Action Semantics and the Action System Architecture: Implications for "Embodied Cognition".



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In memory of Eleanor Saffran

Embodied Cognition: Knowledge = Simulation

As an experience occurs, the brain captures states of the body and the world across the modalities (e.g, perception, motor activation) and integrates them into a multimodal representation stored in memory. Later, when knowledge is needed to represent an entity or category, multimodal representations are reactivated to *simulate* how the brain represented perception and action associated with that entity. (paraphrased slightly from Barsalou, Annual Review of Psychology, 2008, p 618-619)

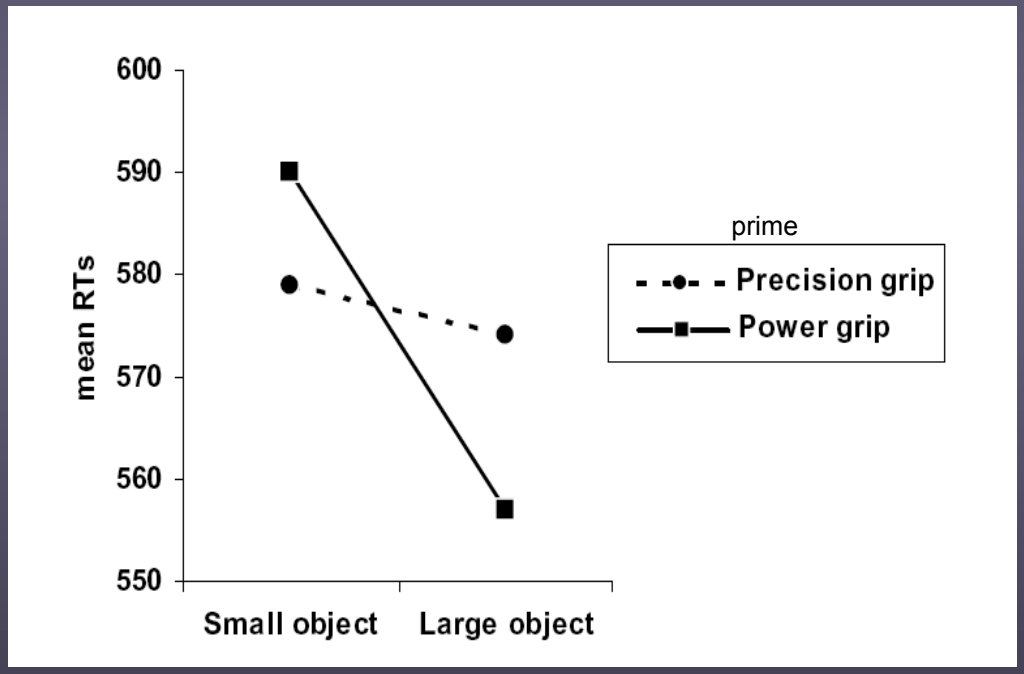
"Deep conceptual processing" is a function of the simulation system (Barsalou, TICS, 2005).

Embodied Object Representations?

- Claim is that manipulable objects are "recognized" because they activate internal representations for action.

•Example from Vainio, Symes, Ellis, Tucker, & Ottoboni, 2008 (priming with grasp videos):

Natural vs. man-made?



→ "Task irrelevant activation!"

Strong claim: "…identifying a graspable object includes the processing of its action-related attributes"

Conclusion: manipulable objects are "recognized" via access to action features?

- One problem: many objects are associated with multiple actions.

- Does object perception obligatorily entail activation of *all* associated actions?
- Thus, are all of these actions components of the object representation?
- Can consideration of functional neuroanatomy help us constrain findings of activation of actions by objects?

Hypotheses:

- Many studies claiming that action simulation is obligatory upon object identification (and therefore an "embodied" part of the object representation) use priming and/or response preparation prior to viewing objects.
- We (and others) have shown that response preparation modifies attention to specific action-relevant object attributes (e.g. Pavese & Buxbaum, 2002). If we see these attributes "activated" in an experiment using response preparation, can we conclude that the attributes are a fundamental aspect of the object representation?

NO.

Hypotheses, cont.

- I will suggest that object USE actions are persistent memories closely linked to the identity of an object (could be termed “action semantics”), and computed by a specialized neuroanatomic system (unique to humans?), while object GRASP actions are computed online based on structural object information, and then discarded when no longer relevant.

- Only the former has relevance for the notion of “embodied” object representations.

2. Taking a step back-- a very partial history of "action semantics":

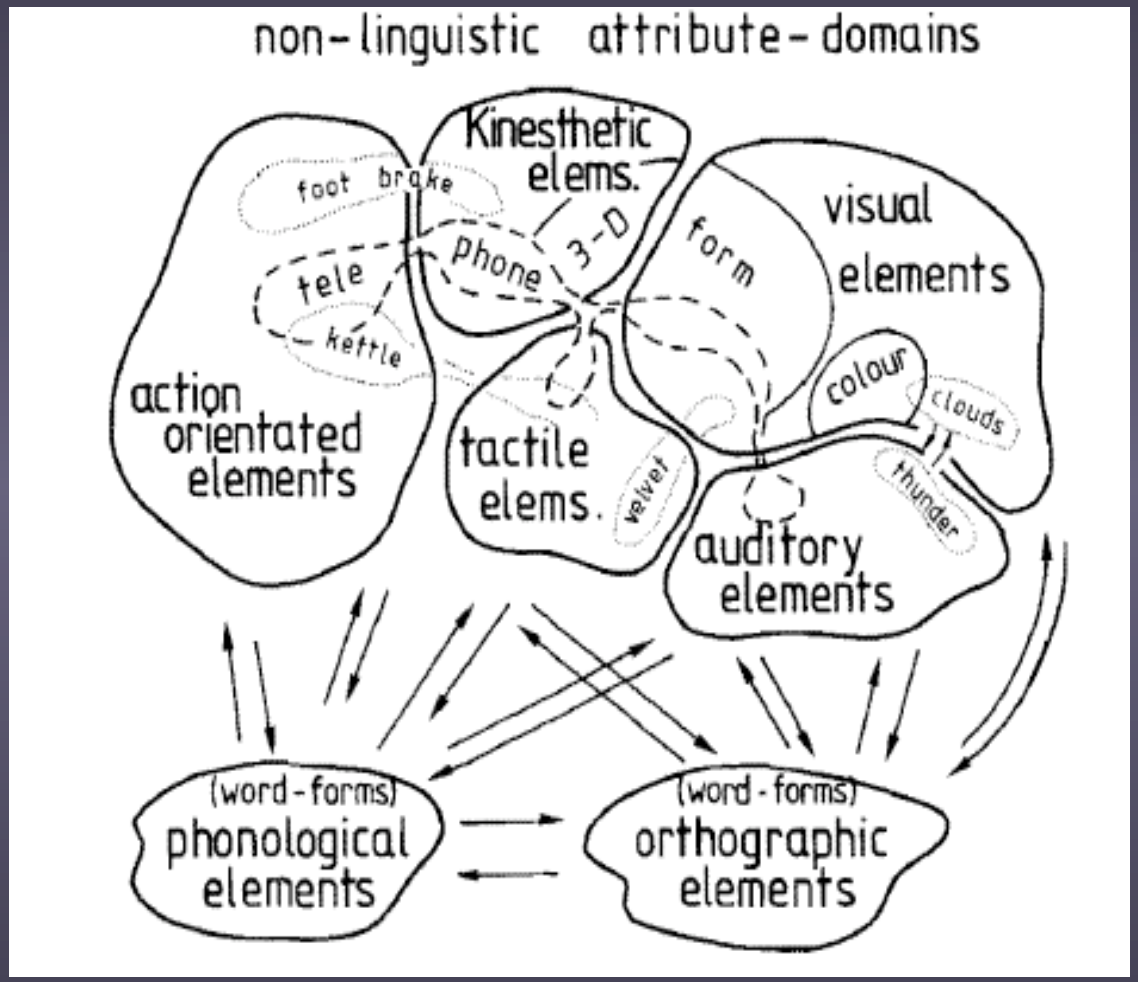
Dissociations in semantic knowledge of objects

Warrington and Shallice (1984): Earliest reports of category specific semantic memory deficits. Four patients with preservation of artifact knowledge, deficit in living things knowledge.

Warrington & McCarthy (1983), opposite pattern (and see Hillis & Caramazza, 1991, and others).

Explanation: sensory-functional theory (later, sensory-motor theory)

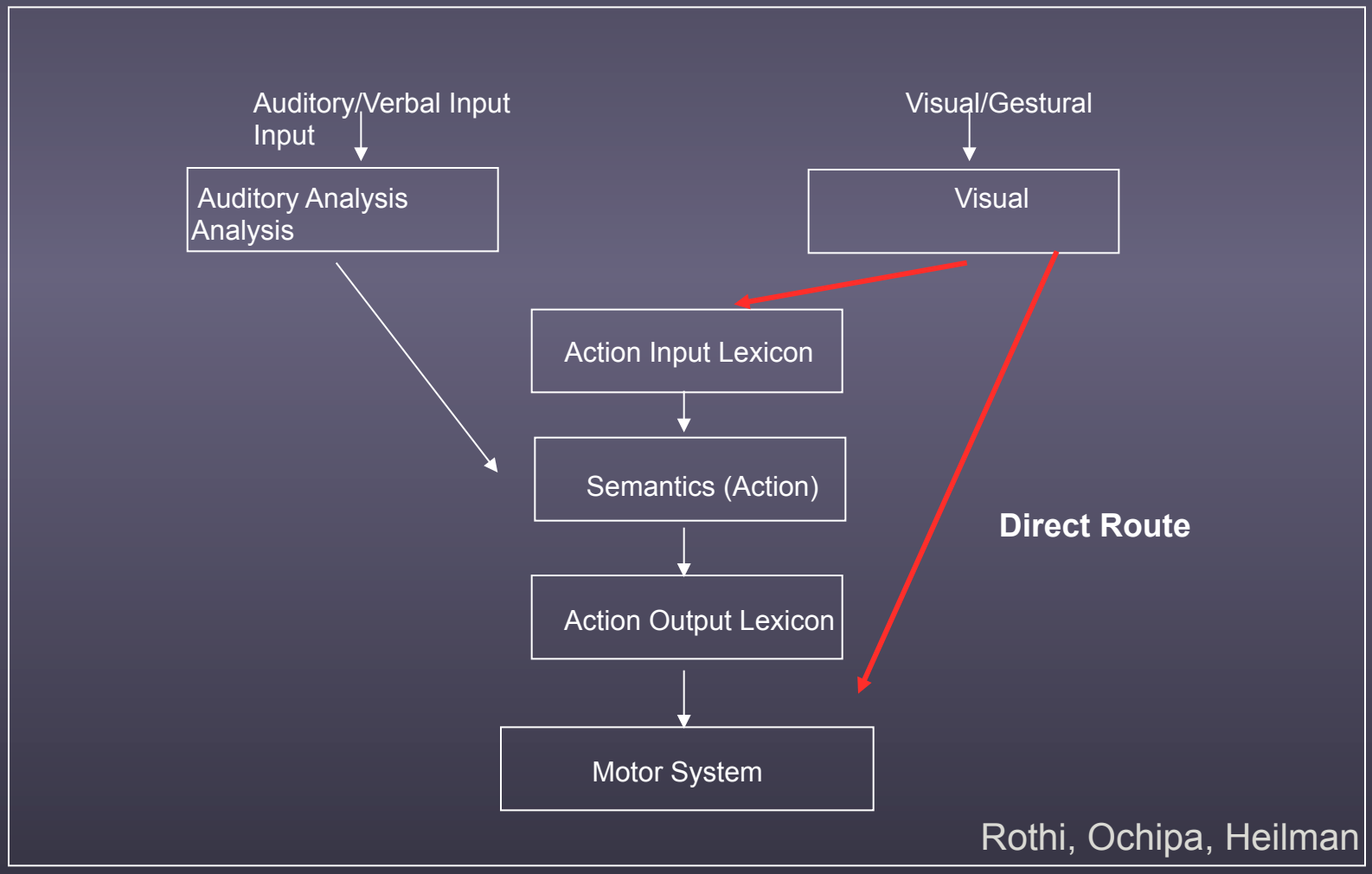
An influential distributed account of semantic memory



