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Sensorimotor grounding and reused cognitive domains

By Maria Brincker

Abstract: *Anderson suggests that theories of sensorimotor grounding are too narrow to account for his findings of widespread "reuse" supporting multiple different cognitive "task domains." I call some of the methodological assumptions underlying this conclusion into question, and suggest that his examples reaffirm rather than undermine the special status of sensorimotor processes in cognitive evolution.*

Anderson's massive redeployment hypothesis (MRH) proposes that "reuse" of local cognitive circuits is a general evolutionary principle. "Reuse" is understood as the exaptation of cognitive circuits to new cognitive uses, while retaining prior but separate functions. The evidence for widespread reuses is based on statistical analyses of overlapping activations across predetermined task domains in a wide array of fMRI studies. On this basis, Anderson raises a two-pronged objection to theories of sensorimotor grounding: (1) That they cannot explain all his findings of reuse, and (2) that the functional properties of sensorimotor circuits are not special in regard to evolutionary reuse, nor in grounding higher cognition; these are simply older circuits and hence reused more in evolution.

While I am deeply sympathetic to the project of questioning modularity and investigating neural co-activations and overlaps, I am puzzled by Anderson's approach and suspicious of his conclusions. I propose that his assumptions about "reuse" and "task domains" seem implausible from such a sensorimotor grounding point of view – and hence that his arguments against such theories lose their bite. Anderson analyzes findings of fMRI activation overlaps in terms of predefined "task domains" (such as visual perception, action execution, inhibition, emotion, memory, attention, language, etc.); and given this methodology, he finds significant activation overlaps in regions beyond typical perceptual or motor areas for multiple, typically "cognitive" tasks domains. He concludes that sensorimotor theories are too narrow to accommodate such findings of "reuse."

In spite of many admittedly ambiguous expressions, the idea of sensorimotor grounding is not that all cognitive processes are localized in areas supporting typical action output or perception input. Rather, generally the core claim is that brains develop and have evolved on the basis of and in support of sensorimotor engagements between animal and environment (Clark 1997; Glenberg 2010; Haggard et al. 2008; Hurley 1998; Nunez & Freeman 2000). In short, it is not simply about location, but also about evolution and development. But how can we tell whether fMRI activation overlaps are due to evolutionary "reuse," rather than simply repeated use of the same functional circuit? Anderson's answer seems to be that, "For neural reuse theories, anatomical sites have a fixed working, but many different uses" (sect. 3.3, para. 3). That is, exaptation does not imply an evolutionary change in the local circuit, but simply a reuse of this very circuit to form a new combination with other circuits to support a new cognitive function.

This sort of atomistic combinatorial idea features prominently in Anderson's methodological equation between fMRI activation overlaps and evolutionary reuse: "Reuse" simply is repeated use of the same anatomical circuit across task domains (sect. 4.4., paras. 4–5). Anderson himself notes his theory does not address how the brain circuits have expanded and changed over the course of evolution. This is, however, a central issue for sensorimotor grounding theories, and such a perspective precisely calls Anderson's notion of reuse and methodology of counting task domains into question. First, primitive cognitive circuits might be multifunctional at the outset – that is, supporting not only action and perception, but also other of Anderson's "task domains" such as, for example, primitive attention, emotion, and memory functions. Secondly, differentiation from within, in concert with newer cognitive circuits, could form cognitive support systems for increasingly more complex organism-environment engagements. Accordingly, cognitive exadaptions could involve both old and new anatomical regions, and local activation overlaps might be the result of either "repeated use" of already evolved processes, or of evolutionary "reuse."

Anderson's key assumptions that (1) neural activation overlaps equal evolutionary "reuse" and (2) his statistical use of predefined "task domains" are therefore questionable. And, given a sensorimotor grounding of reuse and "task domains," there is no obvious incompatibility between findings of areas outside the sensorimotor system, say, medial prefrontal regions, being involved in multiple higher cognitive tasks such as memory, imagery, or motivation – or that other additional "cognitive domains" such as attention would interact with these "default network" processes (Buckner et al. 2008).

Anderson uses the phonemic character of human speech as an example of a reuse exadaption. His discussion is illustrative in that it shows how he assumes that certain abilities or "task domains" as functionally independent and to a certain extent reified by their cognitive purpose independently of the actual neurobiological instantiation that they happened to get. He describes (via Graziano et al. 2002b) how the evolution of phonemic speech piggybacked on the specifics of the preexisting motor control mechanism organized around endpoint postures. So far so good. But then he writes: "Had the motor control system been oriented instead around (for example) simple, repeatable contractions of individual muscles . . . the result of the inheritance might have been a communication code built of more purely temporal elements, something closer to Morse code"(sect. 4.6, para. 4). Anderson here assumes that complex symbolic and structured language *could have evolved* absent a motor system organized around perceptual end-goals in abstraction from the precise physical vectors of the kinetic movements. Maybe so, but he makes the tacit assumption that one can separate the sophisticated cognitive function of language not only from its phonetic character and the concrete physical constraints of the vocal system, but also from what might be a core organizing principle of motor control, namely, sensorimotor goal or end-state representations (Gallese 2003; Hommel et al. 2001; Rizzolatti et al.1988). In my work on mirror neurons and sensorimotor integration (Brincker 2010), I argue that this organization of the motor system exactly presents a seed for abstraction that can be exploited for higher cognitive processes, including language. Accordingly, one might think that sign language could have evolved without our specific vocal system but probably not without sensorimotor end-state organizations.

In summary, Anderson's assumptions differ significantly from the essential ideas of sensorimotor grounding, namely, that there is something about the basic biological acting and perceiving organism that structures the evolution and development of higher cognition. His findings of neural activation overlaps are not incompatible with sensorimotor grounding per se, as these statistical findings simply suggest that neural regions are used independently of sensorimotor engagements and say nothing about whether their evolution and primary function can be understood independently of such.

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