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Opinion

Modules in the Brain and Our Versions of the World

Hans Lenk*

Professor, Department of Philosophy, KIT/Karlsruhe, Germany

***Corresponding Author:** Hans Lenk, Professor, Department of Philosophy, KIT/Karlsruhe, Germany.

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Mental (or mental) renditions and representations in the brain occur according to the so-called "building block" principle: brain and mind are organized in modules and do indeed work modularly.

Jerry Fodor's [1] definition of 'modularity' is methodologically speaking dependent on using building-blocks: this structural property means that it belongs to and works via functional units that are:

1) Operating relatively quickly,
2) Autonomously, quasi automatically,
3) Remain area-specific,
4) Are informationally closed, and
5) Are furthermore "binding", i.e. would "necessarily" respond to each relevant stimulus. (This latter property is of course related to automaticity).

Modularity, according to Fodor's thesis, is characteristic for many of the brain processes, especially for the representation of the mental. This thesis has however been criticized many times.

Nevertheless, it can be said that serious - even intentional (i.e. content-oriented) - models of the representation of the mental, especially representations by schemas ("scheme-representations"), are modular or almost modular (quasi-modular or pseudo-modular).

However, in doing so, we have to give up some of these mentioned five characterizing properties, e.g. "absolute obligation" and perhaps in a certain way (but only in this restriction!) also the fixed automatic recall[1]. If we cancel the requirement of absolute "bindingness" and do indeed restrict automatic retrievability, we still have at least the following other three characteristics: informational coherence, speed of application or retrieval, and domain specificity - as well as possibly a somewhat restricted quasi-automaticity - or better: involuntariness - of retrievability.

[1]Schemata can indeed be activated "automatically" by certain traits or even sub-schemata, but since they are not absolutely binding - and also variable - this retrievability need not be understood as "hard-wired", fixed or even genetically pre-designed. To be sure, there are genetically-established primary schemata, but most other schemes are not hard-wired by specific basic hereditary structures.

Thus, we have for this kind of quasi-modularity three characteristic properties, which indeed seem to apply particularly to scheme-representation, pattern reproduction, and schema processing in the cognitive processing areas of the brain. Especially the coherence of processing seems to be important for the classification and processing of information.

Regarding domain specificity: it seems to be true that the application of schemata with respect to sensory modalities is domain-specific. Neuroscientists already established that obviously spatial-visual structures and configurations are normally "recognized" rather and better (especially faster) by certain "centers" of the right brain hemisphere than by the left one. Also, corresponding specific centers are present whose functions can be modeled by using an approach called "connectionism", i.e. by procedural feedback processes of and within networks with repeatedly adjusted weightings for the improvement (reinforcement, stabilization) of links.

Certainly, different forms of memory-like centers are operating. Of course, this is true for all sensory modularities. One also distinguishes, for example, a rather passive receptive memory (which, functionally understood, is still located above the sensorimotor cortex) from the motor memory[2]. In this respect, a domain specificity of schema applications is indeed functioning and important. This arrangement can also be modeled in any action-like scheme-application: The human being as a subject of perception and action is able through its brain to recognize patterns, images, figures, structures etc. The brain is supposedly our best organ of perception, but it is also an organ of action - working very quickly, almost "instantaneously", to "structure" some overall content by patterning it via using schemata, without having to work through the patterns successively and element by element, as a serially working computer would have to do. Thus, the speed of this application of the scheme-formation could be made understandable, which may be explained of course only by a kind of parallel processing operation(s) of the neuronal network structure under "connectionist" guise in the first place. This is not to be grasped by a serial processing like in the architecture of a von Neumann computer. Can this speed of pattern recognition now plausibly be understood this way? Of course, it is model-like - it is an analogue process after all. May it be captured by parallel processing and so-called neuronal networks or be imagined as graspable in the first place? In other words: the thesis of schema modularity in pattern recognition does not refer par excellence to the strict Fodorian modularity of scheme-applications, but to quasi-modularity in the mentioned sense, keeping only the three (or with restriction four) important properties of scheme-formation and application.

In general, however, a kind of plasticity and flexibility is incorporated also in the traditional view of the (almost) automatically running and fixed-wired and mandatory, i.e. binding, scheme applications. We are indeed able to use schemata also flexibly, to apply them and to structure or reorganize our memory in a certain way.

