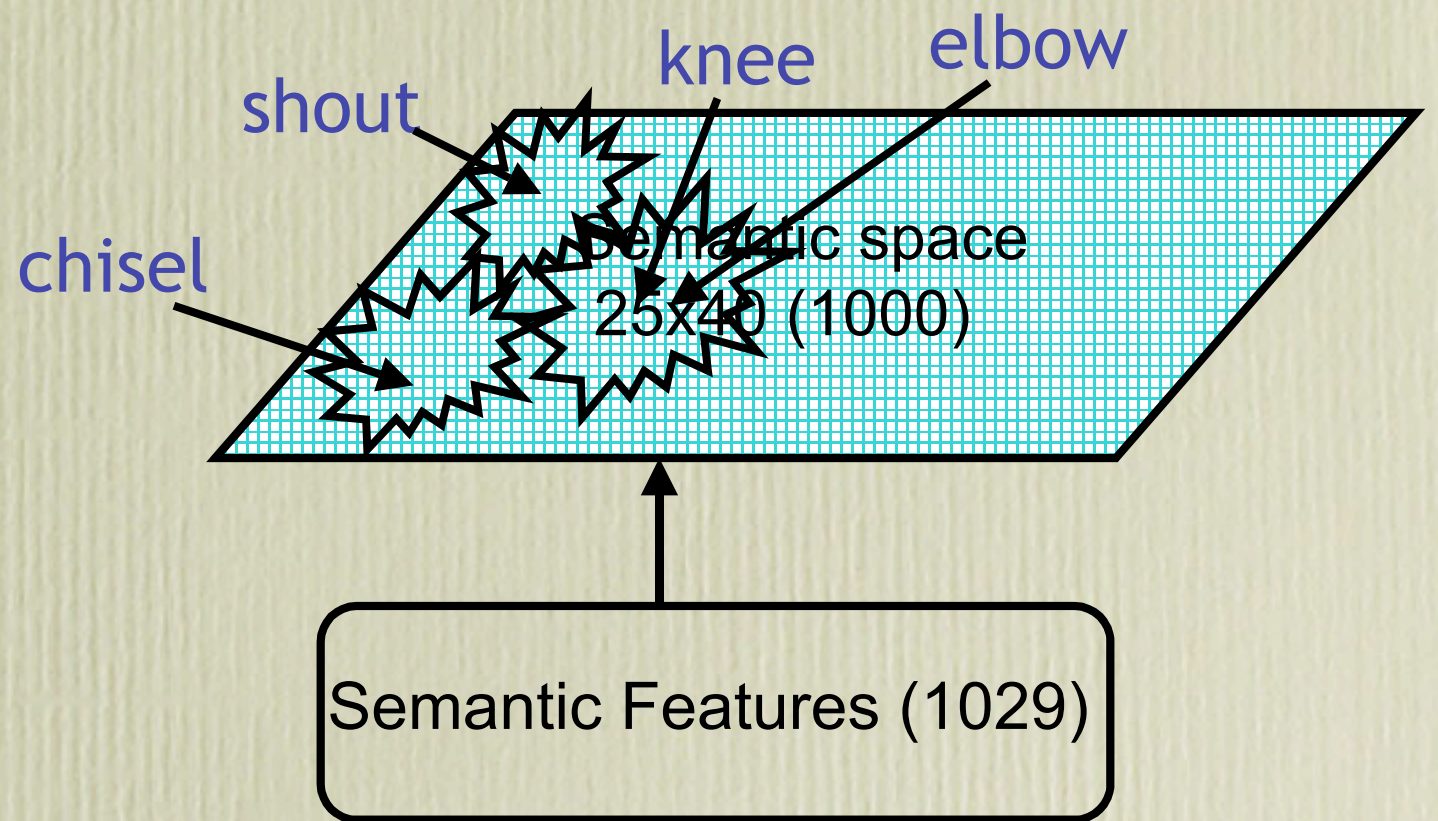
- red (20)
- fruit (18)
- sweet (13)
- has seeds (12)
- grows (10)
- small (6)
- taste (6)
- food (5)
- from garden (5)
- juice (5)
- dessert (3)
- eat (3)...

to scream

- loud (16)
- fear (14)
- noise (9)
- vocal (8)
- high-pitched (6)
- yell (6)
- emotional (4)
- extreme (4)
- help (4)
- sound (4)
- action (3)
- by human (3)...

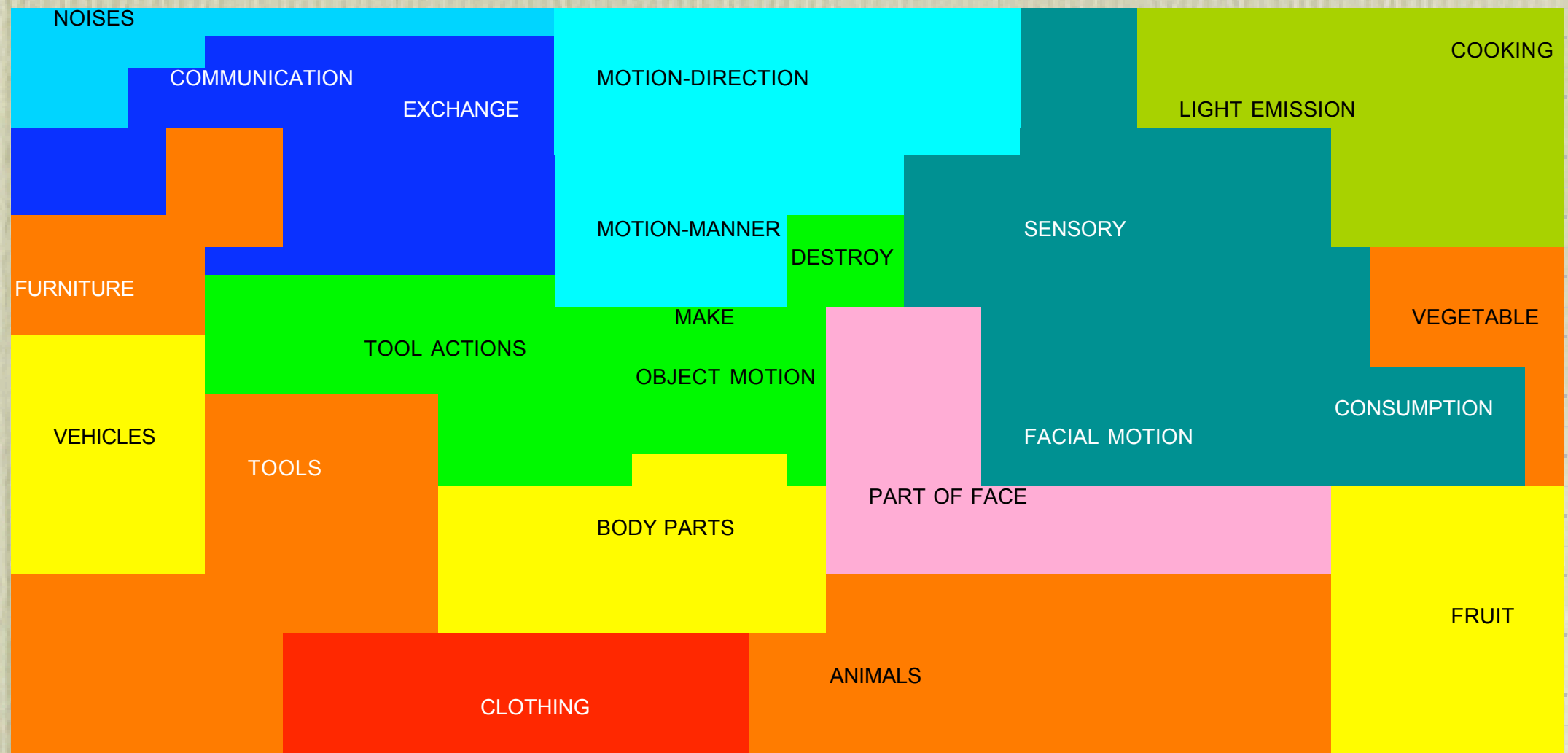
From Conceptual Features to Semantic Similarity among Words

