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On the unproductiveness of language and linguistics

David M. W. Powers

School of Informatics and Engineering, Flinders University of South Australia, Adelaide SA 5001, Australia. **David.Powers@flinders.edu.au**
http://www.infoeng.flinders.edu.au/people/pages/powers_david

Abstract: van der Velde & de Kamps (dvV&dK) present a response to Jackendoff's four challenges in terms of a computational model. This commentary supports the position that neural assemblies mediated by recurrence and delay indeed have sufficient theoretical power to deal

with all four challenges. However, we question the specifics of the model proposed, in terms of both neurophysiological plausibility and computational complexity.

It is often assumed that language is vastly different from and largely independent of other cognitive processing, and this modularity fallacy is apparent even in this target article, notwithstanding its attempt to explain aspects of language in more general cognitive and perceptual mechanisms exemplified in the examples given. In particular, in introducing the massiveness of the binding problem (sect. 2.1), it is suggested that *cat*, *mouse*, and *chases* activate specialized populations of neurons and distinguish word order in a manner similar to the operation of motion detectors for a vertical bar. But then it is argued that language is fundamentally different because motion detection is able to be specialized for motion of a limited set of possibilities, but language has unlimited combinatorial productivity. In fact, the productivity has nothing to with language or linguistic theory. Rather the complexity derives from our environment, and even without language, an organism is continually faced with new situations, new entities, and new interactions and interrelationships.

The fact that many things can chase a mouse has nothing to do with language. In a book, Dumbledore would be introduced with a sentence, whereas in real life he would be introduced verbally and mutimodally by a person in a direct personal encounter or might just be seen chasing the mouse without his name or profession being known.

The visual system detects the motion of Dumbledore, the cat, or anything else irrespective of any linguistic bindings. The fact of motion is detected at a very primitive level, and work such as Hubel's (1995) indicates that there are neural detectors for salient features such as edges in motion. The mechanisms by which an object is recognized, its motion is recognized, and its name is recognized all seem to be similar and are often theorized to be associated by neural synchrony on the basis of empirical evidence of synchronous neural activity (Roelfsema et al. 1997; Samthein et al. 1999; Shastri & Ajjanagadde 1993b; von Stein et al. 1999).

The problem of variables (sect. 2.3) is in essence an artefact of the assumption of rule-based structures, and both are linguistic constructs that probably have no concrete correlate in brain function. Rules and variables, moreover, do not necessarily occur in modern statistical language learning approaches: rules are implicit in supervised approaches involving tree-banks (Marcus 1991), probabilistic grammars (Charniak 1993), and/or data-oriented parsing (Bod 1995) but are supplanted by a more general concept of prosodic, phonological, morphological, syntactic, and semantic patterns in unsupervised approaches (Clark 2001; Hutchens 1995; Powers 1983). The underlying phenomenon whereby variables get attached to values (in a rule-based approach) or abstracted patterns get matched with current sensory-motor or linguistic content is again a matter of binding or association, which is commonly dealt with by theories of synchrony (Weiss et al. 2001).

However, van der Velde & de Kamps (vdV&dK) do not see synchrony or recurrence as a panacea for Jackendoff's challenges but rather show how various early models exhibit exactly these problems. They point out that that the Shastri and Ajjanagadde solution to the multiple binding problem is duplication and that this then faces problems with nested structures and implies a "one-level restriction." This is technically incorrect, but the argument does indeed imply a "finite levels restriction" which is consistent with Miller's (1956) Magical Number Seven constraints, with the inability of humans to cope with arbitrarily complex embedding, with phenomena such as subjacency, and with the observation that there is insufficient space in our heads for the infinite stack implied by linguistic theories that see language as strictly more complex than context-free.

Synchrony involves a specific pattern that is present in each neuron triggered as a result of a specific object or event, and this pattern represents a temporal encoding that would seem to encode low (<20 Hz) frequencies as well as information correlated with spatiotemporal location that results in higher-frequency components and evidently has a reverberatory or recurrent origin. A Hebbian neural assembly is intrinsically a spatiotemporal association, and the concept of synchrony adds the potential for overloading in the sense that the same neurons can synapse into multiple assemblies with different characteristic signatures. The circles or triangles that represent terminal or nonterminal symbols linguistically in vdV&dK are in fact intended to represent assemblies neurologically, and these are intrinsically dynamical structures that exhibit synchrony and provide evidence of recurrent processes (Hebb 1949; Pulvermüller 2002), although this is not made explicit in the target article.

