On Modularity

By Alexander Starz

1. Introduction

The study of language deficiencies has ignited a discussion about the modularity of language. The systematic defaults in language production and acquisition have lead to the idea that different faculties of language operate independently from each other--at least to a certain degree. Crocker (1991) distinguishes four such language modules that operate parallel to each other and take care of either phrase structure, chains (movement, case), thematic structure, or coindexation (binding, control). Other studies involve neurobiological research and speak against at least the innateness of modularity (Karpf 1991), if not against the whole idea (Benke and Wagner, 1990), as incompatible with findings in this field.

With this project I will develop a theory for the biology of modularity. For this I will treat modules of the mind as distinguishable sets of knowledge. They are not part of the 'hardware', the brain, but part of the 'software', the data. Data in the brain have a chemical realization in the form of protein. These macromolecules have different geometries and therefore distinguishable features. My claim is that these geometric features are the modules of language.

2. Mind and Memory: Neurons and Beyond

So far, data in the brain were thought to consist of electrical impulses in neurons. An electrical impulse can be there or not, but it can not be marked as belonging to a certain module or class of data. It is binary. Therefore the idea that modularity could be a part of the data rather than something organic never occurred to any neurolinguist. But impulses in neurons are only a small part of the mental processes that in sum create the mind. Other parts are the chemical processes in mid- and long-term memory.

Two experiments from the sixties show what happens beyond neuronal activities in the brain: In one experiment (Babich et al.[1]), rats were trained to find their way through a labyrinth. After they had acquired the task the animals were killed. A substrate from the brains of the trained rats was transferred into brains of untrained rats. Exposed to the labyrinth, they found their way through it right away.

The impact of this experiment is that there is something in the brain that keeps its information value even after death and that can be transferred from one individual to another. This goes far beyond the capability of electrical impulses. But then, what is it?

When the other experiment I am going to describe was directed, the suspicion was that protein might play a role. So in this experiment (Flexner et al.[2]), the animals involved were medicated during acquisition phases. The medication blocked protein synthesis. The animals never acquired their task.

Further variation and comparison of the two experiments showed that the rats from the first experiment had a long-term knowledge about their way through the labyrinth. They were able to perform their task even days after their last run. The animals in the second experiment could acquire knowledge about their task so that they were able to perform the same task several times in a row. But after a time lapse of a certain

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[1] see Shepherd for exact reference
[2] see Shepherd for exact reference

length they could not perform anymore. They only had acquired midterm memory that was lost in a day.

It follows that there must be a step between neuronal patterns and the synthesis of protein. Although we do not know all the details at the moment, a good guess for the mechanism of this intermediate level of data processing is RNA. RNA is necessary for protein synthesis, is proven to contain data, has chemical reaction times that make it fast enough to be counted to the processing unit, and is normally stable for several hours. All characteristics we would want our model of midterm memory to have.

In summary, what was said above shows that proteins play a crucial role in learning. Furthermore it very strongly suggests that RNA is the mechanism of midterm data processing. This enables us to postulate a very clear-cut model of short-, mid-, and long-term memory:

input -> short-term memory -> midterm memory -> long-term memory

3. Modules are in the Data

With this model of cognition in mind, I would now like to shift the discussion about modularity from "Where in the brain are the modules?" to "Where in the data are the modules?". The traditional claim for modularity of language states that language consists of independent and distinguishable, though interacting modules. A module in this sense is seen as a machine that fulfills a certain task, like an organ in the body, with a certain location. Though studies in aphasia and acquisition support the idea of modularity, neuroscience makes it clear that modules can not be located in certain regions of the brain. The model of cognition developed above now provides explanations independent from specific regions of the brain. Modules can be regarded as bits of information that are built in the geometrical form of the relevant protein. These modules make the data distinguishable and classifiable for language use. Every module that theory and further research finds necessary to claim is a special adjunct that defines that class of data: NP, V, Wh-word, S, etc.

4. Implications from Data based Modularity

The second part of this paper will deal with implications from this model of modularity and its impact on research in the fields of aphasia and acquisition. Furthermore the notion of 'strict modularity' needs some discussion in the new light of data based modules.

