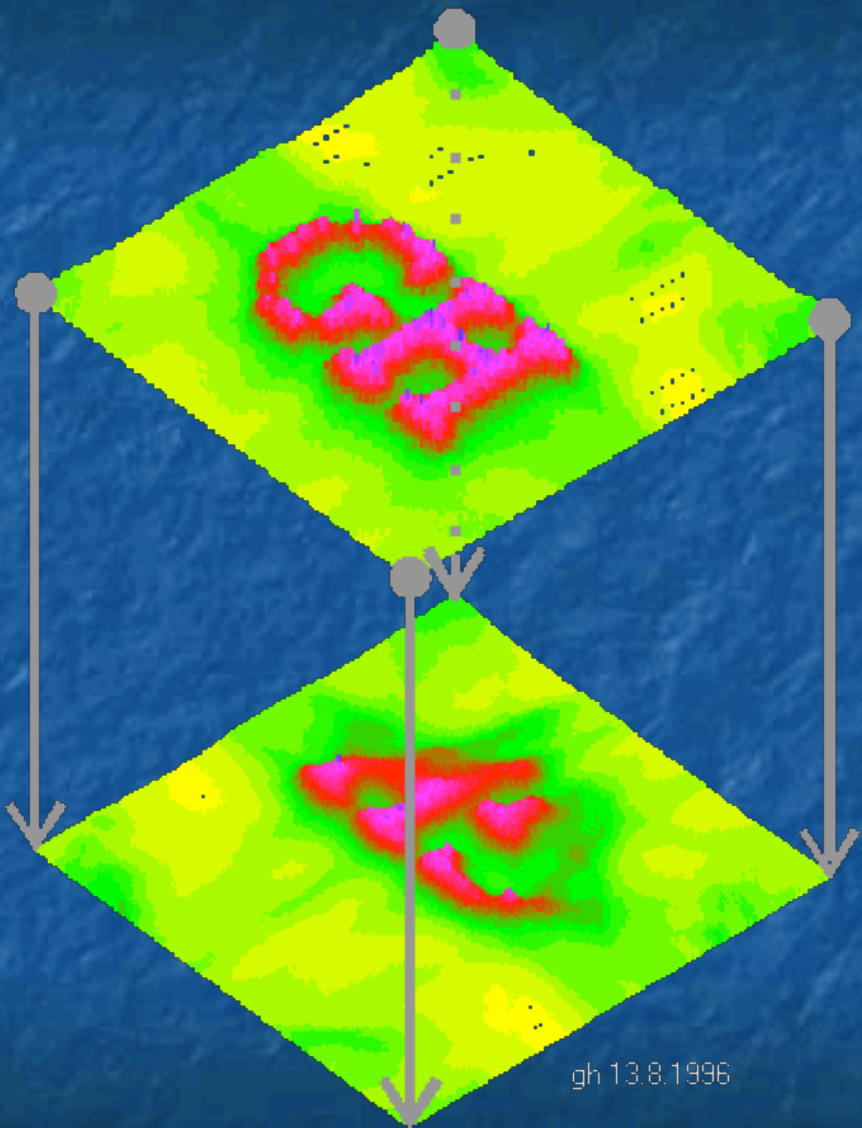
Cognitive Neuroscience of Language: 3: Systematicity and grounding in language and the brain

Richard Shillcock

Goals

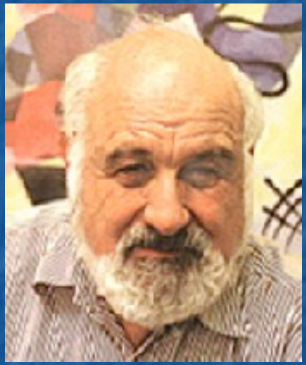


Look at how the brain seems to prefer to work.

Look at how systematicity in the brain might elicit systematicity in language.

Reading

Rizzolatti, G. & Arbib. M. (1998). Language within our grasp. *Trends in Neuroscience*, *21*, 188-194.

Michael Arbib 

 Padraic Monaghan

Monaghan, P., Chater, N. & Christiansen (2005). The differential role of phonological and distributional cues in grammatical categorisation. *Cognition*, *96*, 143-182.