Features need to be bound into a *lexical representation* in order to interface with syntactic, phonological and orthographic information. Self-organizing maps reduce dimensionality of the featural space on the basis of the featural distributional properties



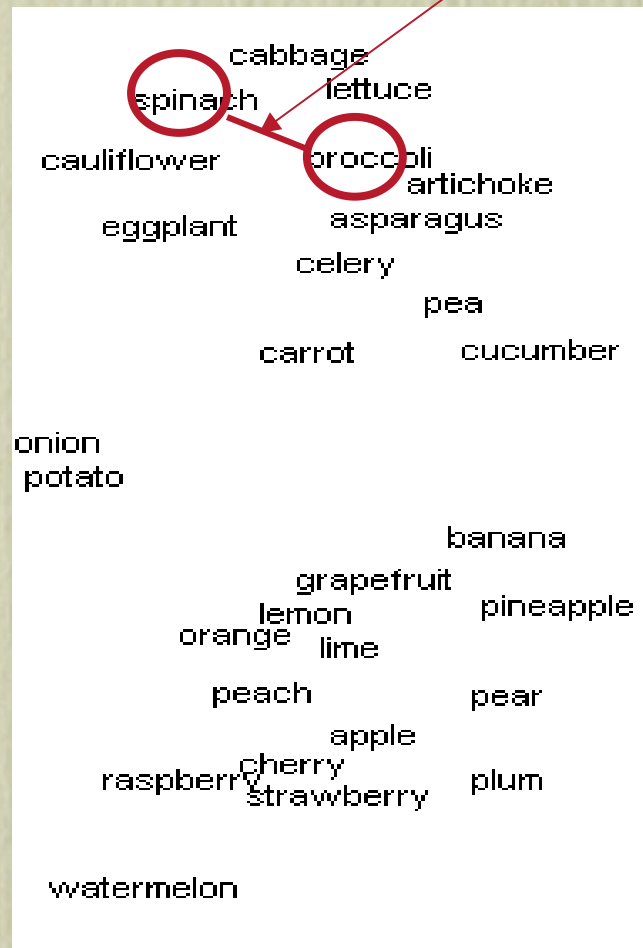
In the resulting semantic space, words = units and semantic similarity among words: Euclidean distance between units.