4.1. Aphasia

Certain forms of aphasia affect special language skills. In one patient grammatical skills are affected, while in another patient, lexical reference is inappropriate. How can the new model of cognition answer to that? How can data in the protein be unavailable?

Again, there is a biological answer that employs some basic mechanisms in protein synthesis and protein interaction. This field is far too complex to have even the hope to present final answers at this point. But some 'mishaps' in protein synthesis are known that can give us an idea what might go on. I will use one mechanism, the one of protein blockage, as an example. Protein is produced at all times in large quantities everywhere in the body. Accidents can and do happen. One kind of accident can be the production of an antigen to an existing molecule. This leads to the destruction of the molecule in question. Or a 'mirror' protein might be produced that has the exact opposite geometry to a certain molecule. These two bodies fit together like a key and its lock. When they combine, the result can be a bigger, but worthless protein that has lost all the properties of its components.

A stroke, as one of the most common causes for aphasia, would trigger many repair mechanisms in the brain. All these repair mechanisms include protein synthesis, since antibodies must be produced, structural elements must be replaced, etc. Here it can happen very easily that antibodies for a certain language module are produced that then block exactly these modules on the language information proteins. The data can not be retrieved, hence the language performance of the speaker is affected. However, it must be understood that this is not the answer to aphasia. It is just one of the multiple possibilities that the human body is capable of and that might play a role.

4.2. Acquisition

The model of cognition introduced above should be expected to be relatively independent of maturational processes. As such, it could be taken as support for the anti- critical period league in language acquisition. But this is not necessarily so. Though it can be taken for granted that the mechanisms described above start working from the first moment on and keep doing so throughout life, they cannot be seen in isolation. The brain undergoes maturational processes, and puberty is a hormonal (guess what: protein again) shock in which we don't know exactly what happens. So data processing might be affected in ways we do not know yet.

Two conclusions can be drawn from this model for acquisition. The first one is trivial and simply states "eat healthy, so that you provide the necessary nutrition for your body to produce protein". The second one is well known, too, but finally gets a biological foundation. Only constant repetition guarantees learning. I will add to this later on when I talk about 'Problems' of my theory and discuss LTP.

4.3. Strict Modularity

'Strict modularity' is the idea of absolutely independent modules of language. It is opposed to the notion of interacting modules. Data based modularity can not finish this dispute. It can be used for both.

One single protein may very well contain several module parts. So the information can be read by all these modules. Whether this makes the modules interact or not is unanswerable at the moment.

5. Problems to be Solved

Biology gives us some basic mechanics of the brain which I used as a tool to create a model of cognition that answers nicely some questions in linguistics. Other questions remain open: How do we retrieve certain information from storage? How much information is stored in one protein? Can proteins be transferred to other regions of the brain and be read and transformed into neuronal patterns there without losing information, or is the whole system bound to the neurons that got the input?

I will not try to answer these questions here, but two important problems shall be mentioned that definitely need to be answered by further research. The first one consists of the question of bidirectionality for protein synthesis. Although the way from the input over neuronal patterns and RNA to protein is taken care of in the research (except for what I will discuss below), the way back is not yet documented.

The other problem is the transfer of neuronal patterns into RNA. Obviously, not all input is transferred. How does it work, and which input is taken over? A concept called Long Term Potentiation (LTP) (Shepherd, p. 640) seems to form the filtering level: Neurons that are frequently stimulated achieve Long Term Potentiation, which is a higher synaptic response ability that persists over hours and days. The important point is the 'frequent' stimulation, which I addressed earlier.

6. Conclusion

Cognitive mechanisms other than neuronal activity have been neglected so far in linguistic research. The idea of a cognitive model like the one described in this paper is attractive for several reasons. First of all, it can be proven or disproven with the necessary research. It provides a much more reasonable and efficient machinery than the 'just neurons' approach. And it is based on processes that other sciences already deal with effectively. This could form a basis on which theories about language can be compared in a very direct way.

In the end, a vision: We will find the molecules of language. One day in the future, we will have big tanks of bacteria with DNA engineered in a way that they produce these molecules. Language in a jar, learning by injection.

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