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Language is handy but is it embodied?

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ABSTRACT

Part 1 provides Arbib's reflections on the influence of Marc Jeannerod on his career. Part 2 recalls the Mirror System Hypothesis (MSH) for the evolution of the language-ready brain, a theory which emphasizes the role of manual action in grounding language evolution, thus giving one meaning for "language is handy". Part 3 then joins in current debates over the notion of whether or not language is embodied. Our overall argument is that embodiment is a graded rather than binary concept, and that embodiment provides the evolutionary and developmental core of concepts and language, but that the modern human brain supports abstraction processes that make embodiment little relevant in a wide range of language use. We urge that, rather than debate the extent of embodiment, attention should turn to the integration of empirical studies with computational modeling to delineate in detail processes of abstraction, generalization, metaphor and more, bridging between modeling of neural mechanisms in macaque that may be posited for the brain of the last monkey–human common ancestor (LCA-m) and computational modeling of human language processing. Part 4 suggests that variants of construction grammar are well-suited to the latter task.

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1. A personal history (Arbib in relation to Jeannerod) [1]

1.1. *Prehistory: the 1970s. Action-oriented perception, schemas & computational neurolinguistics*

A major theme of Marc Jeannerod's research has been to place cognition and perception squarely in the context of action (Jeannerod, 1997 provides an integrated perspective), with special attention to the visual control of hand movements. My own path to linking action and perception began with "What the frog's eye tells the frog brain" (Lettvin, Maturana, McCulloch, & Pitts, 1959) which showed that the frog's retina extracted features relevant to the detection of prey and predators. Through this, I came to meet David Ingle, a neuroethologist who reported that, when confronted with two fly-like stimuli, the frog would in a few cases snap at "the average fly" rather than at one of the stimuli (Ingle, 1968). This led Rich Didday and myself to consider "What the Frog's Eye Tells the *Frog*," how the brain could transform retinal patterns into adaptive courses of behavior, a program my group pursued under the banner of *Rana computatrix*, the frog that computes (see, for example, Arbib, 1987; Didday, 1970; Ewert & Arbib, 1989).

Crucially, Ingle emphasized that what we learned of action-oriented perception in frogs was relevant to understanding mammalian brains as well. The symposium *Locating and identifying: two modes of visual processing* combined the insights of Ingle, Schneider, Trevarthen and Held (1967). For example, Schneider's study of hamsters distinguished a "where" system in the superior colliculus from a "what" system in cortex that allowed the hamster's behavior to depend on visual patterns whose discrimination was beyond the frog's capabilities. An intriguing follow-up was Humphrey's (1970) demonstration that a monkey without visual cortex could nonetheless navigate on simple visual cues like well-lit contours though having lost visual perception (compare "blindsight" in humans).

These influences helped make *action-oriented perception* a key concept in *The Metaphorical Brain: An Introduction to Cybernetics as Artificial Intelligence and Brain Theory* (Arbib, 1972). Of particular relevance here is the following: "The animal perceives its environment to the extent that it is *prepared* to *interact* with it. … Perception of an object generally involves the gaining of access to [schemas] for controlling interaction with the object, rather than simply generating a "name" for the object … [L]anguage can best be understood as a device which refines an already complex system – [and] is to be explained as a 'recently' evolved refinement of an underlying ability to interact with the environment." One might say

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[1] Portions of this paper are based on a talk given by Michael Arbib for the Symposium in Honor of Marc Jeannerod held on October 29–30, 2012 in Lyon, France. Section 1 thus prefaces the main arguments of the paper with an appreciation of Jeannerod's contributions to cognitive neuroscience. Marc Jeannerod died on July 1, 2011.

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that my hypothesis was that language is rooted in embodiment and may modulate or be secondary to ongoing embodied behavior – but the argument still held that language also supported inferences and concepts that were abstract rather than embodied. One might know that President Nixon was a male by summoning a visual image with his five o'clock shadow, but most of us cannot summon an image of President Polk, and instead know he is male by "disembodied" inference from the generalization "All presidents of the United States have been male".

Another conceptual development came from seeking to reconcile working top-down from behavior with working bottom-up from neural circuitry, and forward from sensory receptors and back from muscles, describing the frog's visuomotor behavior in terms of the interaction of *perceptual schemas* and *motor schemas,* with *cooperative computation* (competition and cooperation based on activity levels) between schemas, rather than binary choices, underlying behavior. Cooperative computation of schemas was taken up by Allen Hanson and Ed Riseman in their VISIONS system for interpreting a visual scene – the result being a spatially anchored schema assemblage. A first-pass segmentation of the image provided the basis for invoking perceptual schemas for entities which represented visual correlates of entities like *sky, roof, house, wall,* and *grass* and possible spatial relations between them in New England suburban scenes. Competition and cooperation proceeded both bottom-up (aggregating visual features to instantiate a schema) and top-down (as instantiation of schemas to interpret one region provided cues to support or oppose interpretations for nearby regions) to yield an interpretation associating schemas with distinctive regions of the scene (Hanson & Riseman, 1978). Although implemented on a serial computer, the system revealed an essentially brain-like style of distributed computation. The HEARSAY system provided a similar, and near contemporaneous, computer system for speech understanding (Lesser, Fennel, Erman, & Reddy, 1975).

Following up on these various studies, I collaborated with the aphasiologist David Caplan to argue that "Neurolinguistics Must Be Computational" (Arbib & Caplan, 1979). We showed how schema models might provide the necessary intermediary between neurolinguistic analysis and utilization of the fruits of modern neuroanatomy and neurophysiology.