Resulting Lexico-Semantic Space

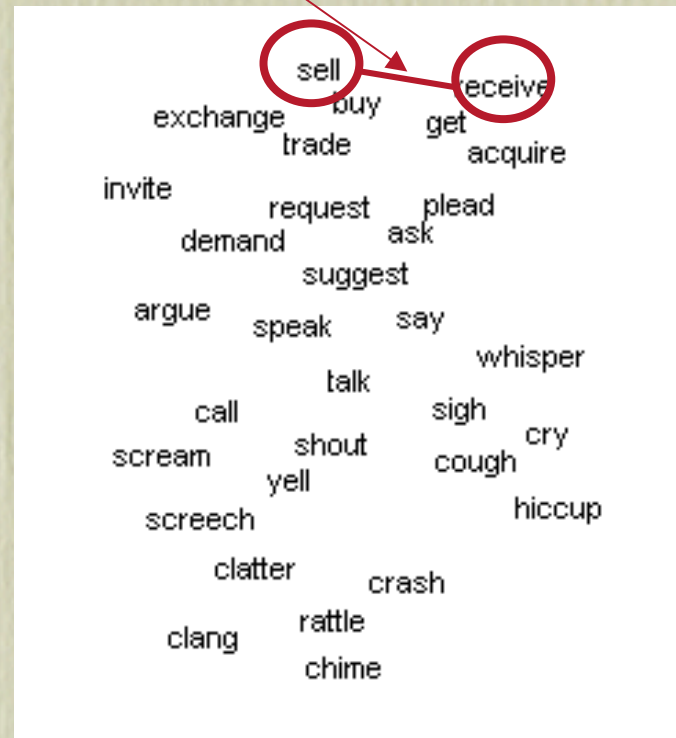


Semantic distance

Some fruits & vegetables

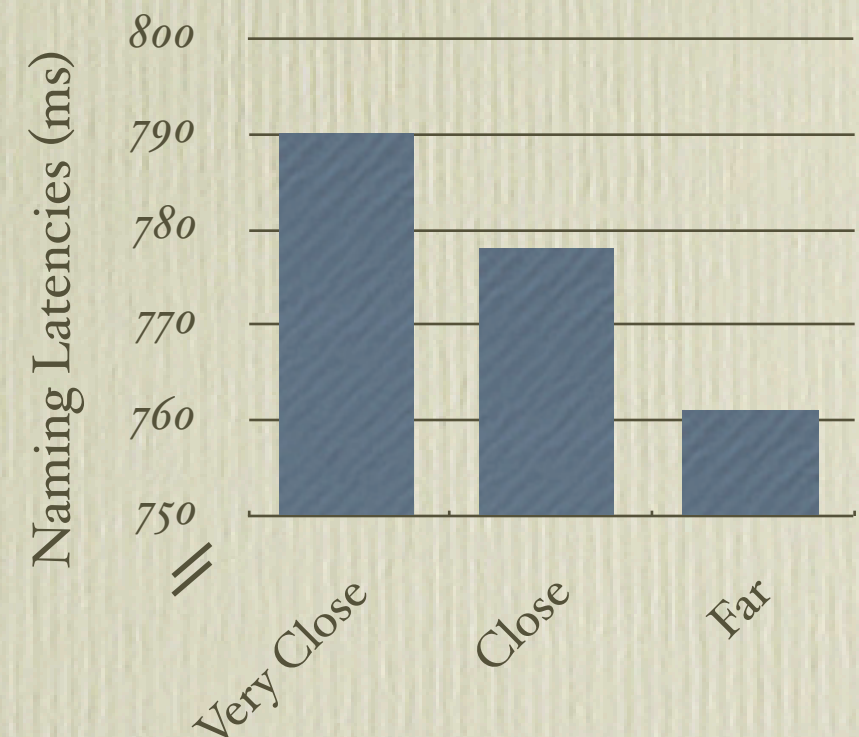
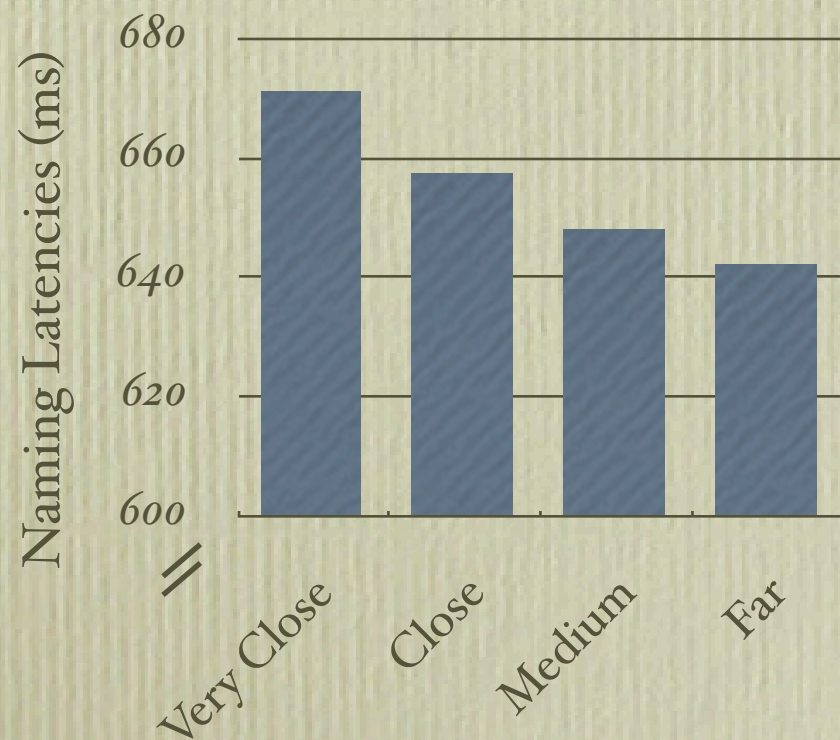
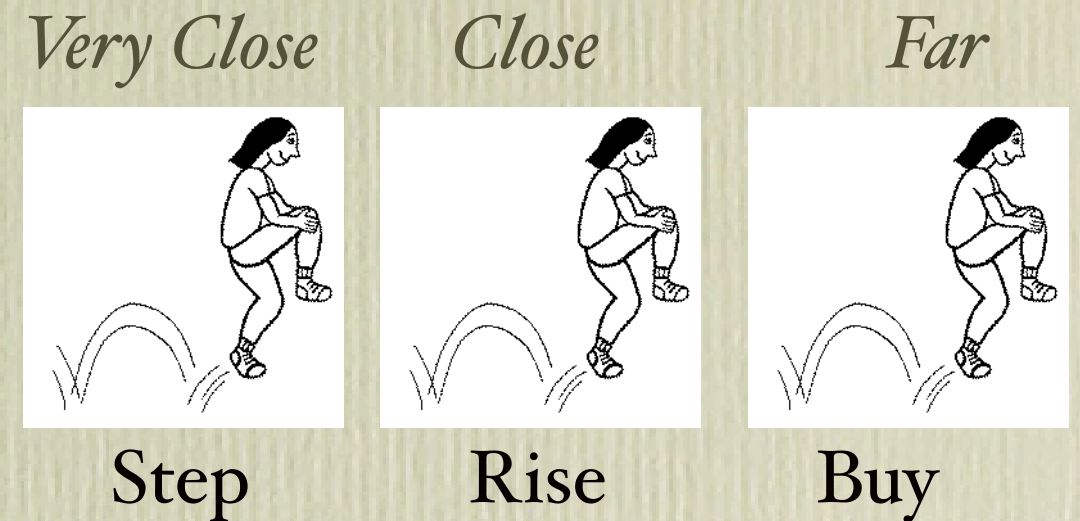
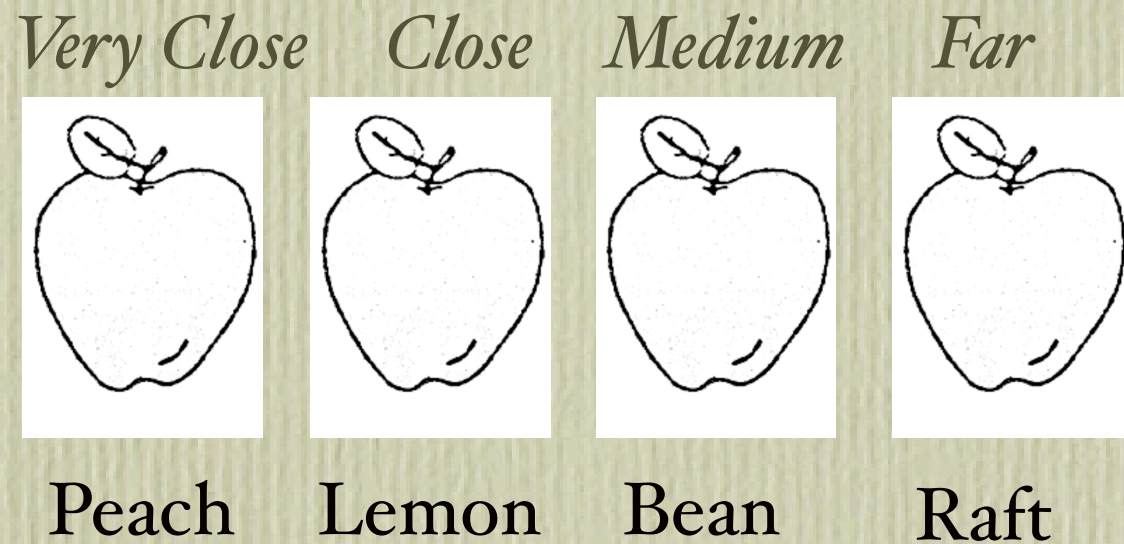


Some sounds, commun. & exchange





FUSS semantic distances: good predictor of semantic effects in different behavioral tasks for objects and events. *Picture-Word Interference Experiments*



FUSS semantic distances: good predictor of semantic effects in different behavioral tasks for objects and events. *Priming in Lexical Decision*