Allport, 1985

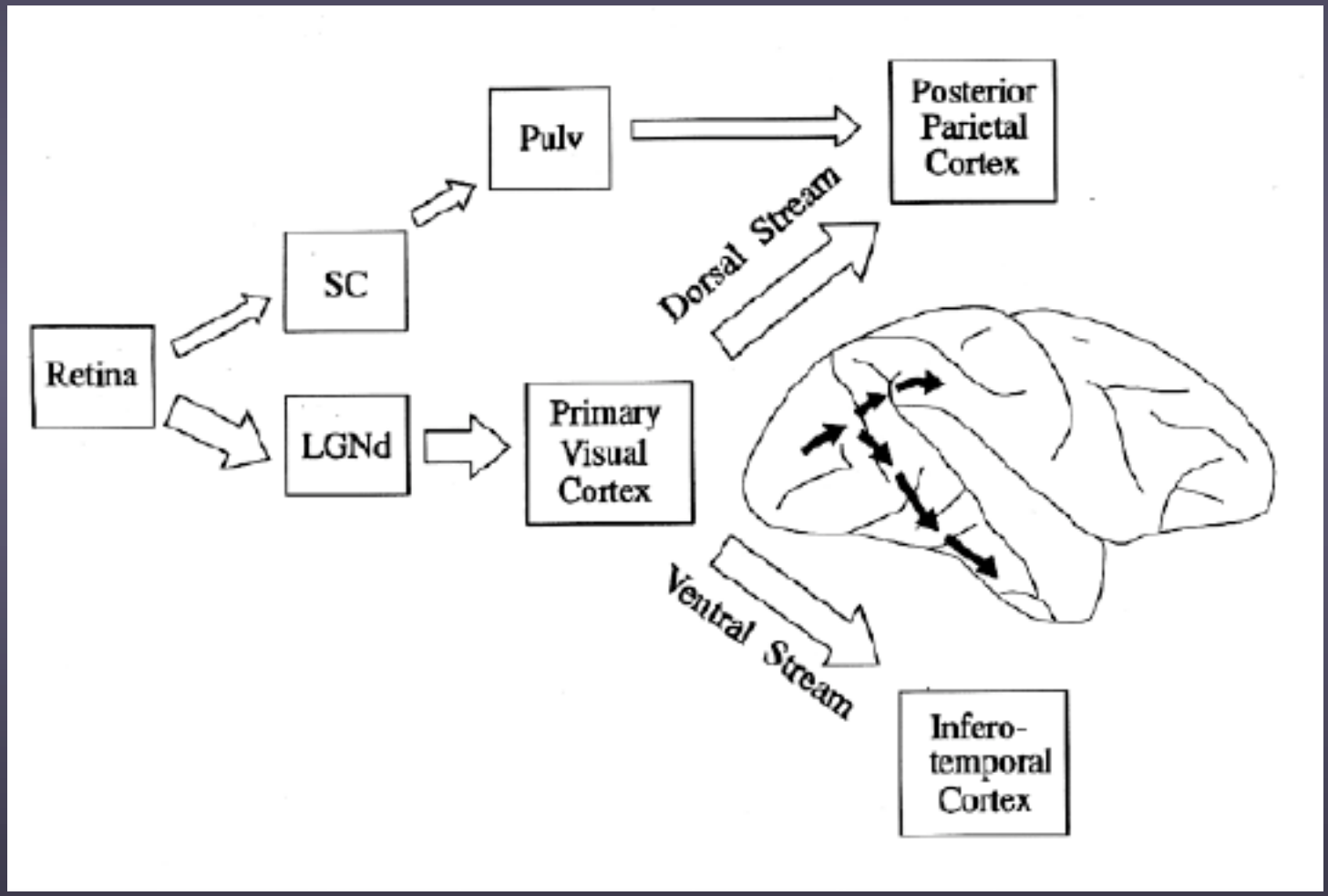
“Action semantics” in the apraxia literature

•ideational apraxia is “an amnesia of usage caused by deficient access to the semantic repository where multiple features defining an object are stored, among which there is the way it must be used” (De Renzi & Lucchelli, 1988, p. 1183).

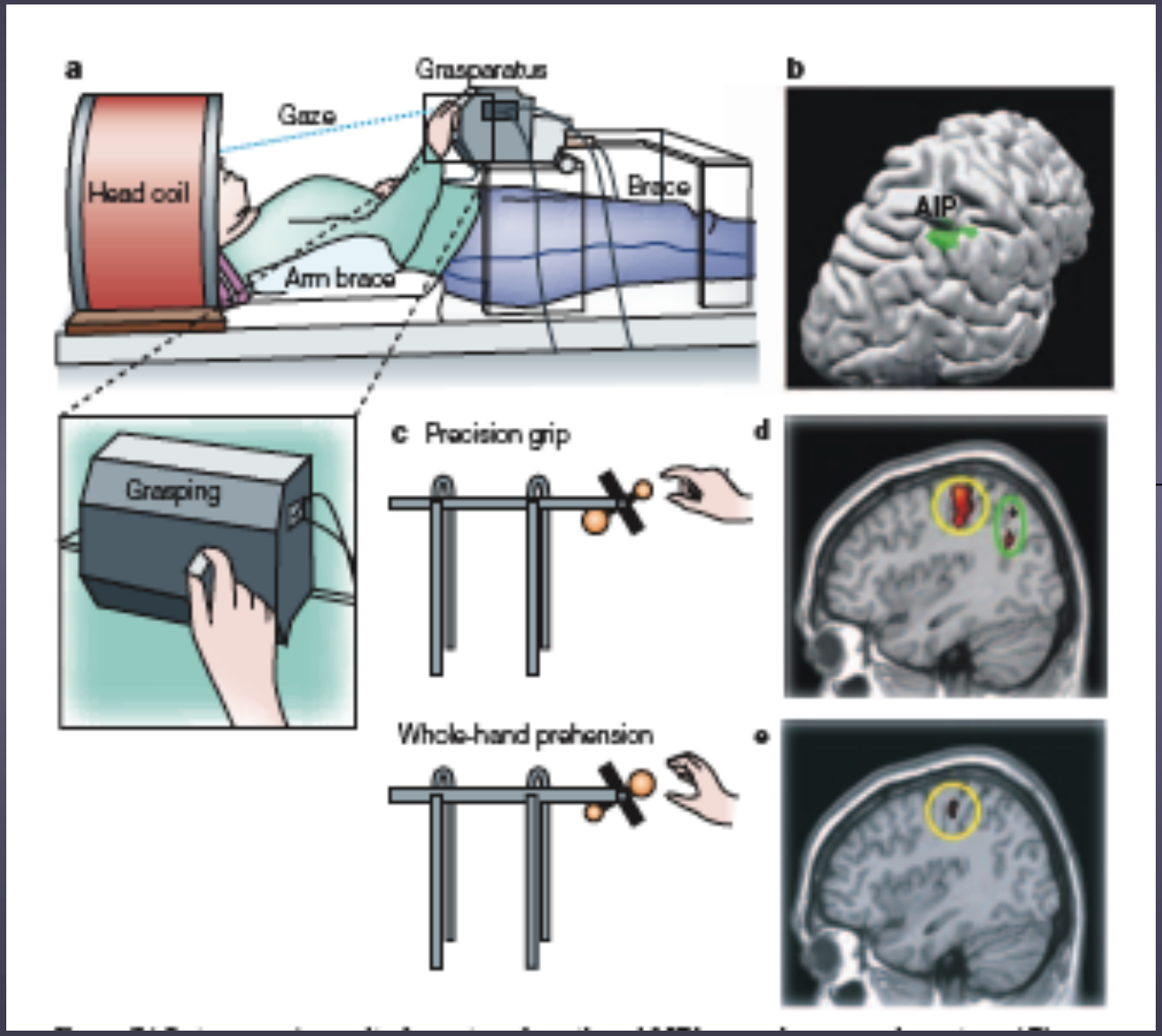


Rothi, Ochipa, Heilman (1991)