Symbol grounding

Harnad, 1990

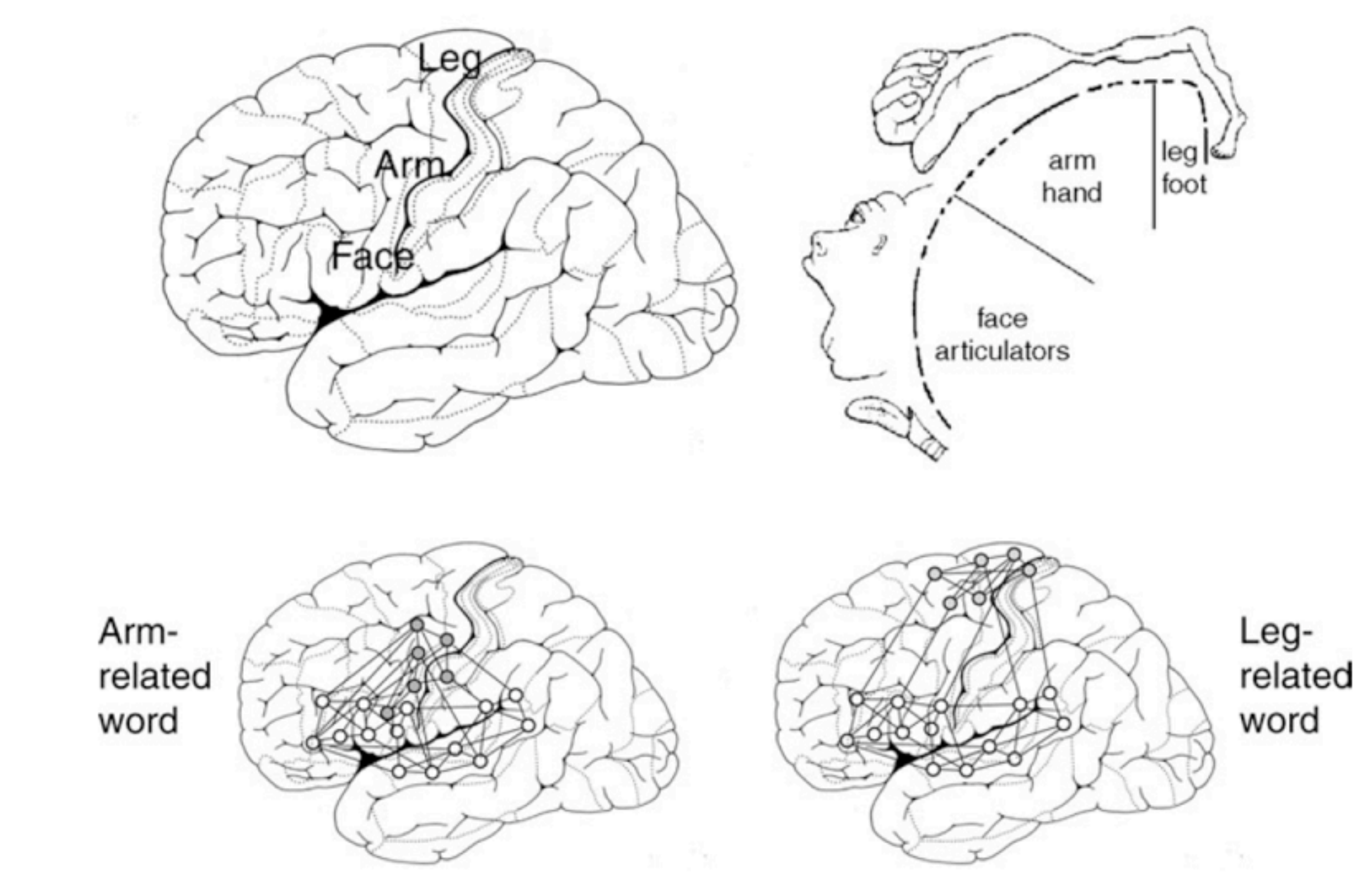
"Can Chinese be learned from a Chinese-Chinese dictionary?"

Can manipulated symbols be grounded, perhaps by attaching them to iconic representations, perhaps by having or learning invariant features.

(The issue of "aboutness", or "intentionality" remains.)

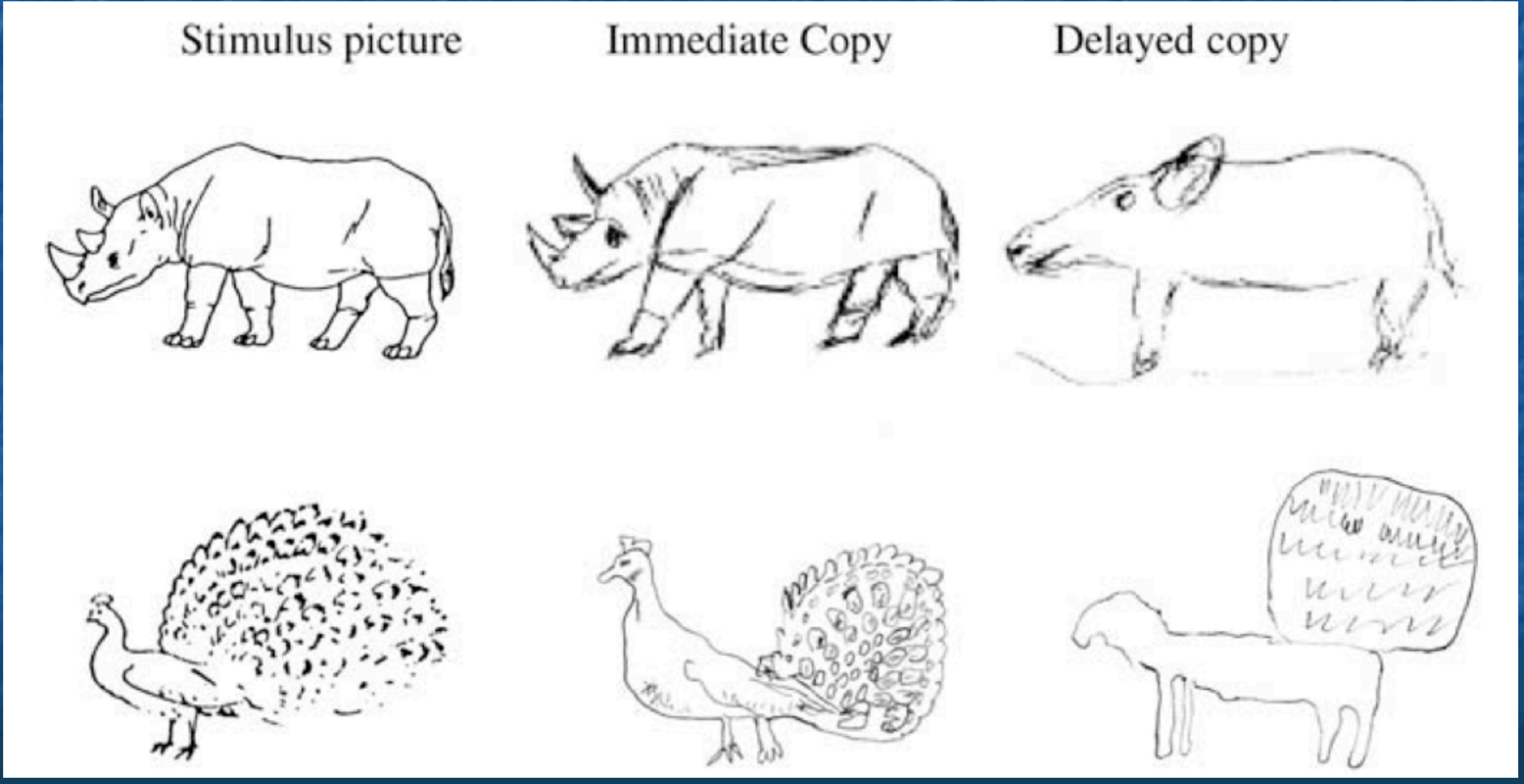
Concurrent cortical activation

Pulvermüller et al. (2005)