Lexical Decision Task: Prime:67ms; 0 ISI

target: **dagger**

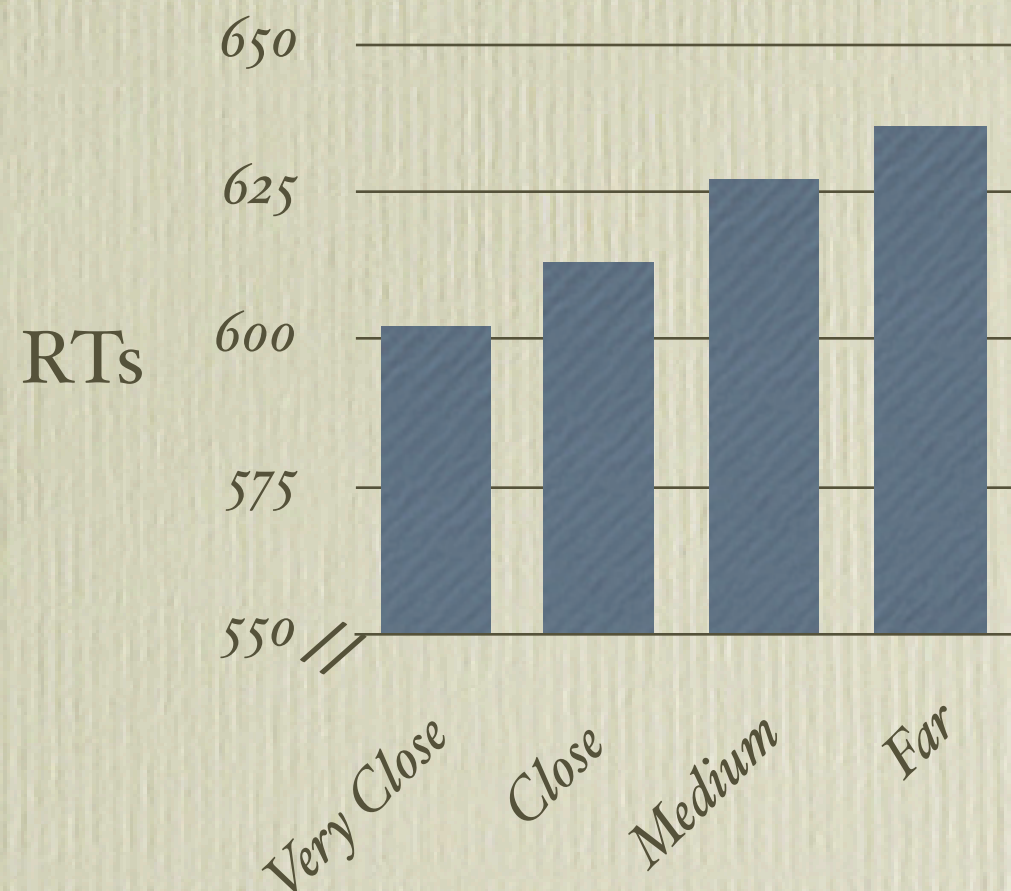
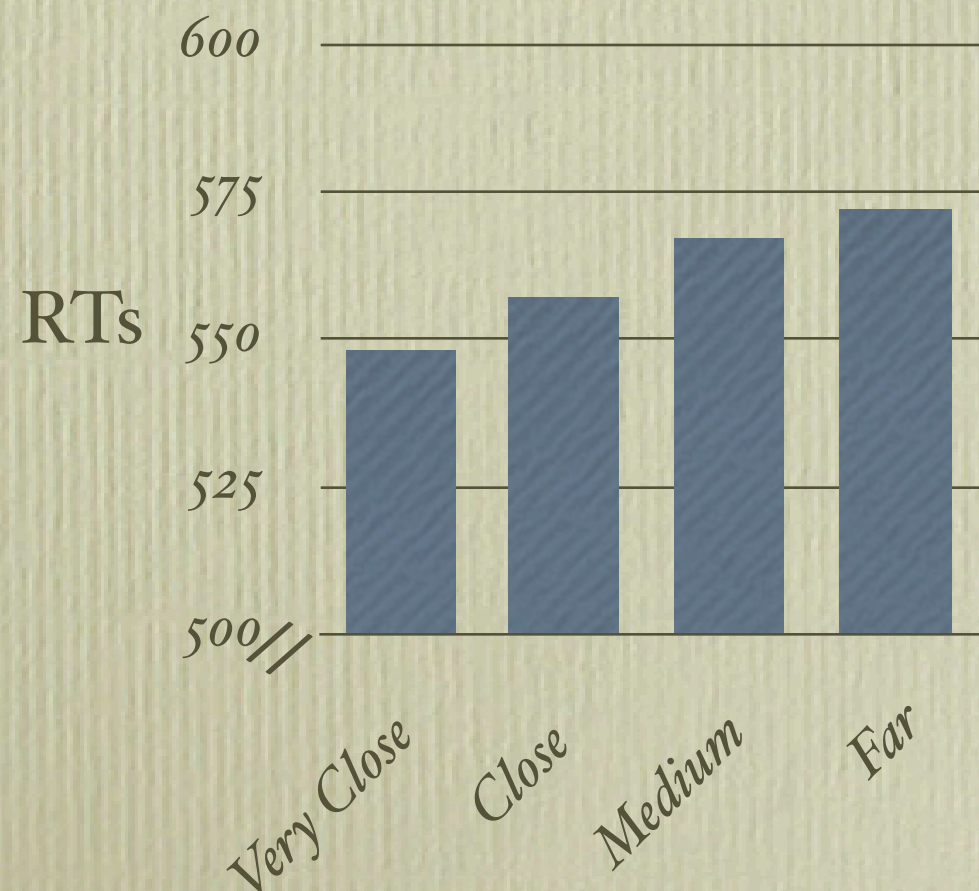
primes:

sword, razor, hammer, tongue

target: **bake**

primes:

grill, cook, eat, drop



We are not alone...

-
- There are other quantitative models for both objects and events:
- Global co-occurrence models (e.g. *Latent Semantic Analysis*: Landauer & Dumais, 1997)
- Hierarchical network models (e.g. *Wordnet*: Miller & Fellbaum, 1991)

Feature-Types and Retrieval of Modality-Related Information

- In FUSS, modality-related conceptual featural information is important
- Feature-type classification provides information on which modality-related features are most important for given words
- Does processing words entail the activation of modality-related information even when we *just listen*?

To run

- fast (15)
- uses-legs (13)
- exercise (9)
- move (8)
- by-humans (6)
- by-animals (4)
- destination (3)
- speed (3)
- uses-foot (3)
- action (3)
- walk (3)

to scream

- loud (16)
- fear (14)
- noise (9)
- vocal (8)
- high-pitched (6)
- yell (6)
- emotional (4)
- extreme (4)
- help (4)
- sound (4)
- action (3)
- by human (3)...

Does processing words referring to *events* entail the activation of modality-related information even when we *just listen*?