3. The functional-neuroanatomic architecture of the action system



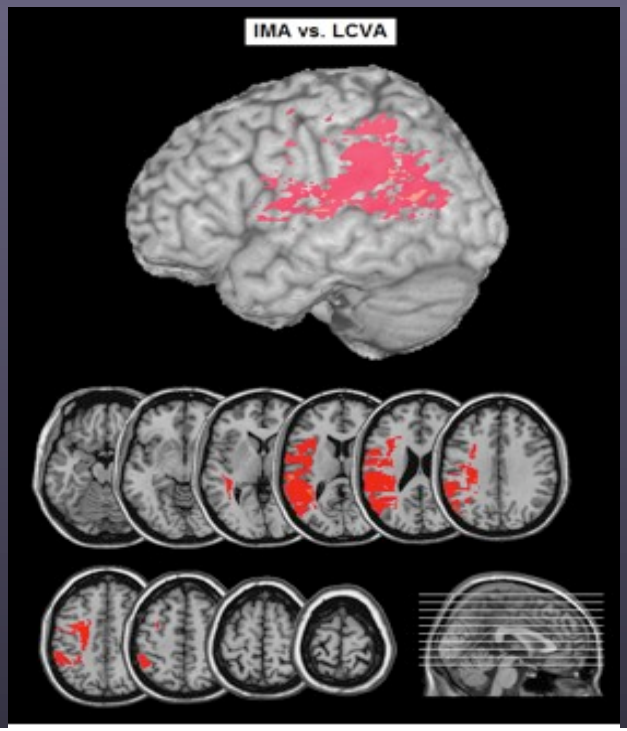
Cortical Regions involved in Grasping



An informative dissociation in ideomotor apraxia

Ideomotor Apraxia

Impaired		Less Impaired
Object-related Pantomime	……	Actual object use
Memory-dependent actions	.....	On-line actions
Body to body part spatial coding	……	Body to object coding
Manipulation knowledge	……	Other object knowledge
Non-prehensile hand postures	.....	Prehensile postures



Three visual route model (two action systems):

Action System	Primary Aspects of Object Coding	Activation of Motor Information without motor intention	Persistence of Information	Relationship to Conceptual Knowledge	Probable mapping onto apraxia routes	Neuroanatomic Substrate
Grasp and Move	non-arbitrary "affordances"	? (example of baseball speeding toward head)	Short (milliseconds)	Weak	Direct Route	*Dorso-dorsal stream: Bilateral* IPS, dorsolateral fronto-parietal
Use	actions distantly related to structure	No, requires relevant intention/ goal	Long (minutes)	Strong	Indirect Route	*Ventro-dorsal stream: Left* superior temporal/ Inferior parietal

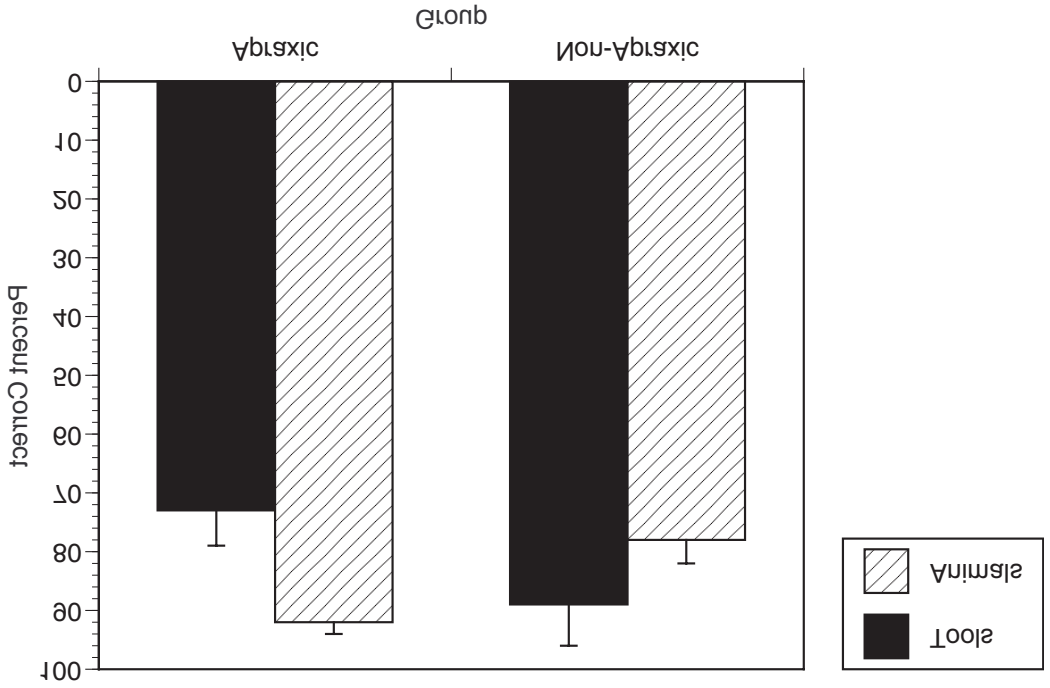
Recall our questions…..

- Does object perception obligatorily entail activation of *all* associated actions?
- Thus, are all of these actions components of the object representation?
- Can consideration of functional neuroanatomy help us constrain findings of activation of actions by objects?

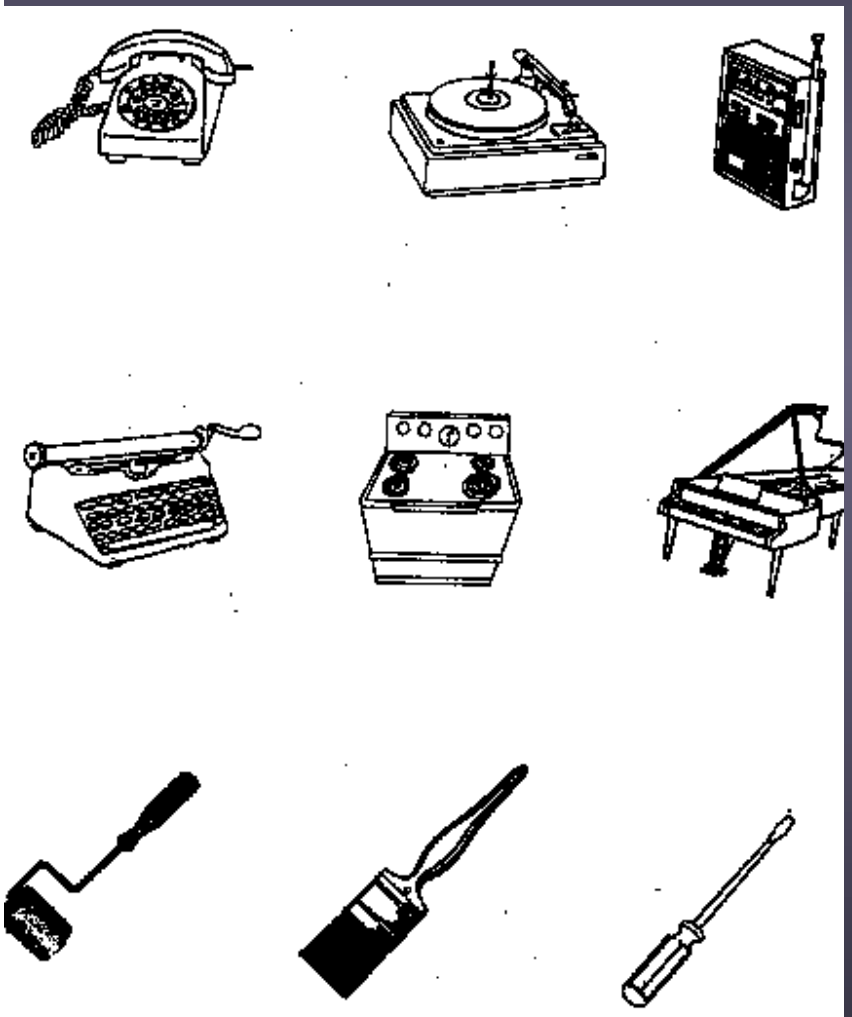
….keep these in mind as we now review evidence of the different characteristics of processing in the 2 action systems.

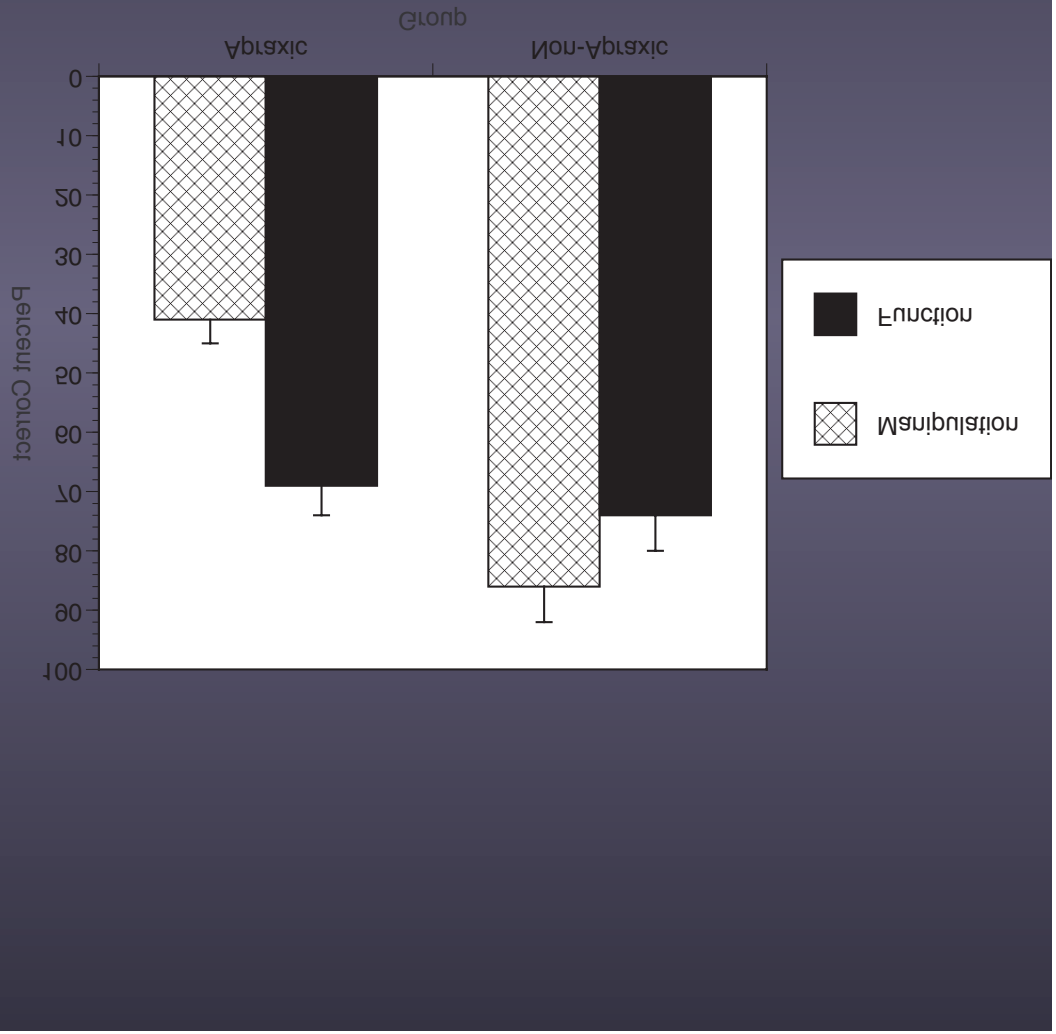
4. Some of the evidence for 2 action systems