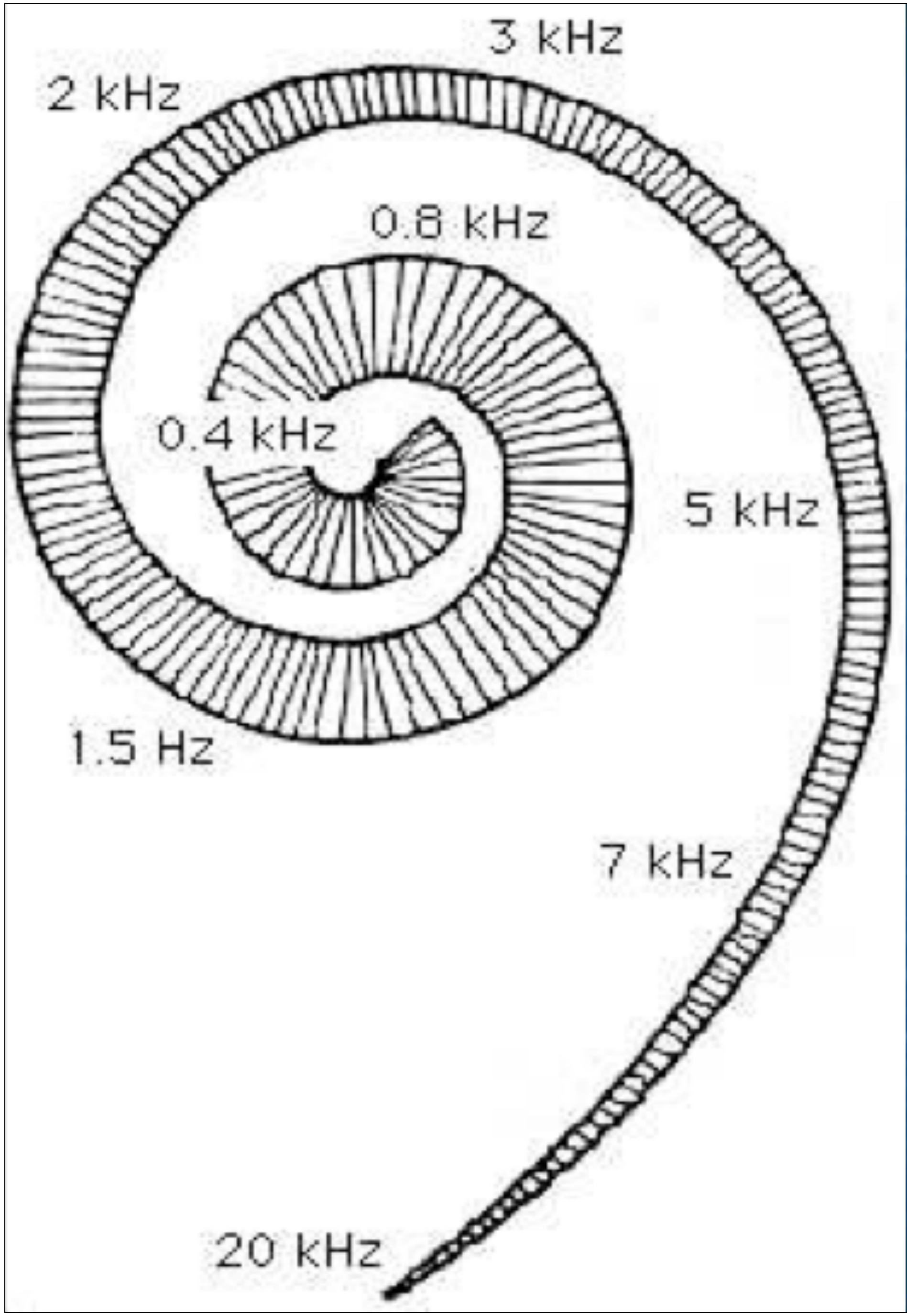


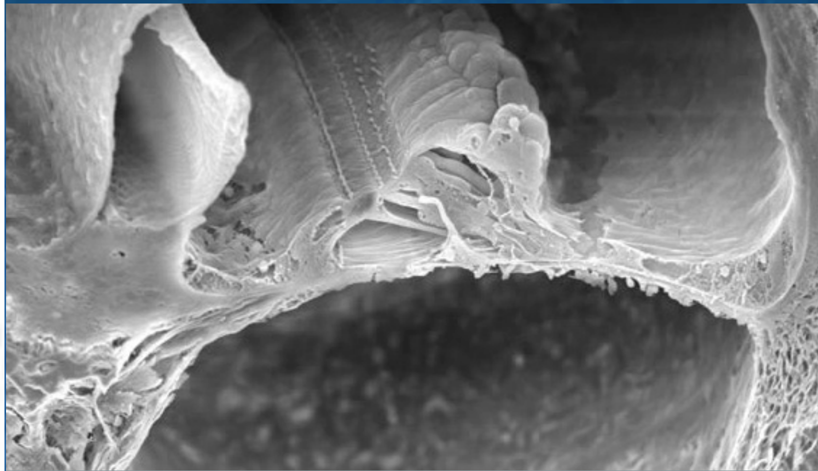
Amodal representations

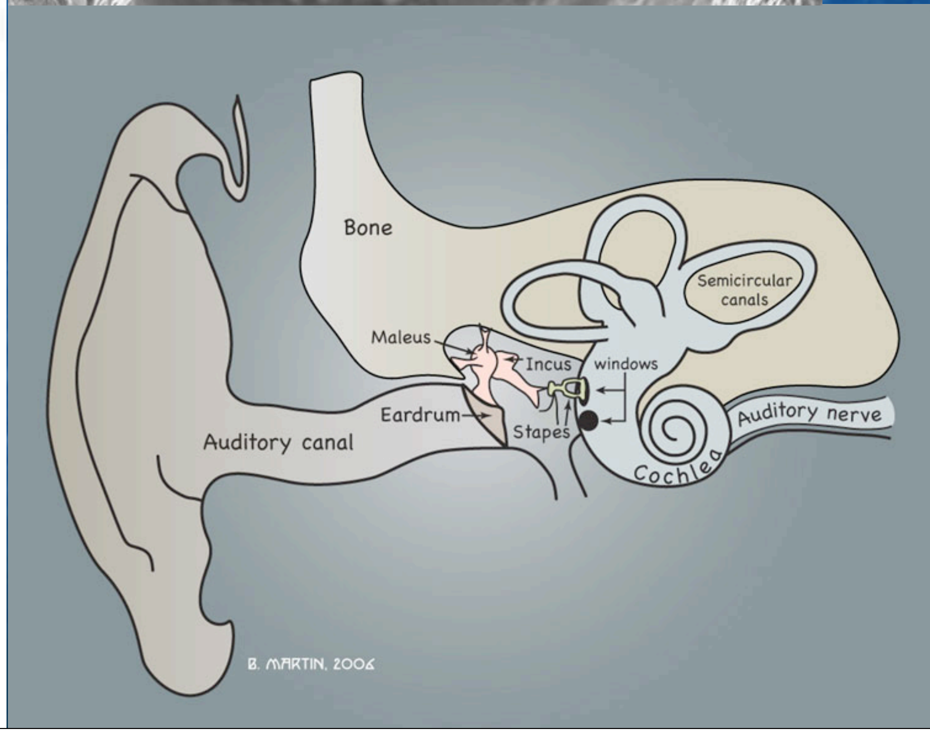
Lambon-Ralph & Patterson (2008)