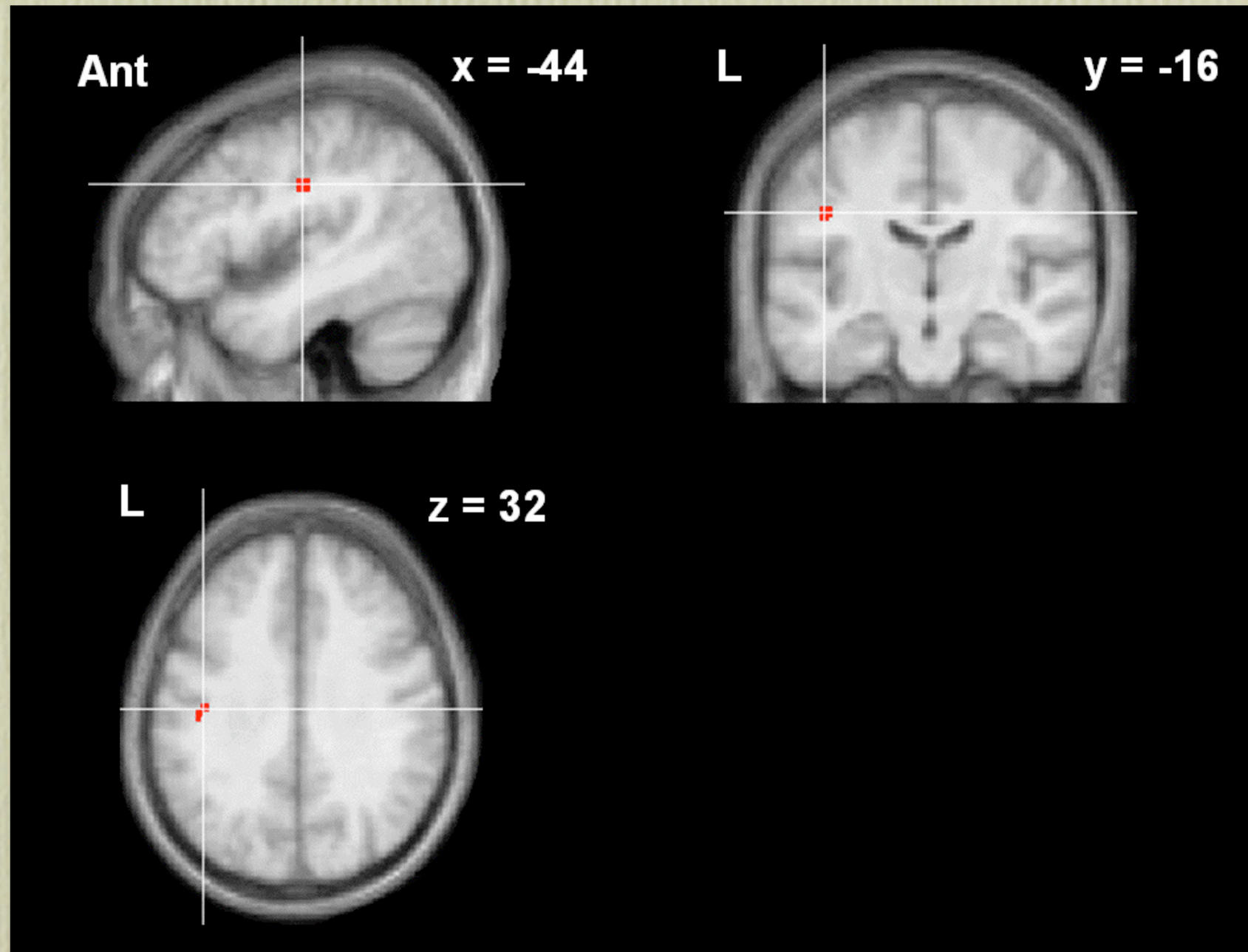
<p>Motion (motion features > others)</p>	<p>Sensory (visual+acoustic etc. > others)</p>
<p>Galoppiano <i>(they) gallop</i> Rincorre <i>(s/he) chase</i> Pattinano <i>(they) skate</i> Giravolta <i>twirl</i> Tuffi <i>dive-pl</i> Atterraggi <i>landing</i></p>	<p>Luccicano <i>(they) shine</i> Starnazza <i>(it) flutters</i> Degustano <i>(they) taste</i> Lampo <i>lightning</i> Oscurita' <i>darkness</i> Ronzii <i>buzzes</i></p>

- PET, 12 Italian participants
- **Task:** listen attentively to blocks of words
- **Baseline:** spectrally rotated speech

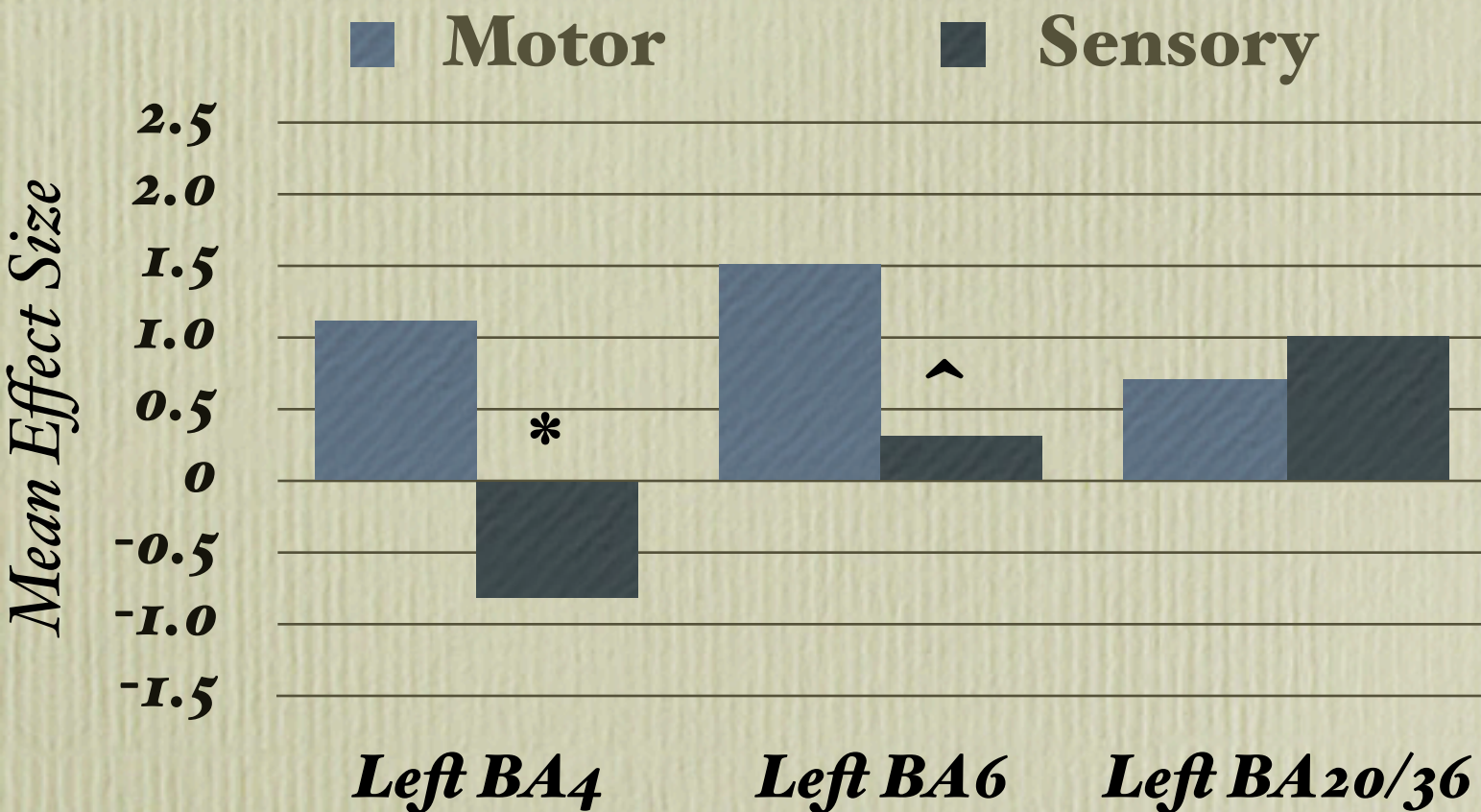
Premotor/motor (BA 4/6) activations for Motor Words

Multimodal temporal basal areas (BA 20/36) for Sensory Words

Motor vs. Sensory Word



Regions of Interest (ROIs) Analysis



* $p < .05$, ^ $p < .10$

Listening (the **most** automatic task) to *Motor Words* activates primary motor cortex.