Tool knowledge is associated with the "Use" system
(Buxbaum & Saffran, 2002)

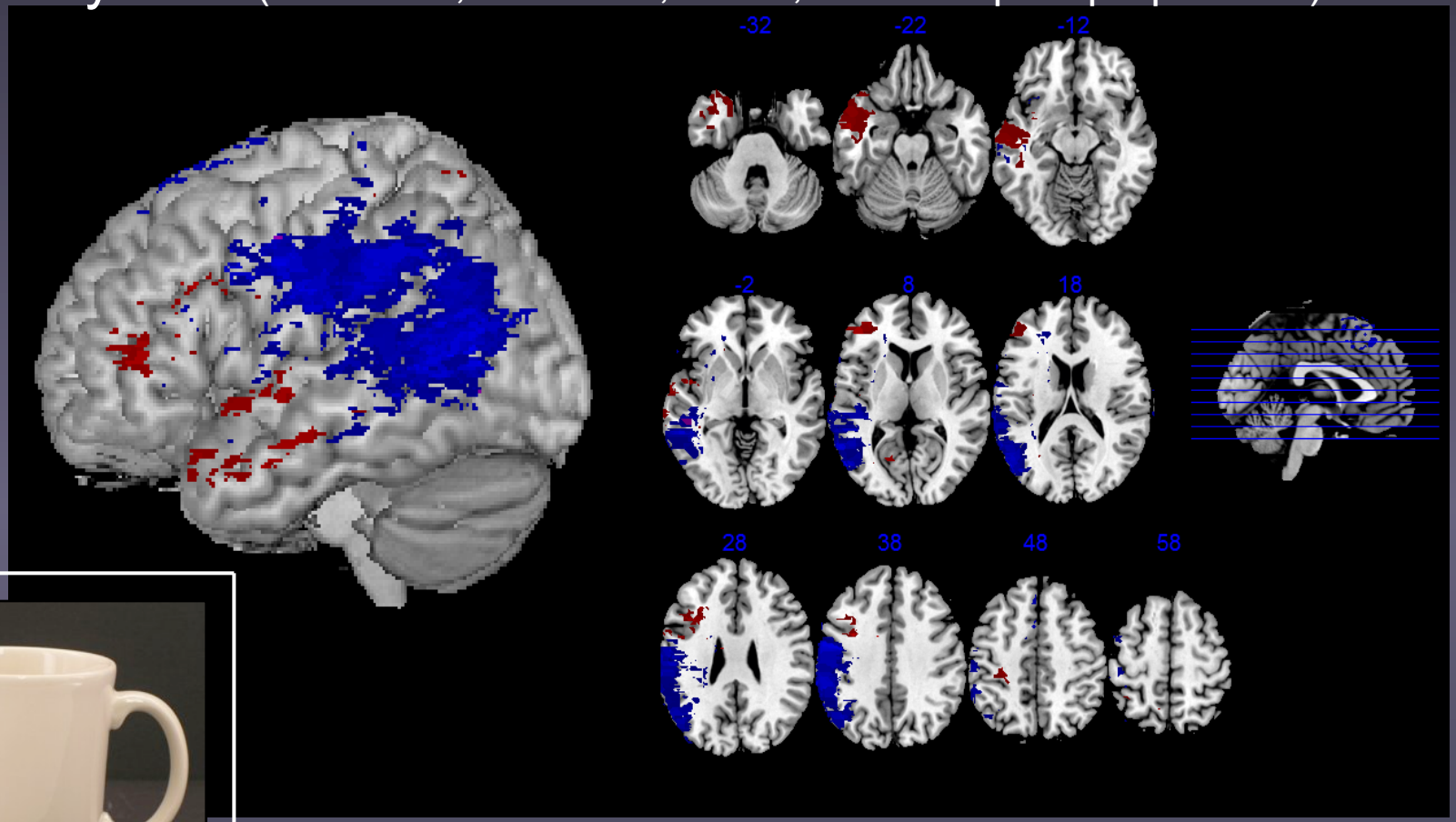


More specifically, manipulation knowledge is associated with the “Use” system (Buxbaum & Saffran, 2002)





Ability to *name* tools is associated with the Use system (Buxbaum, Schwartz, & Jax, manuscript in preparation).

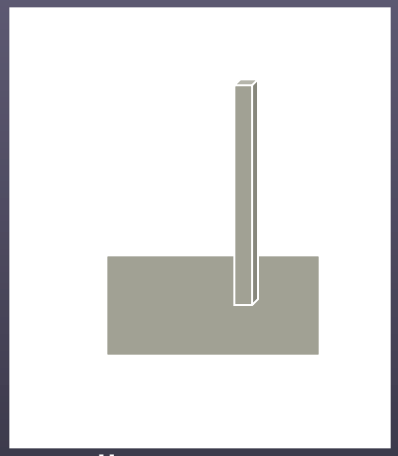


…In addition, apraxics' naming of tools benefits from affordance information (that is, the degree to which objects "signal" action).

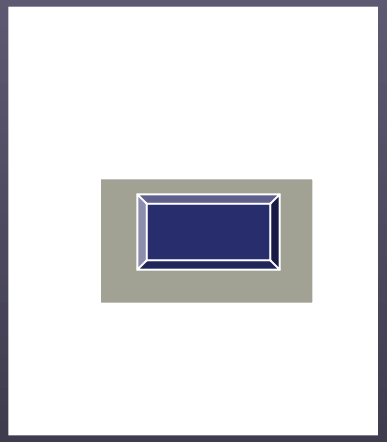
Damage to the Use system impairs knowledge of functional (but not structural) hand postures (Buxbaum, Sirigu, Schwartz, & Klatzky, Neuropsychologia 2003)

No-Conflict between grasp and use (use is prehensile)

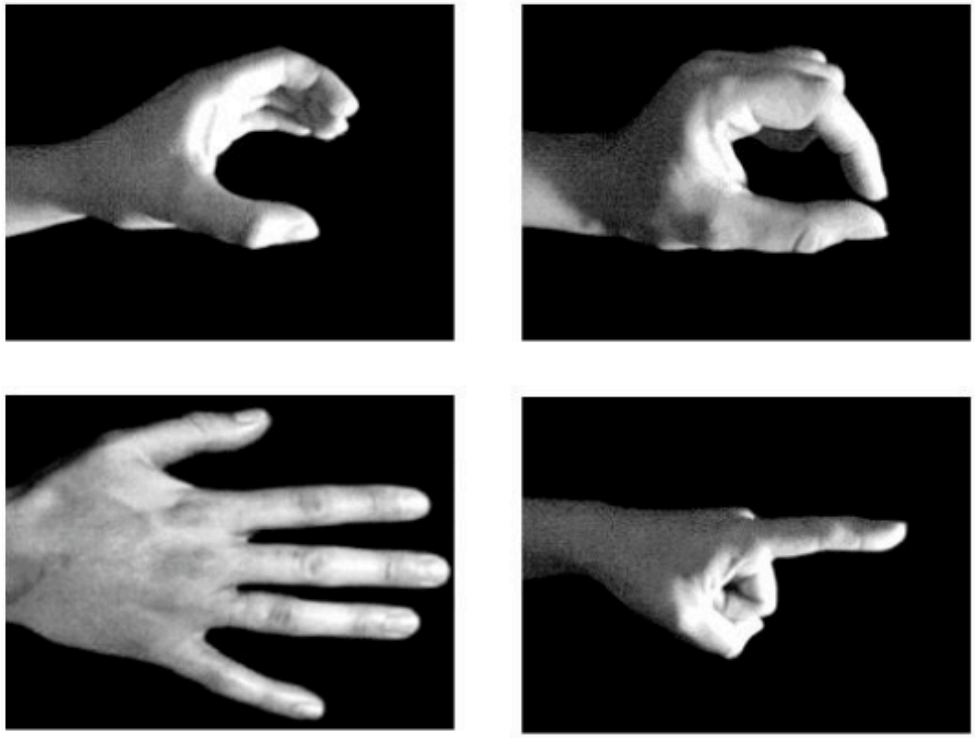
Conflict between grasp and use (use is non-prehensile)