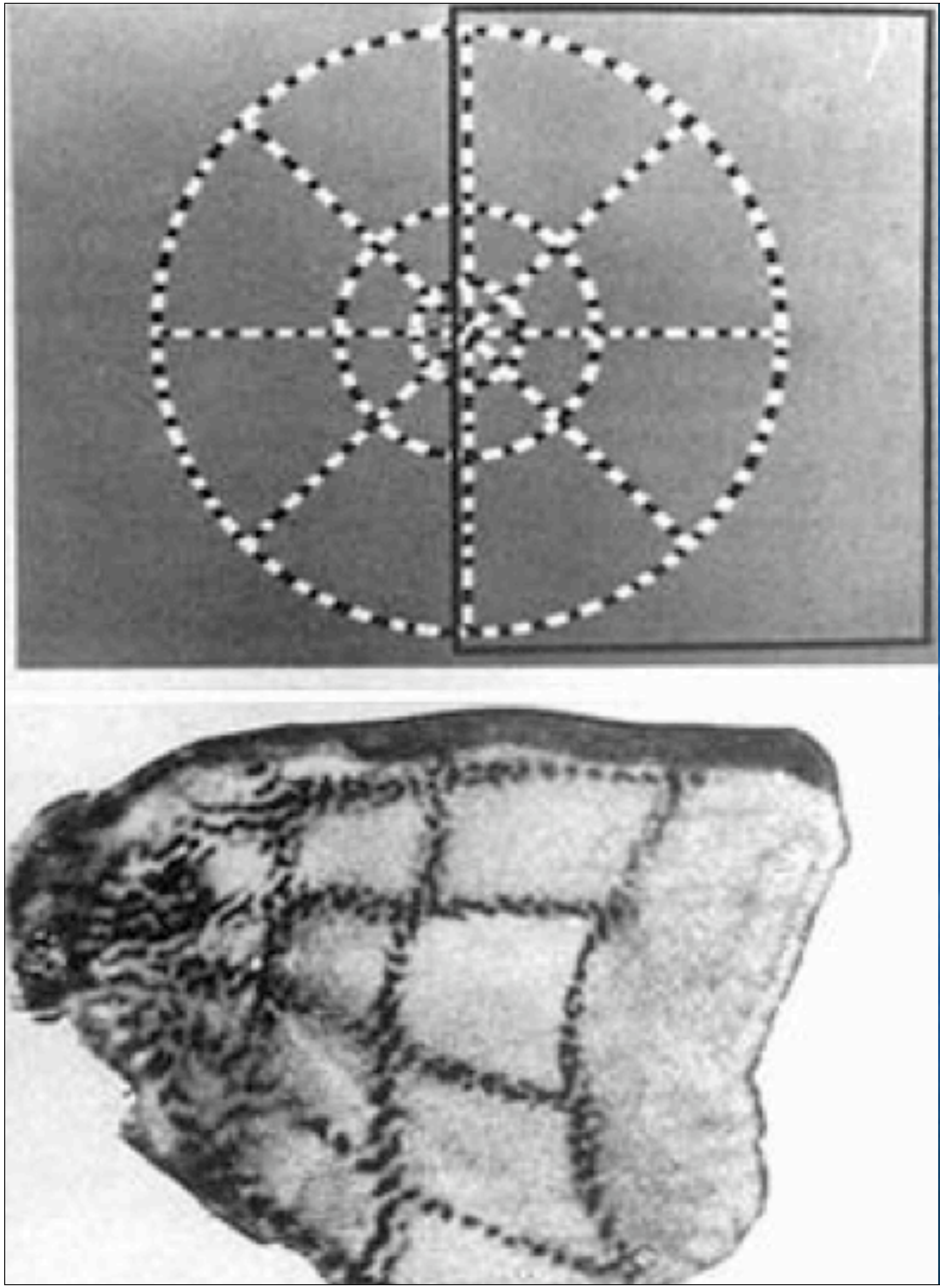
Tonotopic mapping





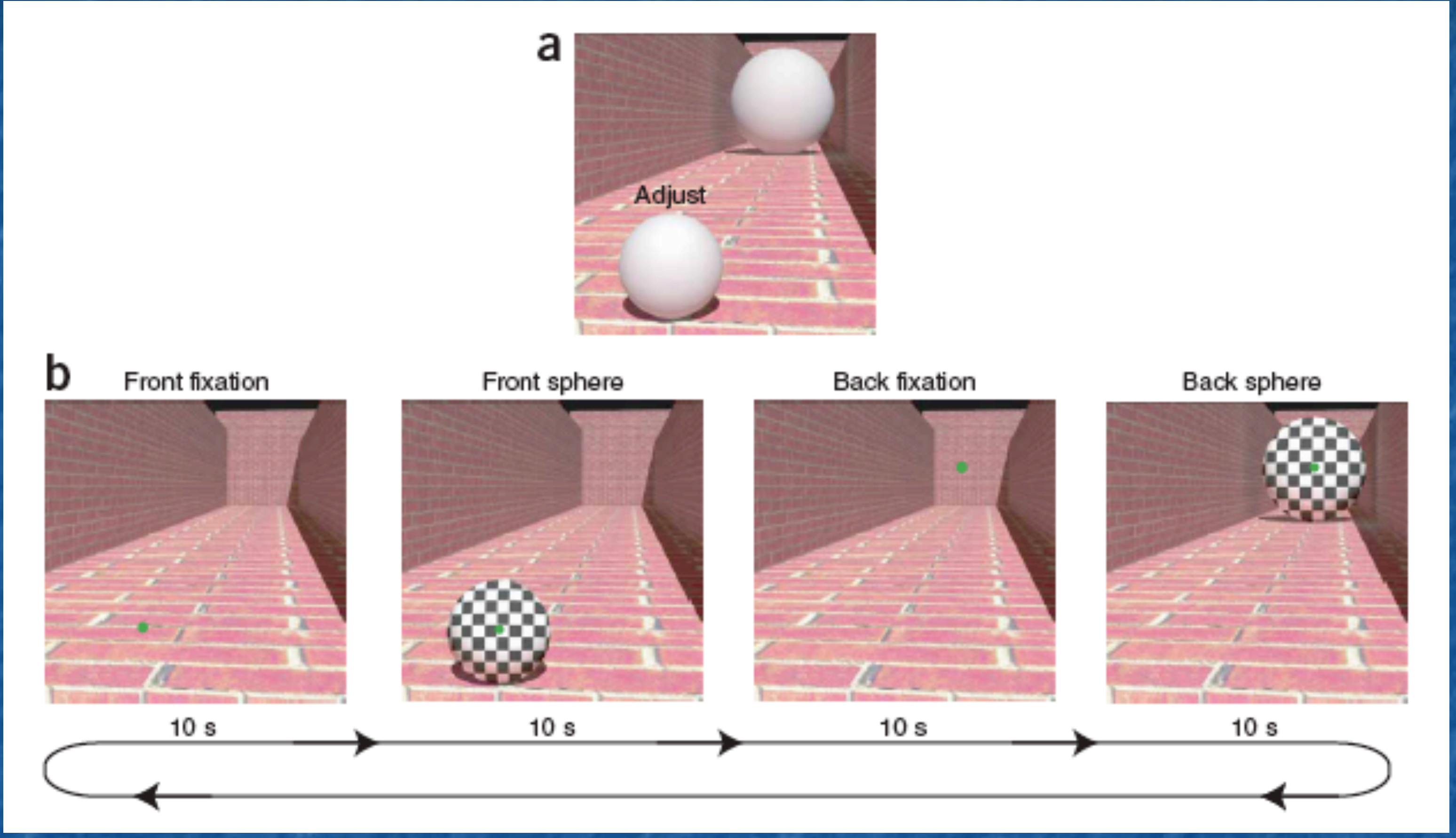


Visual topographic mapping



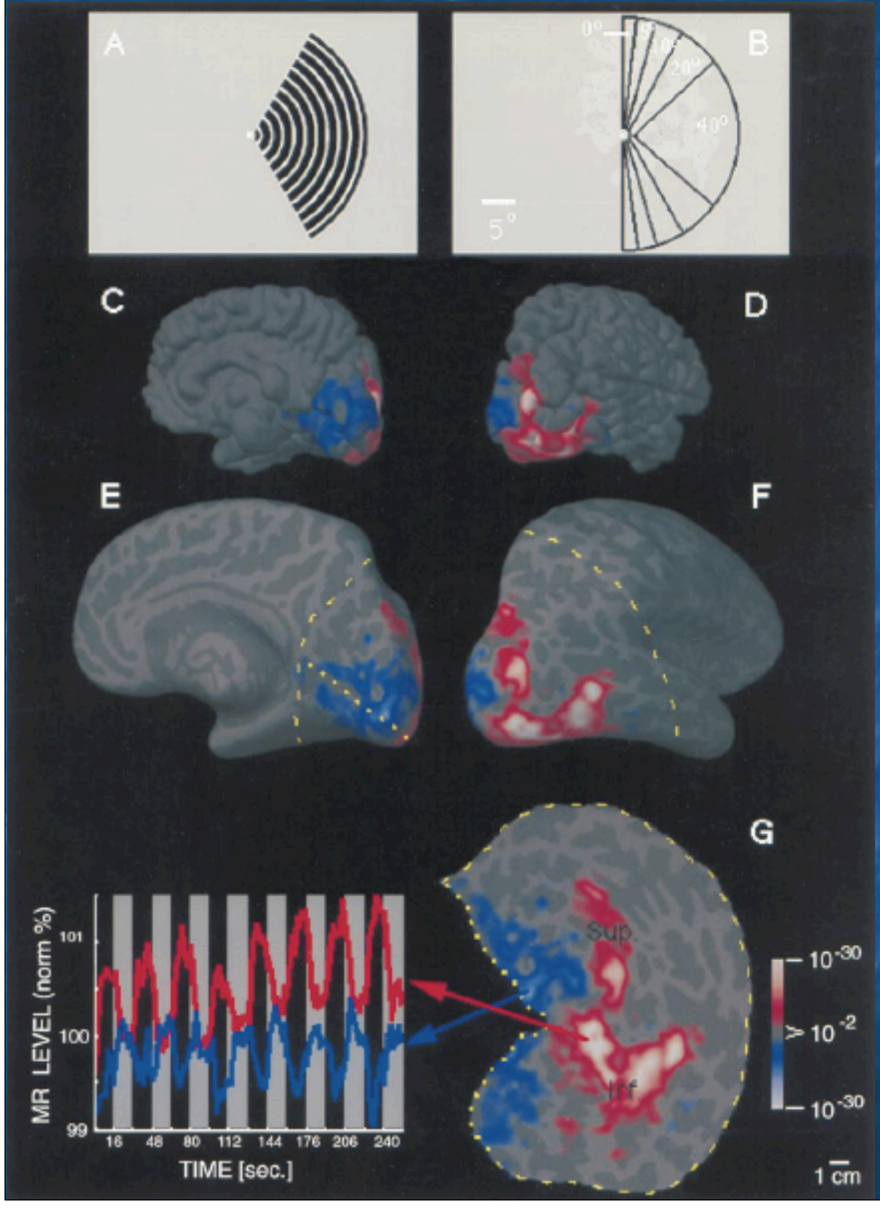
Stained V1 in the mouse, showing the areas that were activated by the visual stimulus. (Note also the cortical magnification of the fovea.)

