Published in final edited form as:

Phys Life Rev. 2014 September ; 11(3): 380–381. doi:10.1016/j.plrev.2014.06.002.

Mental structures and hierarchical brain processing Comment on “Toward a computational framework for cognitive biology: Unifying approaches from cognitive neuroscience and comparative cognition, by W. Tecumseh Fitch”

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Fitch proposes an appealing hypothesis that humans are dendrophiles, who constantly build mental trees supported by analogous hierarchical brain processes [1]. Moreover, it is argued that, by comparison, nonhuman animals build flat or more compact behaviorally-relevant structures. Should we thus expect less impressive hierarchical brain processes in other animals? Not necessarily.

Neuroscientific evidence is showing that the brains of humans and many animals are dendrophiles. The well-established notion of hierarchical brain processing was informed by human and nonhuman animal work [2,3]. Moreover, the form of processing is not just serial or parallel, because human, monkey and rodent brains have both local ‘small world’ connectivity patterns, as well as hubs that interconnect different ‘worlds’ [4]. Also, dendrograms as neuronal representations are prominent in a range of species: dendrograms can well describe monkey ventral frontal cortex neurons responding to vocalization sounds [5], and rodent hippocampal neurons can create multi-layered dendritic structures to encode several features associated with a memory [6]. In neither case is there any suggestion that different vocalizations or memory features are hierarchically organized by the animals for behavior. Also, hierarchically nested brain oscillations responding to speech are evident in humans [7], which is complemented by computational models of speech parsing [8]. Yet, nested oscillations are also evident in monkeys listening to natural sounds [9] and violations to a non-hierarchical artificial grammar that monkeys can learn appears to modulate nested oscillations in auditory cortex [10].

Much less clear, as Fitch suggests [1], is how to access the mental structures that humans and other animals sculpt. He suggests testing alternative hypotheses on the computations being conducted. For example, if one is evaluating strings generated by an $A_n B_n$ grammar, different individuals might glean different structures depending on the mechanisms used, such as: (1) ‘push-down-stack’, where associations are computed and allocated to memory; or, (2) ‘count-and-compare’, where multiple counters keep track of the number of As and Bs

(in the case of $n = 3$, 3 As and 3 Bs) and a comparison function evaluates whether they are equal. In the case of a ‘push-down-stack’, one might envision the human inferior frontal cortex associating different forms of input and holding the associations in memory. But it is unclear how this would differ or be informed by insights on hierarchically organized cognition in studies of neurons from monkey frontal cortex [11], or those on hierarchically organized memories in rodent fronto-hippocampal networks [6]. In the case of ‘count-and-compare’, this could be informed by numerosity encoding in monkey frontal neurons [12]. The danger, however, which Fitch does not appear to condone, is overlooking the insights that we can gain from nonhuman animals if most are viewed as having, at least by human standards, unsophisticated mental structures.

I agree that a priority is for hypotheses to be better developed and tested on the computations subserving different behaviorally-relevant structures, which even in humans has remained largely theoretical. Each computational hypothesis supported or refuted clarifies the types of structures being built by an individual or their species. Neurobiological evidence can provide mechanistic insights. However, it is incorrect to assume that hierarchical neural processes subserve only hierarchical representations of the forms that humans uniquely can build. After all, it is already abundantly clear that the brains of most animals like building elaborate structures.

Acknowledgments

Supported: Wellcome Trust New Investigator Award (WT102961MA); Biotechnology and Biological Sciences Research Council, BBSRC U.K. (BB/J009849/1)

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