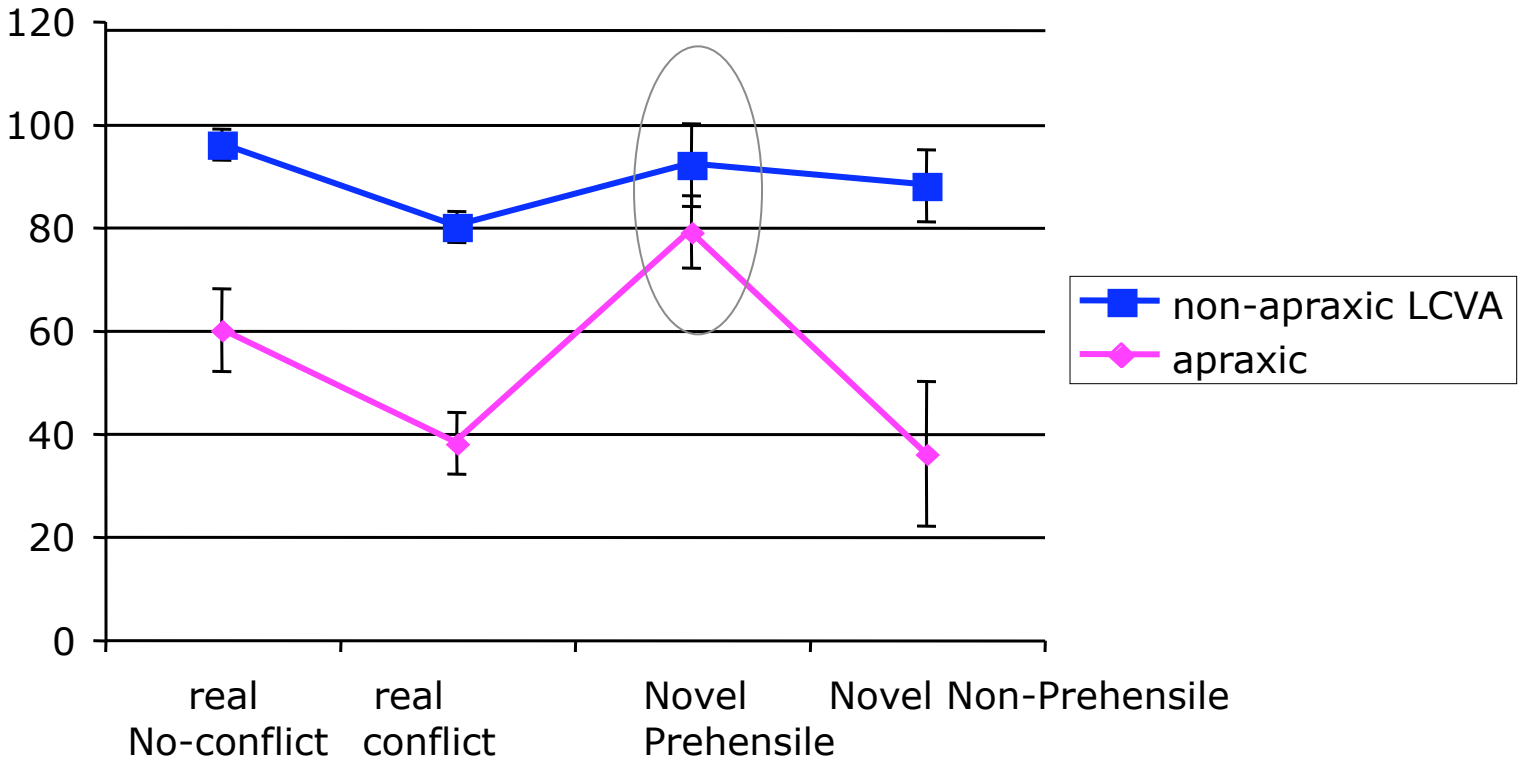
Prehensile



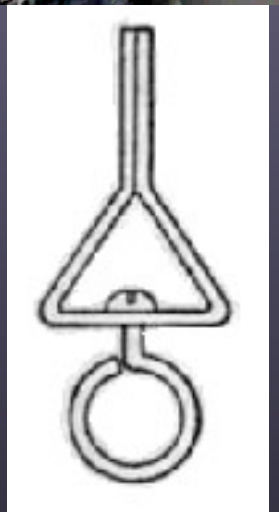
Non-prehensile

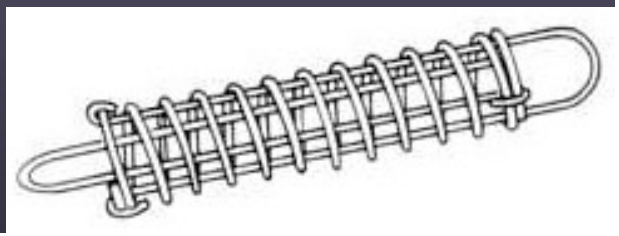


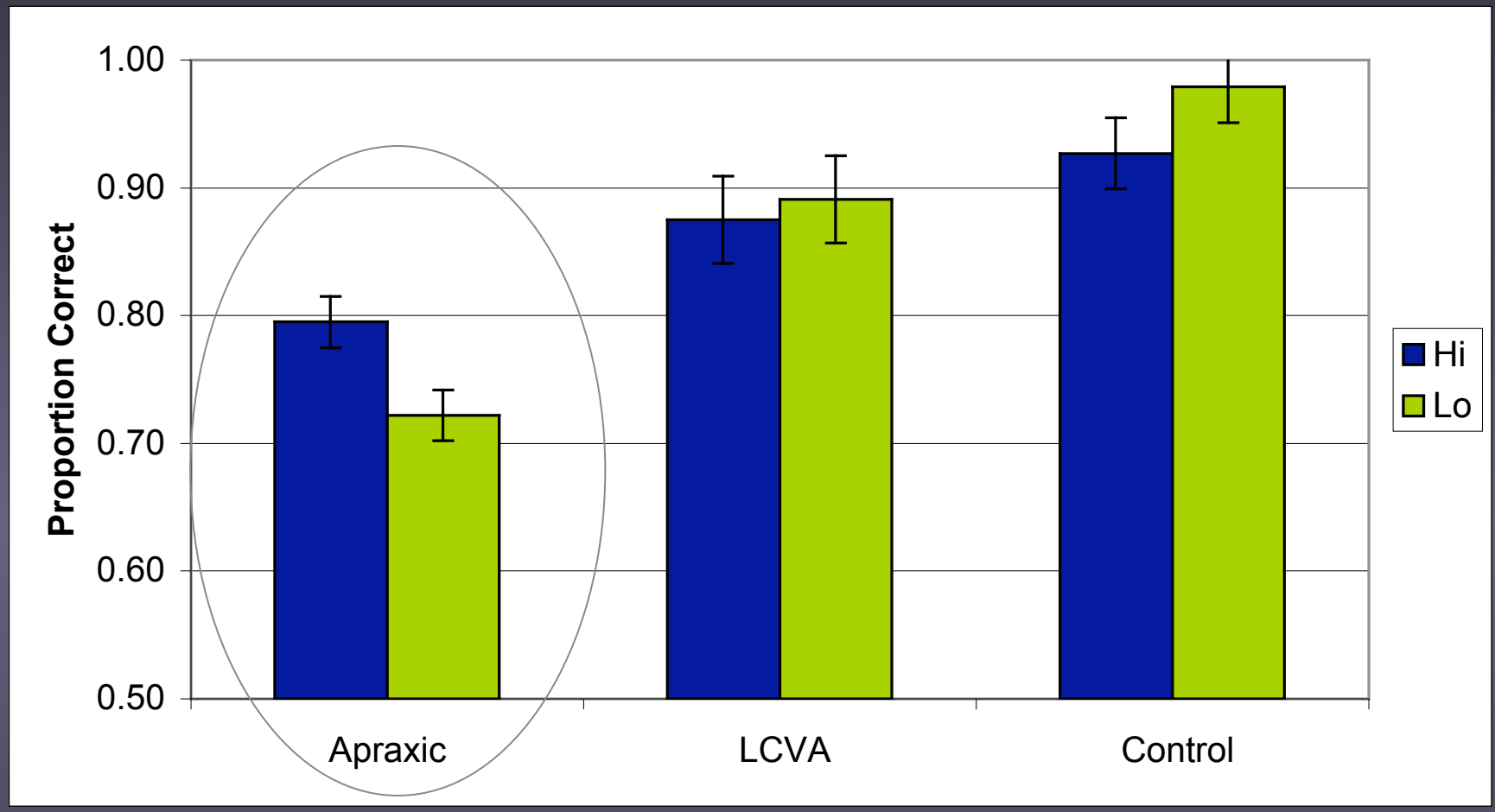
Forced-choice decisions about hand postures for interacting with real and novel objects



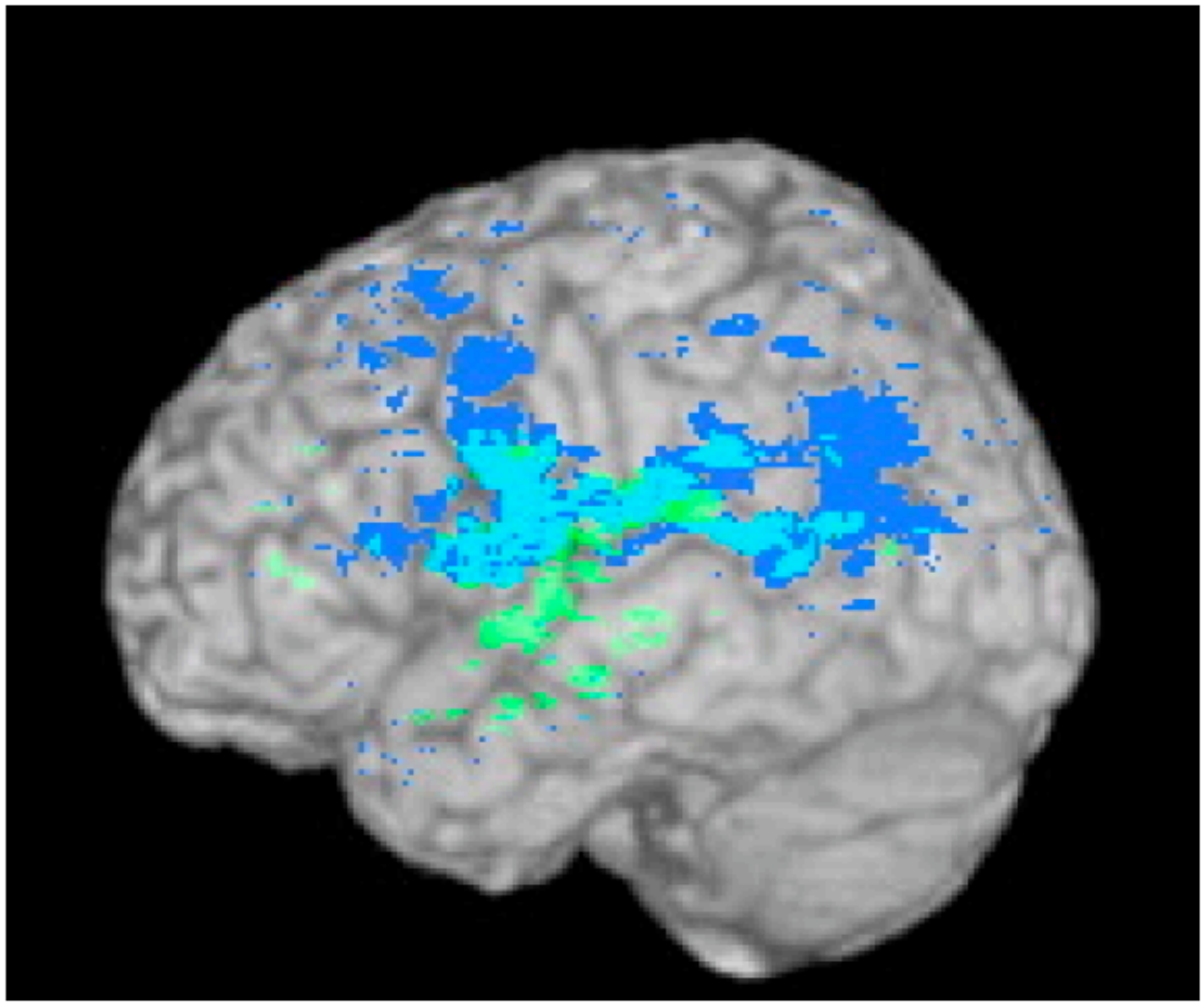
Apraxics *learn* object-related actions better if they are highly structure-based (Barde, Buxbaum, & Moll, JINS, 2007).