1.2. *Marc Jeannerod and the centrality of action*

It was thanks to the frog – and more specifically to David Ingle – that I first met Marc Jeannerod. This was at the NATO Advanced Study Institute on *Advances in the Analysis of Visual Behavior* that David co-organized with Richard Mansfield and Mel Goodale at Brandeis University in June of 1978. Jeannerod's talk "Visuomotor mechanisms in reaching within extra-personal space" (later published as Jeannerod and Biguer (1982)) opened up a whole new dimension of schema theory for me. His insights into the preshaping of the human hand (Fig. 1, top) led me to the notion of a *coordinated control program* (Fig. 1 bottom, adapted from Arbib (1981)). Perceptual schemas here serve not only to recognize objects (as in VISIONS) and their properties but also to pass parameters to motor schemas – as in visuomotor coordination in the frog.

At the same 1978 meeting, Ungerleider and Mishkin introduced their classic distinction between the *what* (ventral) and *where* (dorsal) streams in the monkey. In due course, Jeannerod, Decety, and Michel (1994), Jeannerod, Michel, and Prablanc (1984) and Goodale, Milner, Jakobson, and Carey (1991) developed a *related* analysis of the human reach-to-grasp where the ventral stream determines *what* an object is, and the dorsal stream determines *how* to grasp it. Three observations: (i) Schneider had discovered a *what* versus *where* distinction between cortex and midbrain in the hamster. (ii) Ungerleider and Mishkin related *what* versus *where* to inferotemporal versus parietal cortex for monkeys during a memory task based on spatial pattern versus location,

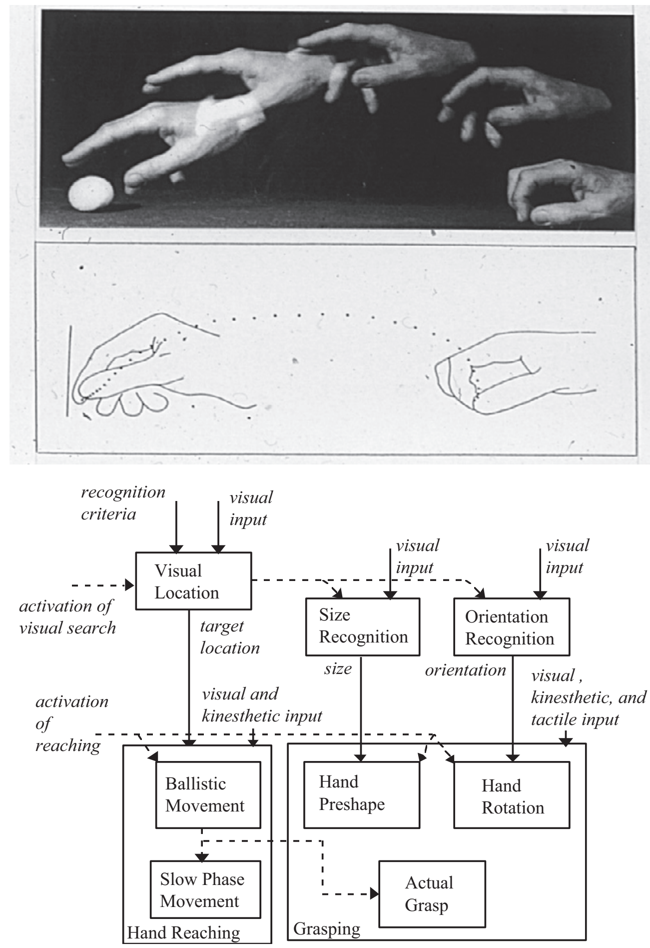

Fig. 1. (Top) (Upper) Preshaping of the hand while reaching to grasp; (Lower) Position of the thumb-tip traced from successive frames shows a fast initial movement followed by a slow completion of the grasp. (Courtesy of Marc Jeannerod. Adapted from Jeannerod & Biguer, 1982). (Bottom) A coordinated control program linking perceptual and motor schemas to represent this behavior. Solid lines show transfer of data; dashed lines show transfer of control. The transition from ballistic to slow reaching provides the control signal to initiate the enclose phase of the grasp. (Adapted from Arbib, 1981).

respectively. (iii) By contrast, Jeannerod and Goodale et al. looked at the online use of visual information during reaching to grasp an object and then extended the involvement of the dorsal stream to a variety of parameters (not just *where* the object was located) related to *how* the action was performed, consistent with the data and model of Fig. 1.

The publication of the model of Fig. 1 gave Ian Darian-Smith the erroneous impression that I had some expertise in the neural control of hand movements, and he invited me to speak at the IUPS Satellite Symposium on *Hand Function and the Neocortex* in Melbourne, Australia, in August, 1983. This provided a great stimulus to develop such expertise (Arbib, Iberall, & Lyons, 1985; Iberall, Bingham, & Arbib, 1986). This in turn led to increasing interaction with Marc Jeannerod which included sending two of my students, Peter Dominey and Bruce Hoff, to work with Marc in Lyon. In particular, Bruce addressed new studies in Lyon (Paulignan, Jeannerod, MacKenzie, & Marteniuk, 1991; Paulignan, MacKenzie, Marteniuk, & Jeannerod, 1991) of human kinematics which studied perturbations of the reach to grasp in which either the size or location of the object was perturbed after the grasp was initiated. This contradicted the hypothesis in my original model that the first phase of the reach was ballistic, but led to models of the motor schemas as dynamic control systems combining feedback and feedforward, and with coupling between them (Hoff & Arbib, 1991, 1993).

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