Visual topographic mapping



The topographic mapping in V1 is affected by real-world understanding of size (Murray, Boyaci & Kersten, 2006)

Visual topographic mapping



The higher visual areas become increasingly attuned to bigger receptive fields, with bilateral inputs (see, e.g., Tootell *et al.*, 1998), and less clear retinotopic mapping.

(The corresponding progression is also true for auditory processing.)

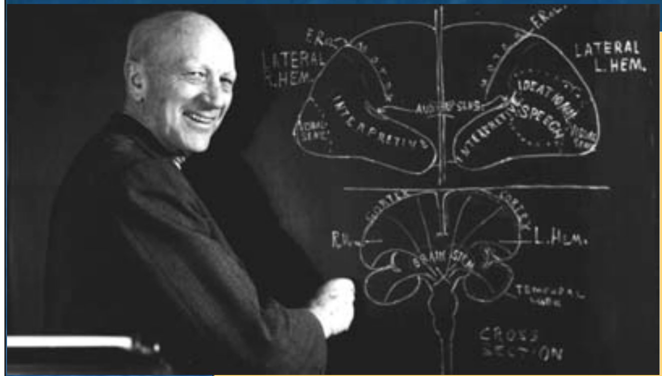
Visual topographic mapping

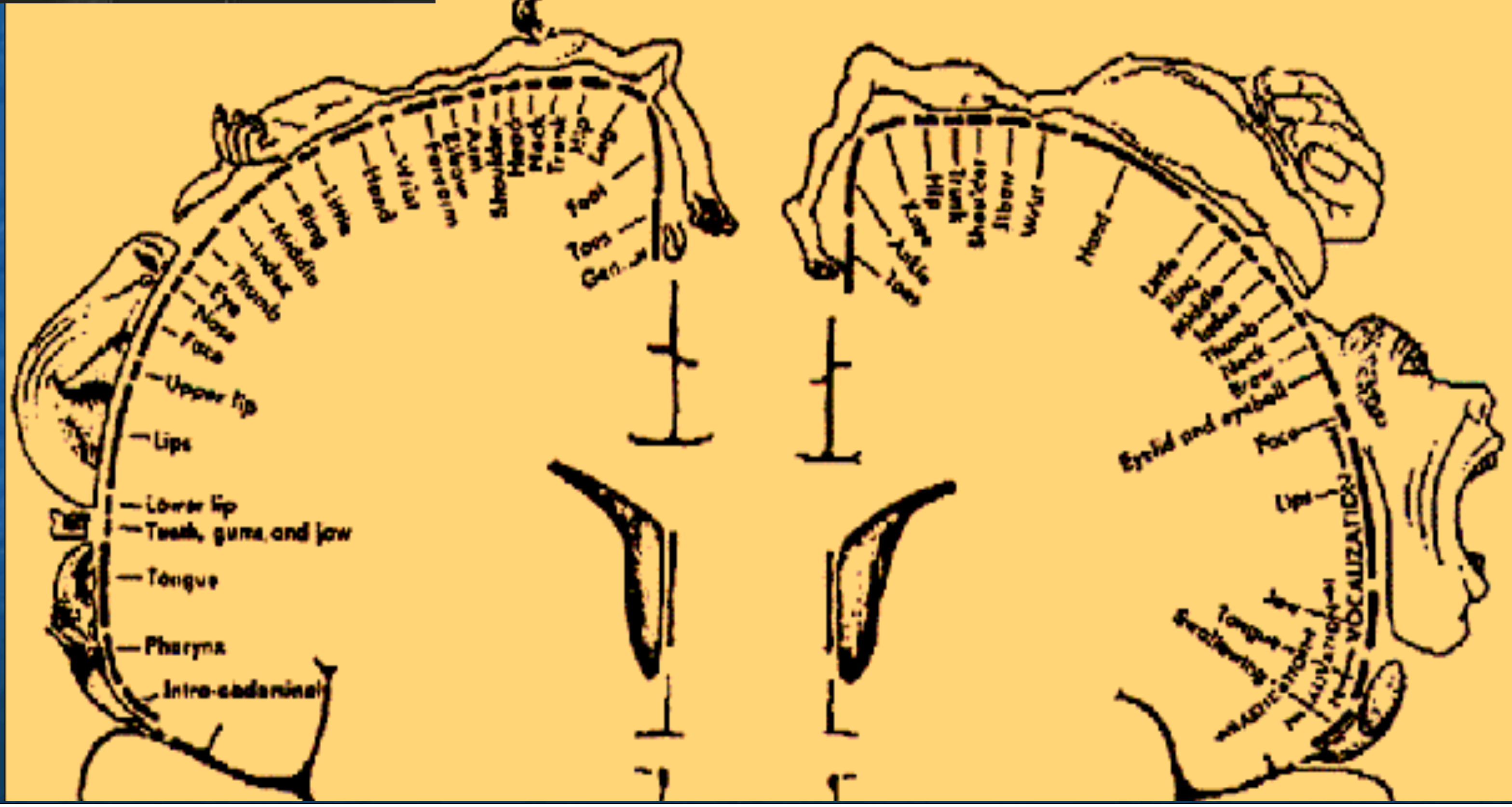
However, there is also an increasing recognition that V1 does a lot of very sophisticated processing (*cf.* re-entrant mapping), and is characteristically retinotopically and contralaterally mapped