Affordance x Group Intxn - $F(2,18) = 7.40$, $p = .005$



Ideomotor apraxia -Medium blue

Benefit of Affordance Information -Green

Intersection - Light blue

Where do we stand?

- Evidence for 2 routes to action:
- Tool knowledge, tool manipulation knowledge, and the ability to identify tools are associated with the Use system
- Prehsensile grasp actions based on object structure are not.

Are these two types of action equally likely to be tied to object identity information (action semantics; embodied object representations)?

Time course info can provide insight here.

“Semantic” representations have some known temporal characteristics. For example, proactive semantic interference on naming of related items may build up over many trials and may persist for minutes (e.g., Damien & Als, 2005).

Use and Grasp activation have different temporal characteristics (Jax & Buxbaum, submitted).

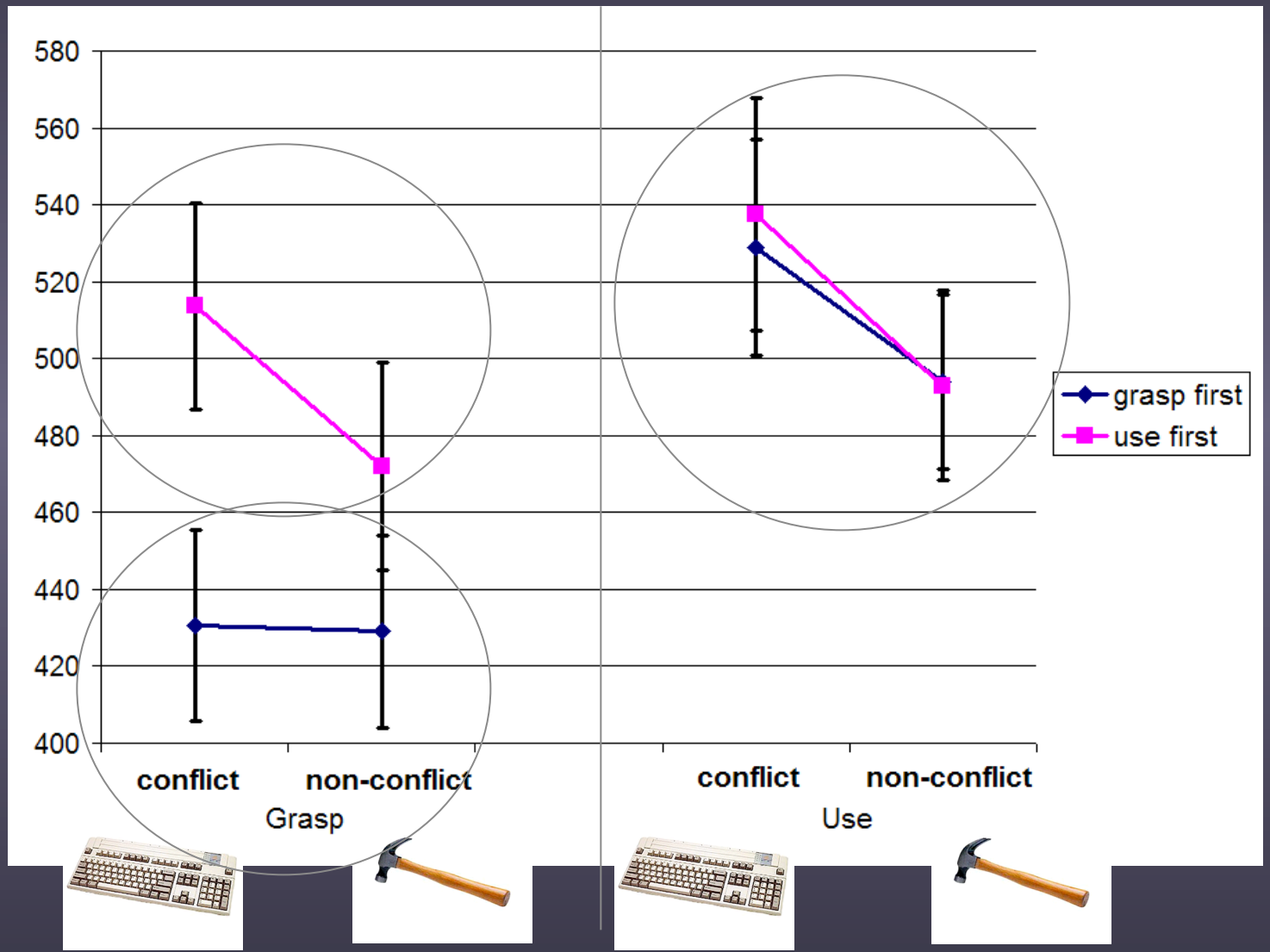
Neurologically intact subjects are asked to grasp or use objects. Grasp or Use is blocked.

Time to initiate movement is measured

Objects are of two types:

Conflict between grasp and use

No-Conflict between grasp and use


580
560
540
520
500
480
460
440
420
400
conflict
non-conflict
Grasp
conflict
non-conflict
Use
grasp first
use first

Discussion of this experiment

- Plan to perform particular action triggers selection of features of an object compatible with that action.

•When objects afford two different actions (conflict objects), non-target features interfere with target features in Use task (but not in Grasp task).

•When “Use” features have been selected repeatedly in conflict objects (“Use” blocks), these features remain activated despite switch to Grasp task, thereby causing prolonged interference.

•The brief activation of structural information is not characteristic of “semantic” memory. The long activation of Use information is consistent with the possibility that it is “semantic”.

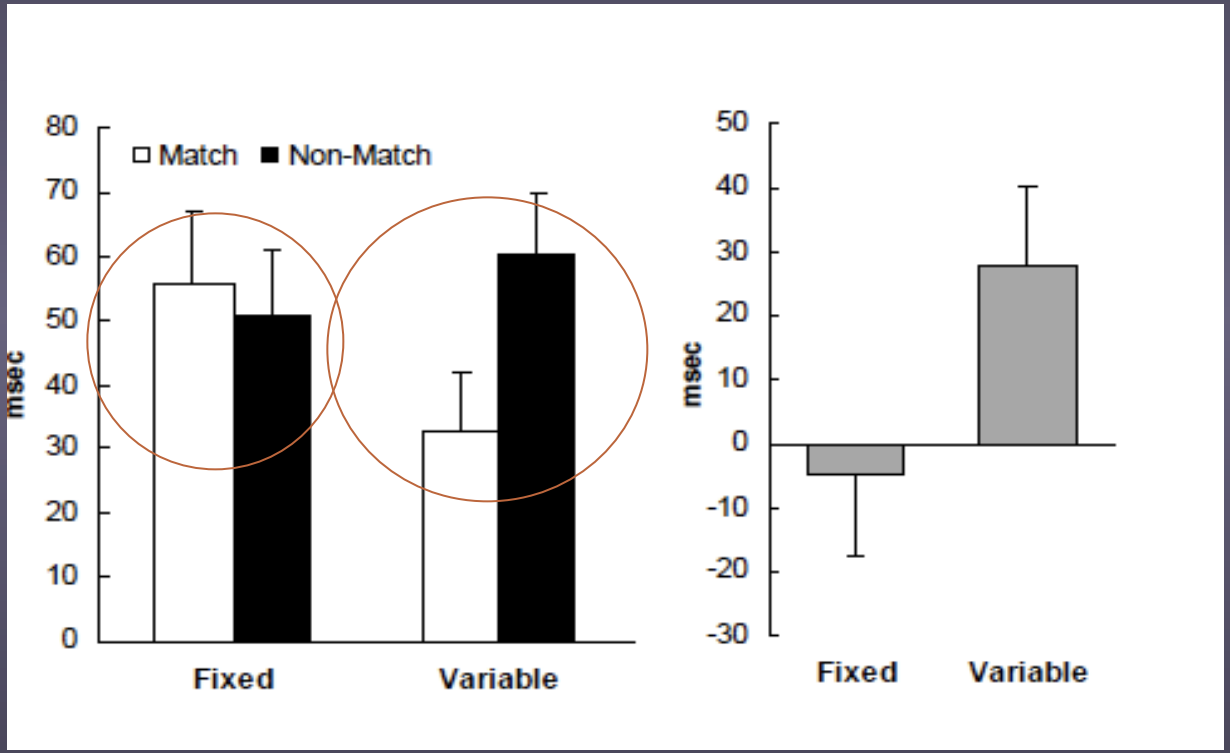
Very brief summary of what we know

Use actions are persistent representations, related to tool identity, and computed by a specialized, left-lateralized neuroanatomic system (the ventro-dorsal stream) in the IPL and posterior STG.

Grasp to Move actions are rapidly activated and rapidly decaying, likely not closely tied to object identification, and computed by the dorso-dorsal stream.

5. The Slippery Representation

- We know that intention biases attention to certain features of objects (Jax & Buxbaum, submitted, Pavese & Buxbaum, 2002; Botvinick, Buxbaum, Bylsma & Jax, 2009)



- Now testing hypothesis that object "knowledge" is actively constructed depending on context and intention, based on biasing of attention

Middleton, Kalenine, Mirman, & Buxbaum, In Preparation.

Throughout the block, prepare to show how to GRASP (or… USE) the target on the manipulandum. Trial 1: Find the PERFUME.

- Does object perception obligatorily entail activation of *all* associated actions?

- Thus, are all of these actions components of the object representation?