This suggest that we cannot help but retrieve non-linguistic information specific to modality

No effect for *Sensory Words* in basal temporal areas.

Validation of our speaker-generated features

Part I: Summary

Words' meanings are grounded in conceptual knowledge:

Concepts: conceived as distributed featural representations; operationalized as speaker-generated features, some of which are related to a specific modality

- ☑ Primary motor cortex activations in listening to words

Words' meanings: conceived as binding conceptual features and as an interface with other linguistic information: operationalized as the resulting output of a SOM where semantic similarity = distance between units.

- ☑ Graded semantic effects in a variety of tasks

The same principles underlie the semantic representation of words referring to objects and events

- ☑ Graded semantic effects for objects and events.

Same representations are consulted during production and comprehension of language.

- ☑ Graded semantic effects in production and word recognition experiments

Part II:

On Concepts,
Words' Meanings and
Grammatical Class

- Knowledge about **words** is organized according to grammatical class (nouns and verbs)
 - Aphasic patients have been described who are selectively impaired for nouns, not for verbs and vice versa
 - Areas of specific activation for **verbs** have been reported.
- However, studies *confounded* the semantic distinction between objects and events and the grammatical distinction between nouns and verbs

● Semantic distinctions are reflected in grammatical class distinctions

- Objects -> Nouns
- Events -> Verbs



● But, semantic distinctions are NOT always reflected in grammatical class distinctions

- Events -> verbs and nouns (e.g., *to walk*, *the walk*)



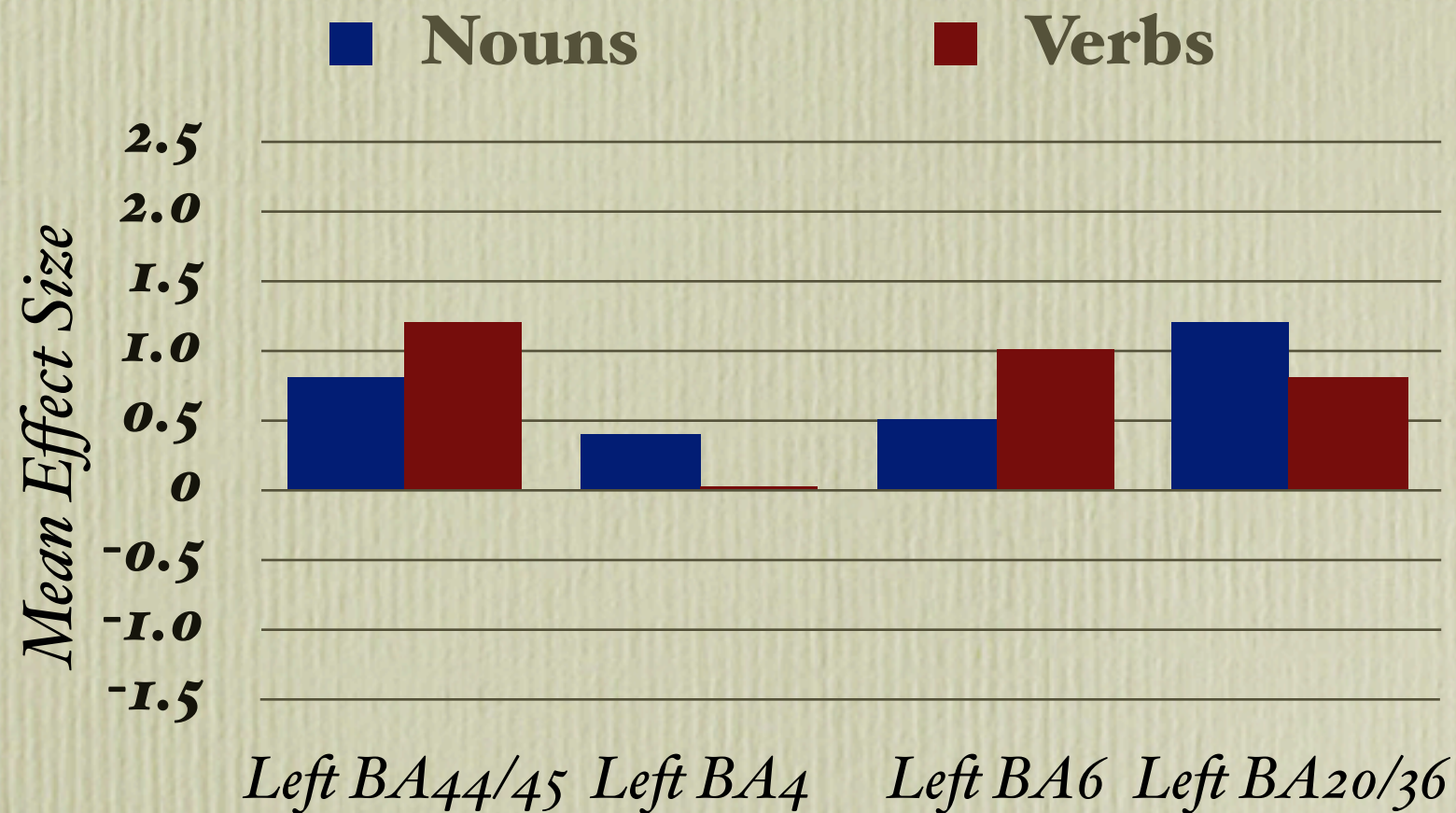
to hit is closer to *to hammer* than to *the hammer*

to smile is NOT closer to *to frown* than to *the frown*

Do distinct neural networks underlie the processing of verbs and nouns?