There are, moreover, alternatives to the duplication approach as well as refinements such as a homunculus model built upon evidence of a propensity for spatiotemporal reception fields and projections that reflect information-distorted sensory-motor representations of the opposite half of the body (Powers & Turk 1989). Plausible models should also take account of attention and saccade and the evidence that we maintain a relatively high-level spatiotemporal model of our environment that is informed by attended events and peripheral change (e.g., in the visual domain, motion or lightening; in the auditory domain, modulation or softening). The spatiotemporal representations have very much the function of the more abstract pretheoretic blackboard metaphor. Powers (1997) envisions the spatiotemporal model as being like the columns of blackboards in a lecture theatre – different columns for different sensory-motor or cognitive modalities, different levels for different times and levels of complexity. In the lecture theatre, a board is pushed up after it has been written on, and a clean board emerges from below. While working on the current layer of boards, one can refer to any board on any higher layer that is still visible.

vdV&dK's model is largely consistent with this kind of model but is more reminiscent of sequential digital logic circuits and in fact makes the analogy explicit through the use of gate terminology. Synchrony, reverberation, and recurrence would seem to be important mechanisms in realizing their model, although there is an interacting pair of neural attributes that they neglect: delay and decay. Delay is clearly implicit in reverberatory and recurrent models, but delayed copies of a signal can exist at different parts of the network even without recurrence. These delayed copies create the temporal dimension of a blackboard-like spatiotemporal representation. Hence a neuron is as much a short-term memory element as a processing element and functions something like a dynamic memory cell that maintains its memory while it is being refreshed as relevant. A complementary effect is represented by the refractory period and its role in habituation. Powers (1983) used this delay-decay model (as well as a more abstract statistical model) for induction of both grammatical and ontological structure.

Although presented in an unhelpful notation that is nonstandard for both neurons and gates, the vdV&dK gating model is similar to sequential digital logic circuits, and the resulting model of memory acts like a static memory cell. Whilst the model is sufficient to provide solutions for Jackendoff's problems, it is considerably more complex than the simple delay-decay model, and there is no direct neurological support for this kind of model except in terms of the ongoing synchronic recurrence between features triggered for the same event that forms the Hebbian assembly.

The elaboration of the vdV&dK model is intrinsically syntactic in nature and this extends to their models of short-term (blackboard) and long-term (knowledge base) memory. There is no ontology, no semantics, no meaning captured in distinguishing *The cat chases the mouse* from *The mouse chases the cat.* There is no discussion of how *cat* is recognized or the verb *chases* is understood, and the representation of words with circles, supposedly representing neural assemblies, fails to capture the inherent overlap of the distributed representation of a Hebbian assembly (Pulvermüller 2002). A more realistic model involves abstraction of entire scenes and association of words with those scenes in the same way as any other attributes of the objects or events involved, these structures reflecting (Piaget 1954) the multimodal multilevel spatiotemporal short-term delay-decay representation of the current ontological context in the blackboard network. The hearing or reading of a sentence generates a sequence of neural patterns that starts off being perceptual in nature and becomes increasingly abstract and conceptual as well-attested neural processes extract features and relationships. The sentence and its context, both linguistic and ontological, are thus represented in different layers of the network at different complexity levels and time points – the spatiotemporal neural blackboard. The function of recurrence and inhibition is not to implement short-term memory but to allow the representation of complex spatiotemporal relationships.

Linguists tend to get this backwards. It is not that language determines who is the subject or the object in a sentence, but rather that in the environment there is an actor and an undergoer (Pike & Pike1977). The reality has primacy, and the underlying representation is arguably there not to represent language but to represent past, present, and potential experience. The issues Jackendoff raises are not primarily problems of linguistics but matters of ontogenesis. In dealing with problems that Jackendoff poses from a linguistic perspective, vdV&dK tend to force their cognitive model into a linguistic mould rather than producing a proper ontological model and showing how linguistic relationships, semantic, phonetic, morphological, and syntactic, can be represented – or, indeed, can be emergent.

It is therefore highly appropriate that vdV&dK conclude by looking at how their blackboard architecture maps onto vision, which is arguably representative of the entire array of sensory-motor and cognitive modalities. This would have been a better starting point, as understanding this kind of feature-binding model can potentially lead to a better understanding of syntactic and semantic binding.