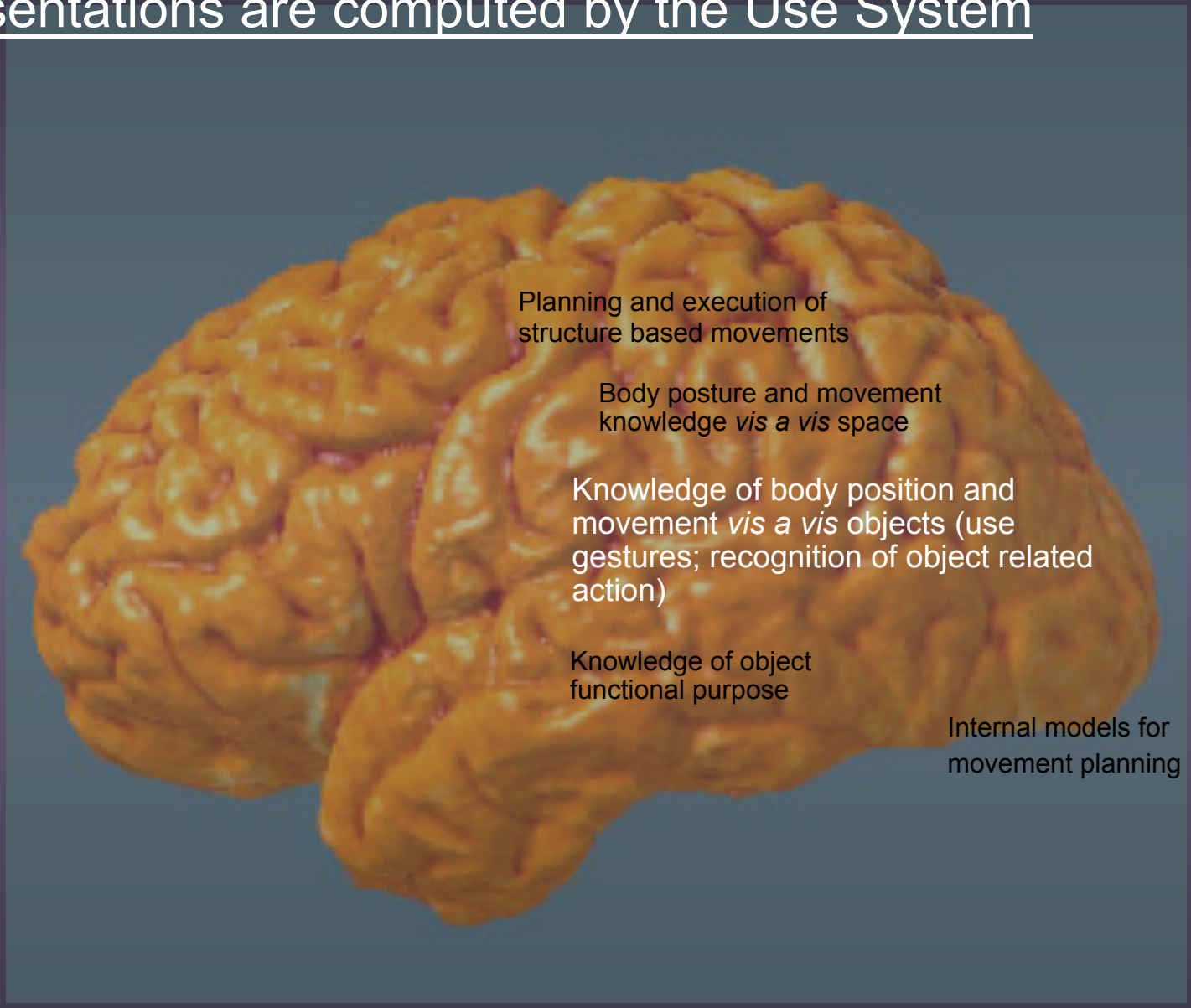
- Can consideration of functional neuroanatomy help us constrain findings of activation of actions by objects?

→ No. Evidence that structural information may be activated rapidly (prior to identification?), whereas activation of functional use information may be accessed when attending to identity.

→ Functional use actions have characteristics of semantic knowledge; structure based actions do not

→ Different actions evoked by objects are based on a functional neuro-anatomic subdivision of the dorsal stream.

The motor features of Embodied Object Representations are computed by the Use System



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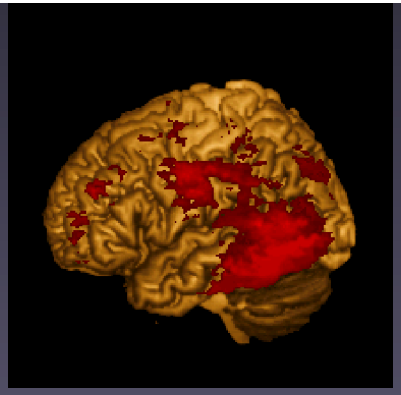
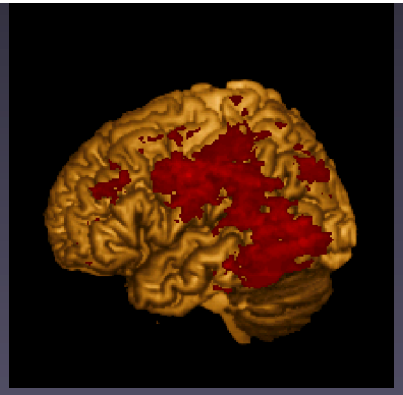
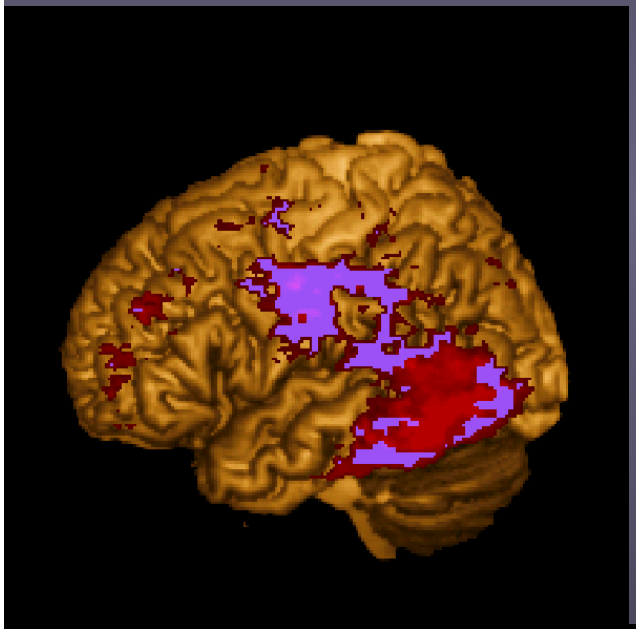
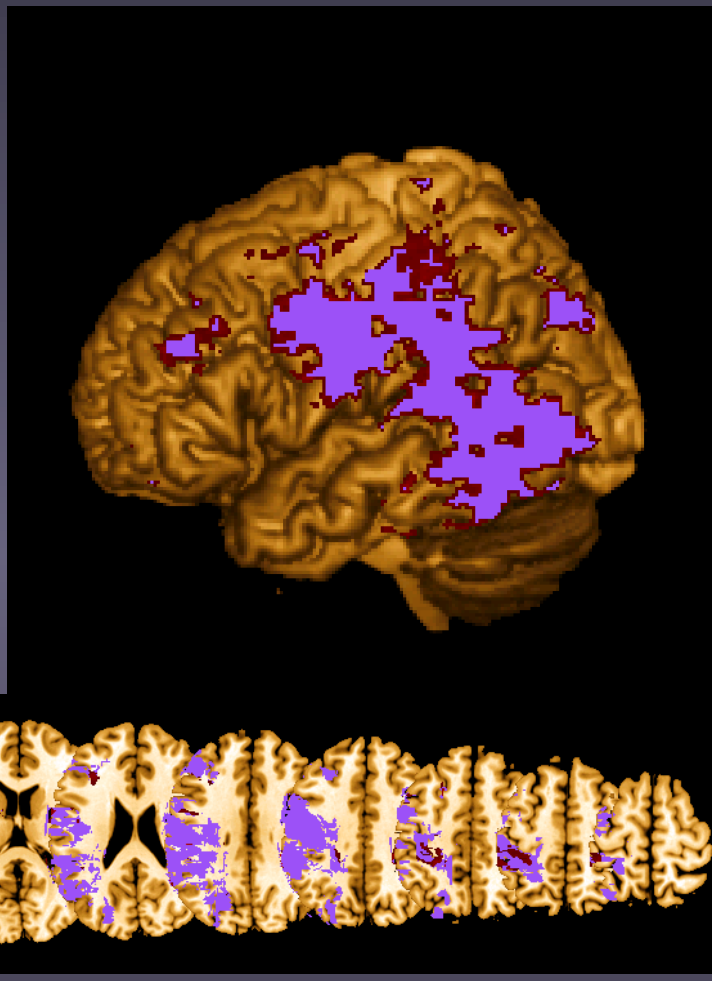
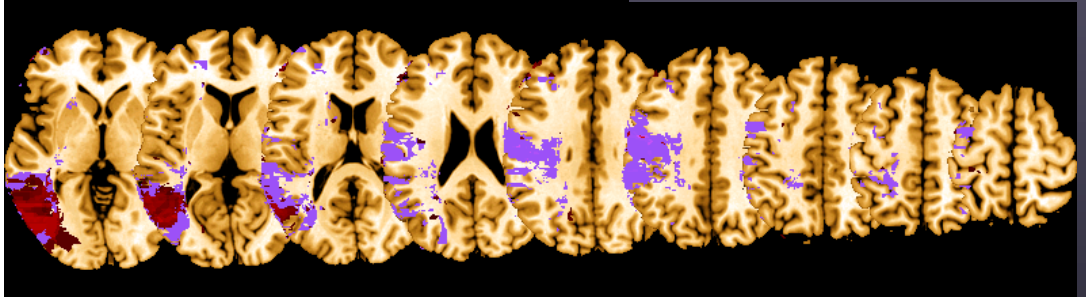




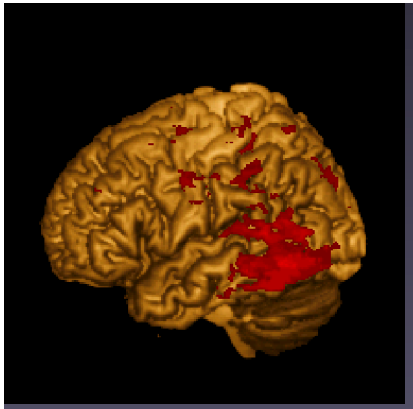
Transitive (59 subj) Meaningless (60 subj)