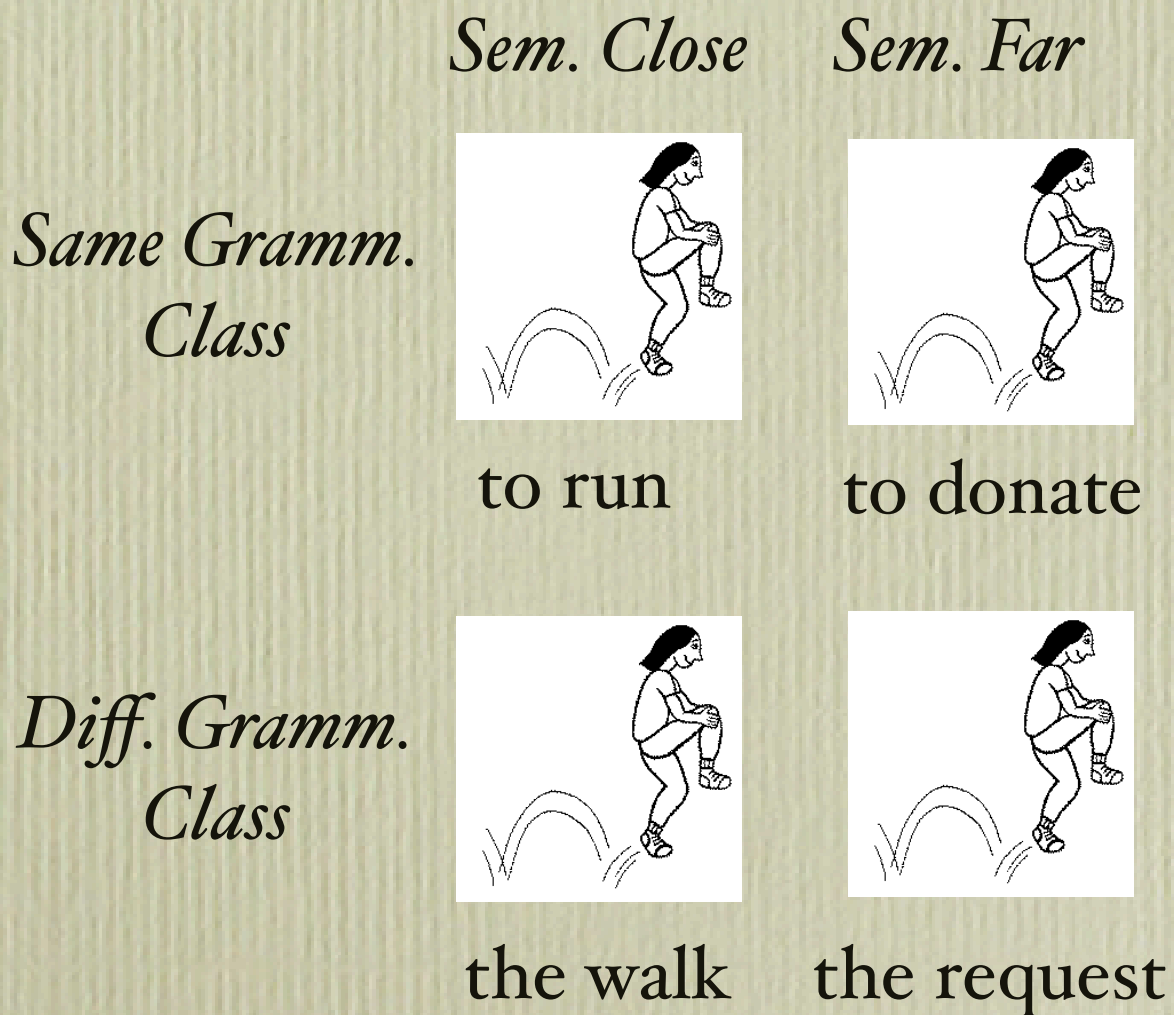
	Motion	Sensory
Verbs	Galoppiano <i>(they) gallop</i> Rincorre <i>(s/he) chase</i> Pattinano <i>(they) skate</i>	Luccicano <i>(they) shine</i> Starnazza <i>(it) flutters</i> Degustano <i>(they) taste</i>
Nouns	Giravolta <i>twirl</i> Tuffi <i>dive-pl</i> Atterraggi <i>landing</i>	Lampo <i>lightning</i> Oscurita' <i>darkness</i> Ronzii <i>buzzes</i>

Regions of Interest (ROIs) Analysis

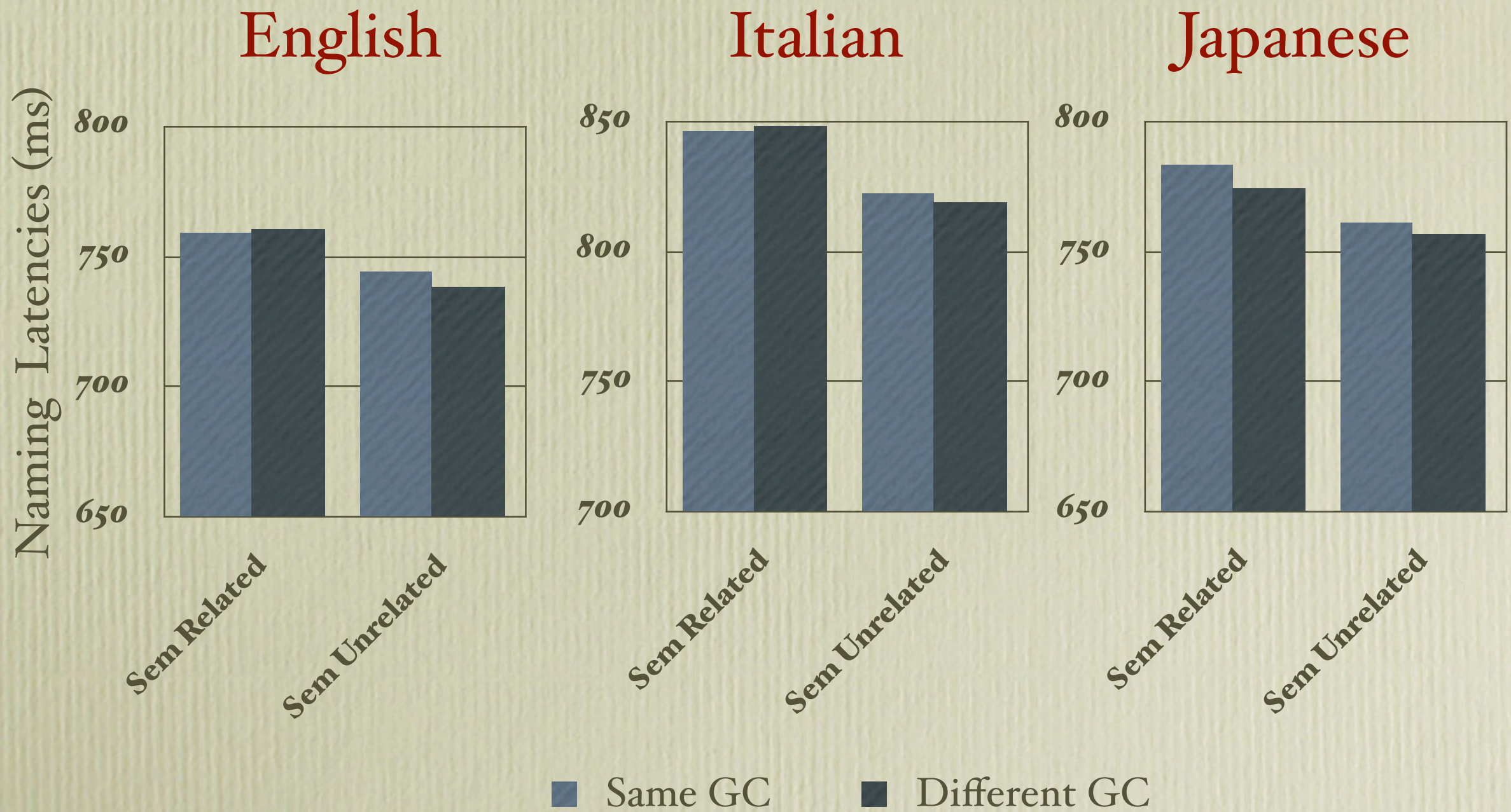


In an automatic task, listening to words, a common neural system underlies the processing of nouns and verbs, once semantics is controlled