Part of the argument may rest on *strength* of response

How much function can we read from the anatomy? We need to distinguish between anatomical, functional, and effective connectivity

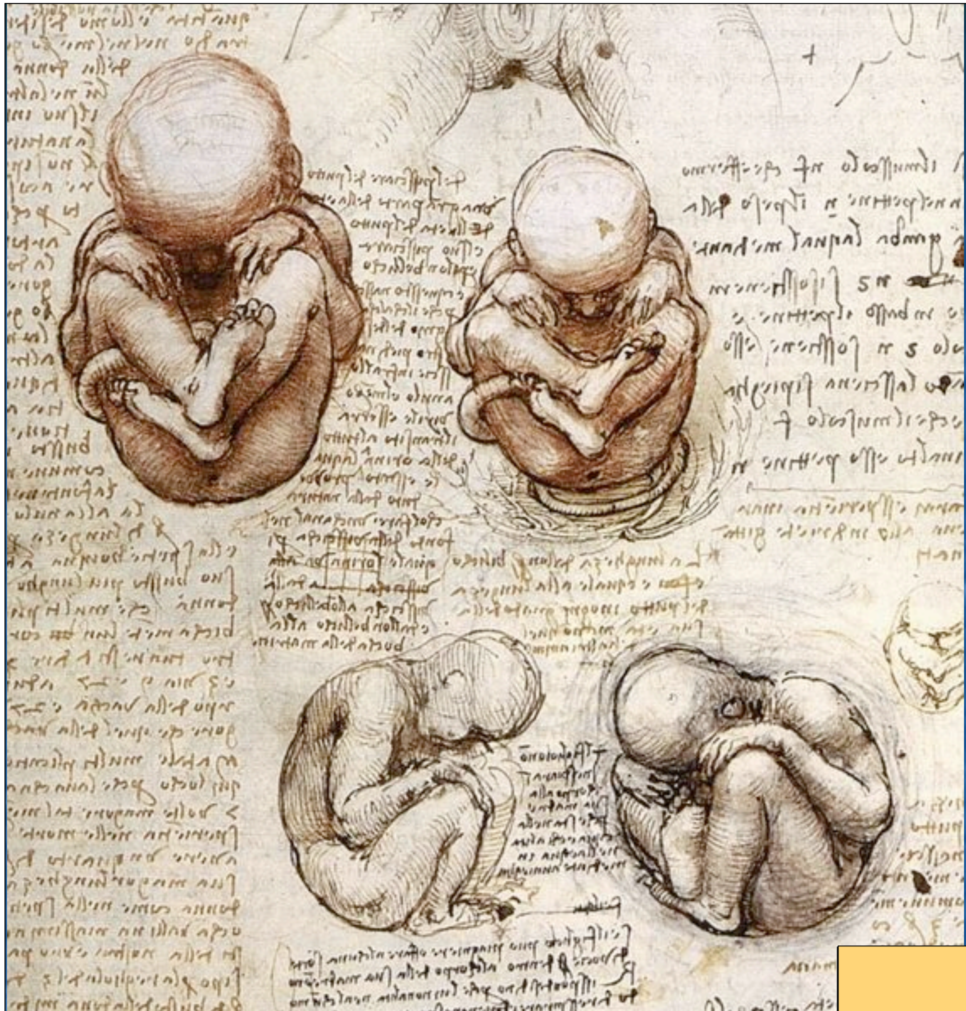
Systematicity: Penfield's homunculus





Why systematic mappings?

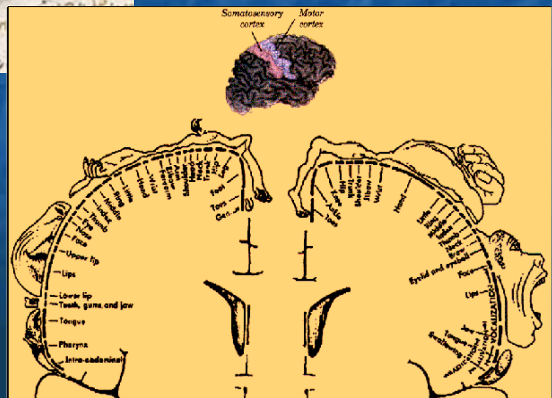
Systematicity is pervasive in the brain, most clearly nearer the sensorium. It is a way of importing relationships and larger-scale representation into the brain "for free".



Why systematic mappings?

Mappings are both neuro-chemically and environmentally controlled

Mapping begins *in utero*(Farah, 1998)



What would ideal words look like?

Things to eat start with /k/

Small things contain /n/

Deep-fried things end with /g/

Large things contain /æ/

… and so on

Bishop John Wilkins

de an element

Bishop John Wilkins

de	an element
deb	the first element, fire

Bishop John Wilkins

de	an element
deb	the first element, fire
deba	a part of the first element, fire; a flame

Phonetic symbolism

"The bond between the signifier and the signified is arbitrary." Saussure

glow, glare, glimmer, gleam, glint ... (Bloomfield, 1933; Ciccotosto, 1991)

mal versus *mil* (Sapir, 1929; Parault & Schwanenflugel, 2006); gender effects in names (Cassidy, Kelly, Shapiro, 1999); syntactic class (Kelly, 1992)

Phonetic symbolism

Any universality of sound symbolism is controversial.

Samples of child-directed speech in Mandarin and in Turkish show that constellations of individually unreliable cues can provide a good indication of whether a spoken word belongs to a lexical or a functional class (Shi, Morgan & Allopenna, 1998).

For indicating syntactic class, distributional information seems to be more important for high-frequency words, and phonological information for low-frequency words (Monaghan, Chater & Christiansen, 2005).

Semantic distances

How can a word be provided with a position in a high-dimensional space on the basis of the lexical contexts in which it falls (*cf.* Landauer & Dumais, 1997, and others)?

Can we use such a measure to assess form-meaning systematicity in English?

Example semantic vectors

The lorry driver swerved on the road. As well as causing pollution, a lorry also has large wheels. A lorry requires diesel to work.