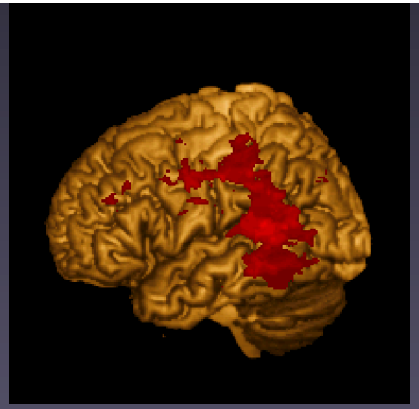




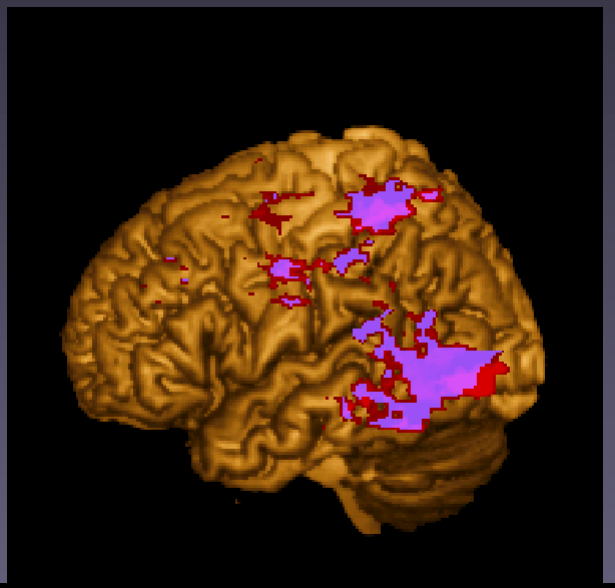


Buxbaum, Kalenine, & Coslett, in preparation



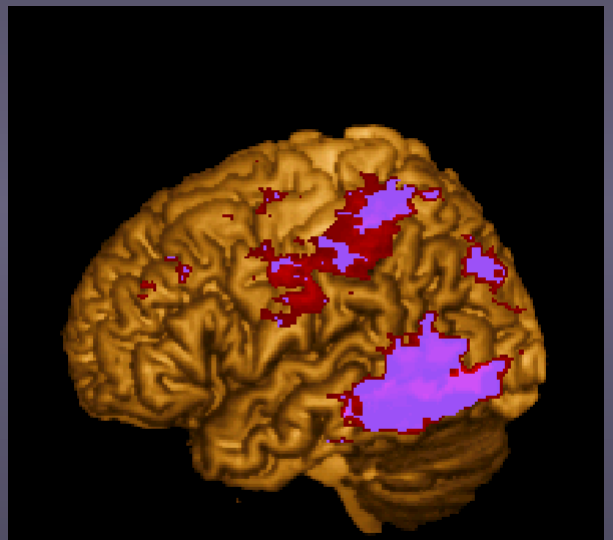


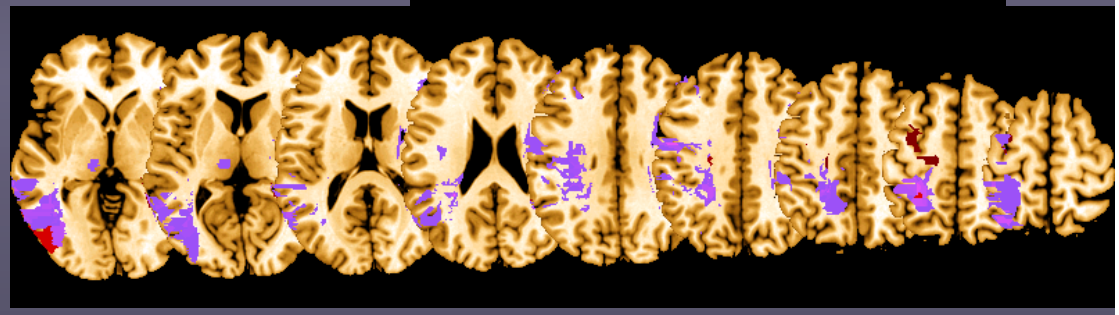
delay

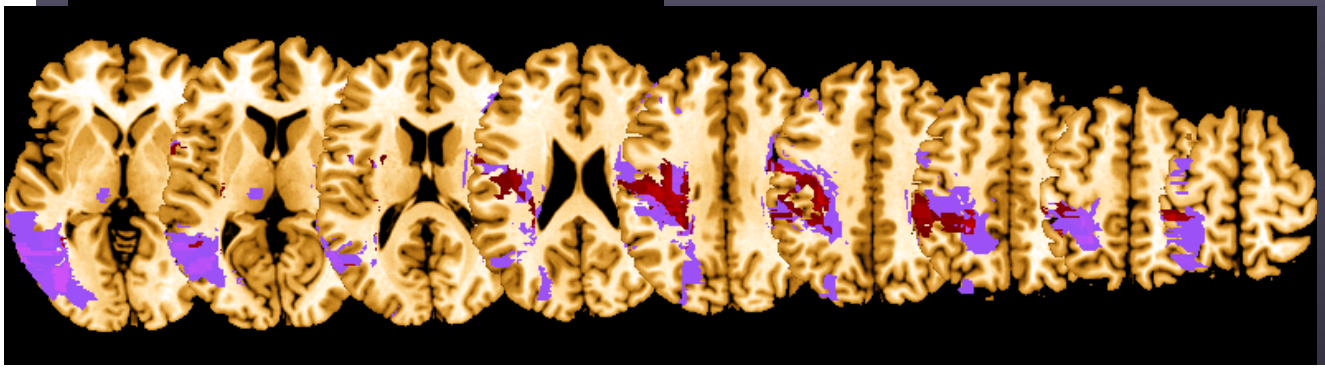


Transitive (33 subj)

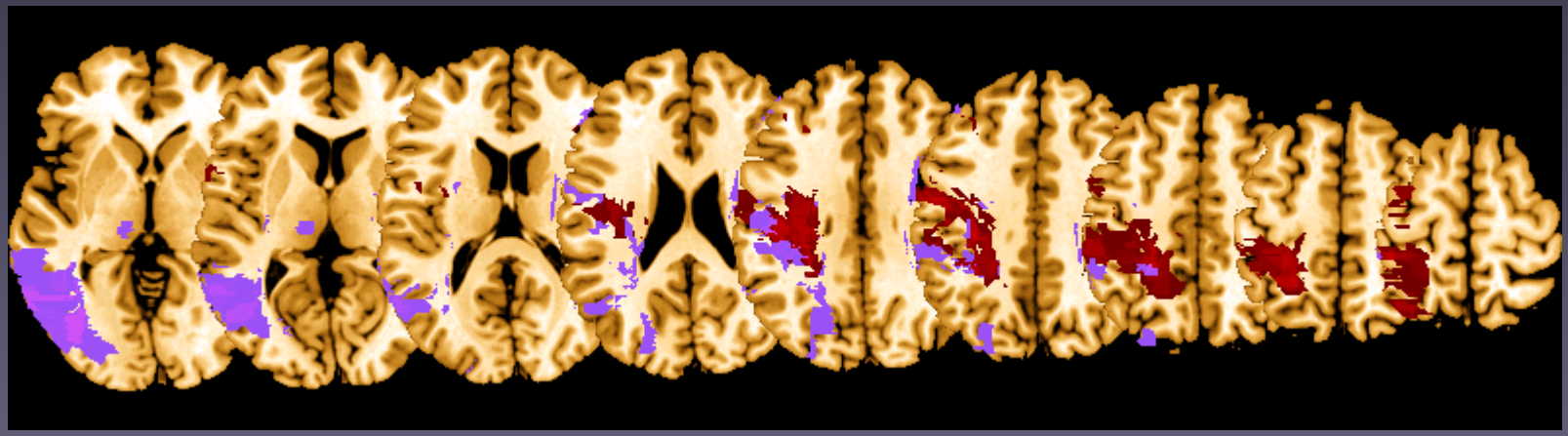
Meaningless (33 subj)

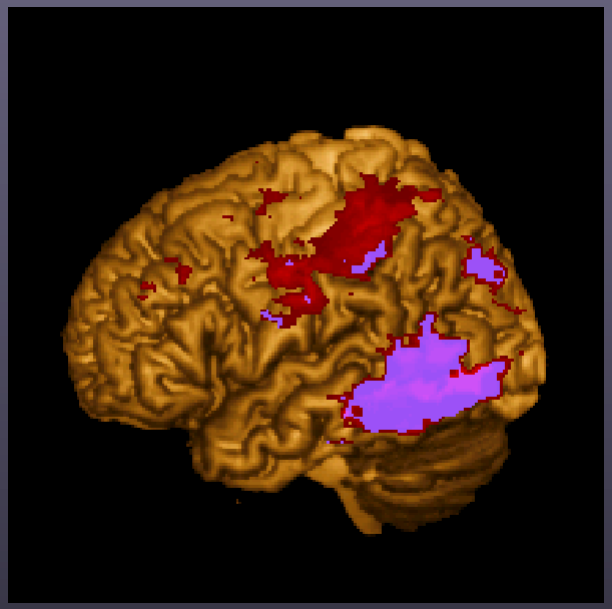






Delay transitive versus immediate transitive (33 pts)

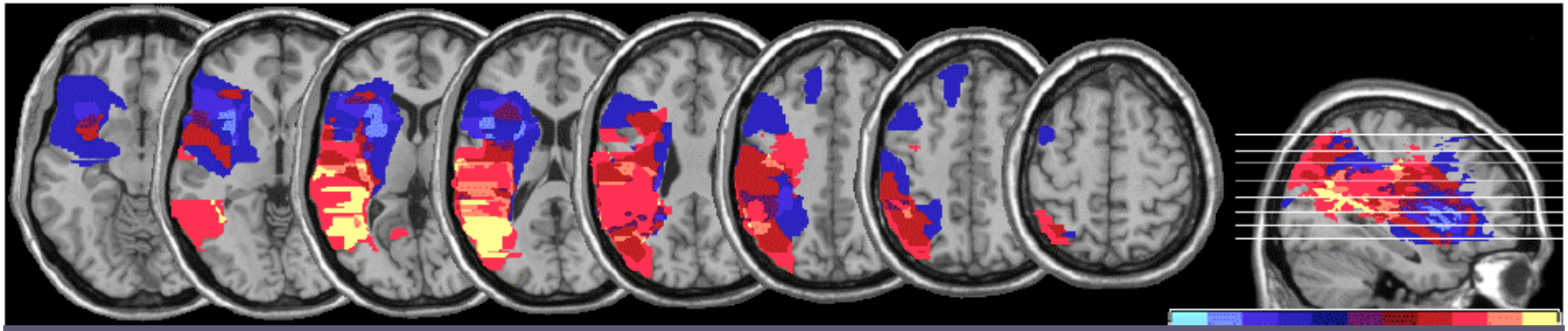




Anticipatory grip force control with familiar objects

Dawson, Buxbaum, & Duff, submitted

Most impaired vs least impaired stroke participants for Load Force Rate, Trial 1 with familiar objects



•Region of interest analysis: STG and IPL significantly Correlated with poor load force rate scaling for familiar objects.

Thematic distractor *Low level function distractor* *High level function distractor*

Neutral context:
"Find the BROOM"

Low-level Schema Context:
"You want to clean the FLOOR.
Find the BROOM"

High-level Schema Context
" You want to clean the HOUSE. Find the BROOM"