Do Grammatical Class effects arise when semantic distance is controlled? *Picture-Word Interference Experiments*

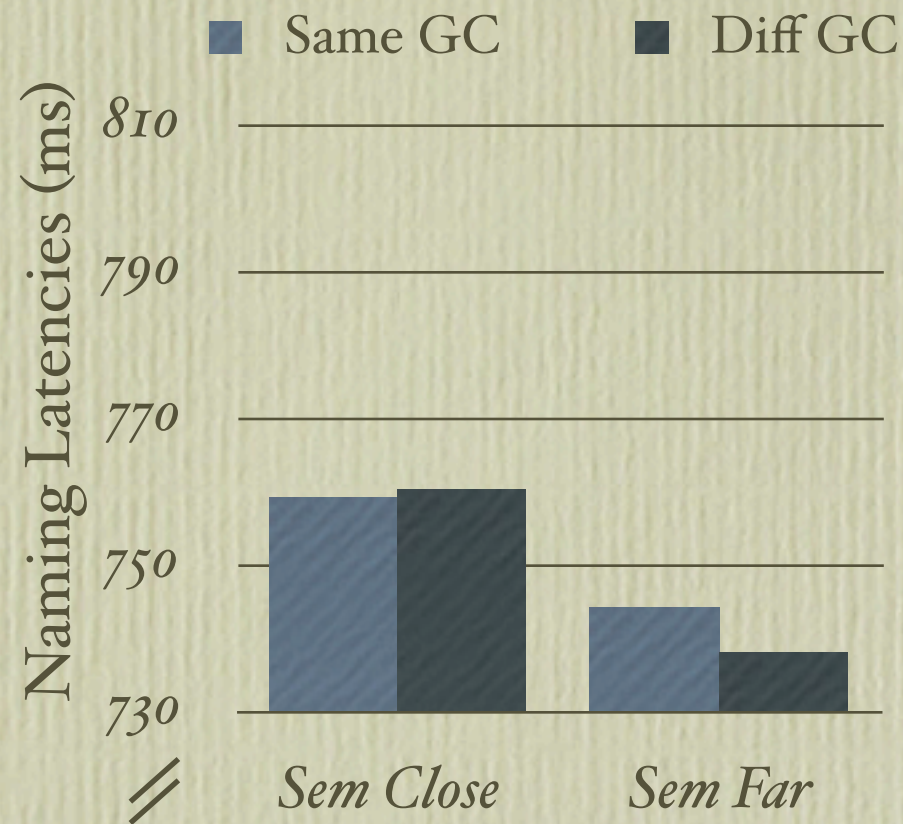


Picture-Word Interference Experiments

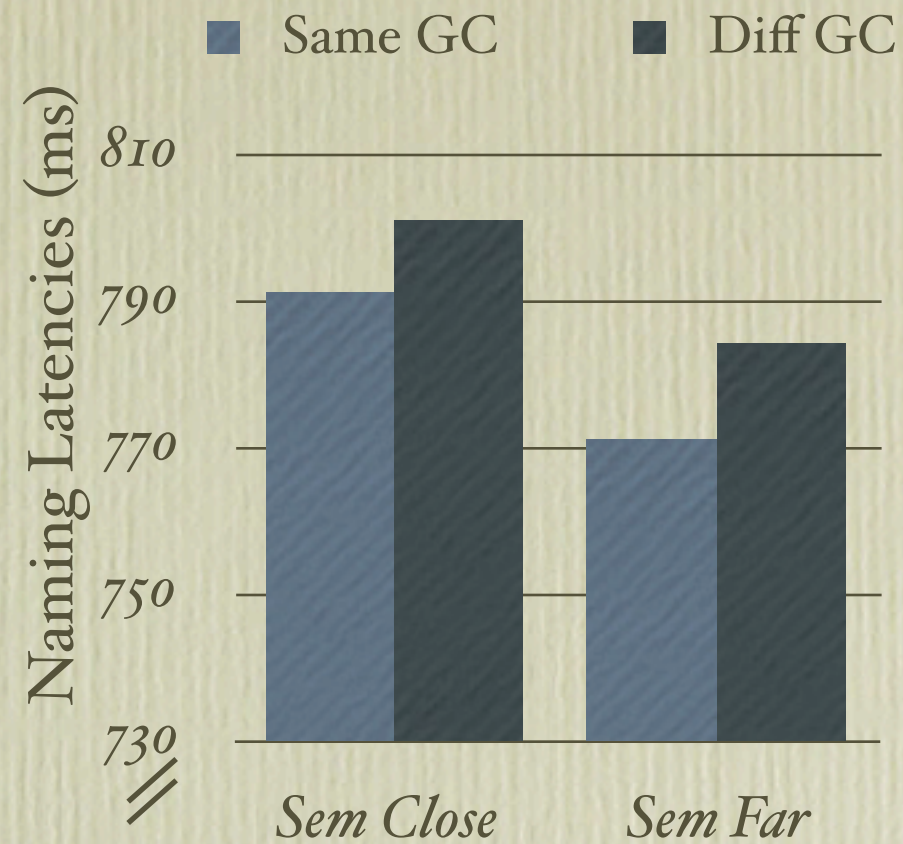


Grammatical class, meaning and sentences

- When semantic similarity is controlled:
 - no evidence for distinct neural substrate for verbs and nouns
 - no effect of grammatical class in producing single words
- But, is that all there is?



Hopping



In this picture he is...hopping

Effects of grammatical class when *sentence integration processes* are triggered in addition to lexical retrieval processes in picture-word interference experiments

Meaning & Grammatical Class

- A large number of previous studies showing differences between verbs and nouns, show, instead, differences between events and objects and can be accounted in FUSS
- Effects of grammatical class beyond single word production, however, cannot be accounted for solely in terms of semantic differences

FUSS as a plausible hypothesis of words' meanings that brings together theorizing and data from different approaches and disciplines:
psycholinguistics, concepts & categorization, neuropsychology and imaging.

FUSS as a useful tool to explore issues in the representation and processing of other types of linguistic information, *correlated* with meaning.

- Syntactic Properties
(Grammatical class, count-mass, classifiers, verb-specific requirements...)

- Stefano Cappa (*San Raffaele, Milano*)
- Merrill Garrett (*University of Arizona*)
- Noriko Iwasaki (*University California-Davis*)
- Will Lewis (*California State University*)
- Simona Siri (*San Raffaele, Milano*)
- David Vinson (*University College London*)
- Jane Warren (*Imperial College, London*)
- Richard Wise (*Imperial College, London*)

*Biotechnology and Biological Sciences Research Council,
Human Frontier Science Program,
McDonnell Foundation*