A lorry might carry sweet apples and bananas. Bananas are easier to peel than apples but apples have nicer trees. Bananas are cheaper than apples in a shop.

	lorry	apples	bananas
sweet	0	0	0
trees	0	0	0
shop	0	0	0
eat	0	0	0
peel	0	0	0
driver	0	0	0
road	0	0	0
diesel	0	0	0
pollution	0	0	0
wheels	0	0	0

Thanks to Joe Levy

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diesel	1	0	0
pollution	1	0	0
wheels	2	0	0

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trees	0	0	0
shop	0	0	0
eat	0	0	0
peel	0	0	1
driver	1	0	0
road	1	0	0
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	lorry	apples	bananas
sweet	1	1	2
trees	0	0	0
shop	0	0	0
eat	0	0	0
peel	0	0	2
driver	1	0	0
road	1	0	0
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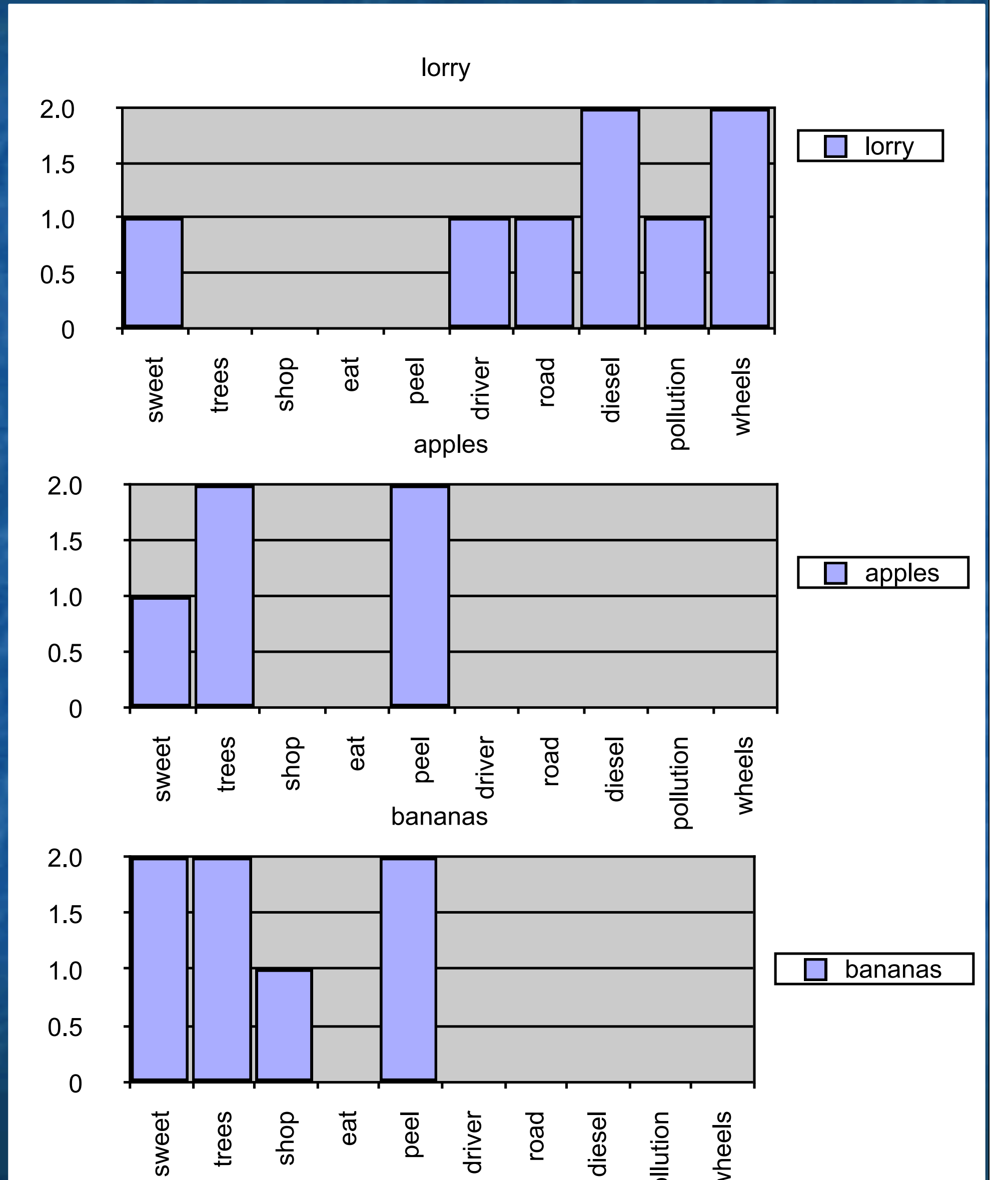

Semantic vectors

These and similar semantic vectors have been used in the psycholinguistic literature to model effects requiring semantic representations. Unordered lexical context can provide a measure of "word meaning".

They are pretty robust, but relevant variables include the window size, the nature and number of context words, and the size and nature of the corpus over which the statistics are run (see, e.g., Bullinaria & Levy).

Looking at *overall* systematicity

A lexical neighbourhood like that of *hand* (*band, sand, land, rand, wand, hind, hard, hang, hank*) is only a tiny proportion of the lexicon.

Is there systematicity overall – over all the words in the lexicon?

Compare phonological edit distances and cosine distances in a high(444)-dimensional space.

Looking at *overall* systematicity

Compare *all* the possible distances – from each word to every other word.

For "phonological" distances and "semantic" distances.

Over 1733 monosyllabic, monomorphemic words of English, there is a correlation between the two: .0611.

This is highly significant, but very small too.

Similarity *and* difference

Similarity is only one end of the relationship

Words also need to be (randomly) different from each other in order to be effective referring expressions

The locus of difference is as important as the locus of similarity

Summary

The brain is pervasively systematic.

Language is wholly a creation of the brain.

It exhibits multiple intersecting systematicities.

Such a high level of complex systematicities is beneficial for learning and for the restoration of a signal in a noisy medium such as speech.