Of course, it is the same with learning. Also there, a "scheme-construct" is first created or "appropriated", formed in interaction with the environment. This seems also characteristic for the fact that we can proceed from a hypothesis of the quasi-modularity of the scheme-application of learning as well as of the memory, whereby of course the genetically grounded (general) possibility of learning is the basis, which however is only partly differentiated in a "fixed" manner. However, there are also areas, where the transient oscillations and the "pathways", the canalized schematization processes similar to the imprinting and priming processes, which ethologists investigated, definitely run in a fixed reflexive way. There are, e.g. reflex pathways that do not even reach the cerebral cortex, because the afferent to the efferent nerves are already short-circuited via a spinal cord ganglion: For example, in the case of the hamstring reflex (patella), one reacts pre- or subconsciously on the basis of this direct reaction circuit: The motor-efferent reflex and the corresponding movement take place immediately, "automatically", obligatorily following the efferent stimulus.

[2]Moreover, many researchers assume different forms and hypothetical activation centers respectively for declarative, procedural, motor, episodic, and pictorial-configural memory, and so on.

One must therefore assume that much of the traditional inherited information is, in a certain sense, genetically fixed as a basic or inborn pattern in humans as well. This of course applies in particular to the perceptual pathways, the visual, auditory, olfactory pathways, etc. and the corresponding locations of the neuronal centers. It should be noted that stimulus processing is quite specific, i.e. no matter how an optic nerve is stimulated[3] - for example, by the famous blow to the eye - the represented result will still be a visual stimulus or a visual sense modality: The person affected (hit) “sees stars”! The same applies to the other sense modalities.

It is interesting, however, that these different sensory pathways are basically all based on the same system, that the transmission “mechanisms” of the brain in the different sensory and cognitive pathways are largely uniform regarding their neural basis. In any case, this is strictly true not only for the neuro-electrical transmission of the action impulses in any neuron, but in principle also with regard to the biochemical transmission for synapse bridging, except that different types of neuro-transmitter substances may play a role here. About 30 different ones have already been identified in the brain, far more than elsewhere in the body[4].

The brain is relatively domain-specific and functionally differentiated, and it is precisely with respect to the applications of schemata formation in memory and learning that it remains largely unexplored. Relatively little is even more known about the processing of higher order cognitions. In fact, cognitive psychologists thus far have only models; they construct model flow diagrams of how, for example, corresponding processing and storage centers function in the brain or in the processing of perceptual stimuli and other higher cognitions. They basically work with merely projected or assumed flow diagrams, directed influences, feedback loops, etc. but at present they are hardly able to make detailed assignments to specific neuronal centers, networks and units, apart from the lower centers up to the visual cortex and up to the reading center[5]. Permanent and in-depth cooperation of neuro-scientists with psychologist is necessary. Thus, for the higher cognitions, what has been said is still to some extent speculative and hypothetical.

But precisely for this reason one may as a philosopher still let one’s speculations play here and try in that sense to tentatively bridge this still existing “gap” - that is, the gap between conscious introspection and the conception of the traditional humanities of how the “mind” and consciousness operate, how we structure our “version of the world” in our cognition and also in action, on the one hand, and on the other hand the neurophysiological and neurobiological correlates or the physiological “building blocks”. Bridging this gap hypothetically in a speculative manner is an important task of a pragmatic, practice-oriented, and science-oriented epistemology and neurophilosophy in general - especially regarding a philosophy of brain and consciousness.

[3]The stimulus is only in some way convertible into the language of stimulus transmission, be it just in the neuron-internal electrical transmission of action potentials or in synapse bridging the transmission by the neurotransmitters.

[4]This fact is very interesting: The brain is indeed the most complicated organ of humans - and not only of them, but the most complicated system we know at all. The Nobel Prize winner Crick claimed (1990, 180) that the most important scientific problem of all is to study the human brain; because our entire worldview and all cognition and action would depend on it. This is perhaps a bit of an exaggeration, for brain research also presupposes certain methodological or scientific-theoretical, indeed certain common-sense presuppositions on its part, which are quasi-philosophical in nature. Basically, one cannot do brain research totally without a world view and without presuppositions. But cum grano salis there is something right about this thesis of the importance of brain research.

[5]However, this may currently change with the further development and finer screening of non-invasive imaging techniques such as PET, nuclear magnetic resonance, etc. [2].

But how can it be imagined in the first place that something is activated or held “in” memory? How are the individual contents anchored neuronally? We know as yet very little about this, especially in the case of higher cognition. But one has tried to develop and investigate physiological storage models in lower organisms. In certain marine nudibranchs (*Hermissenda crassicornis*, also known as the opalescent nudibranch or thick-horned nudibranch, sea slug or “naked sea snail”), comprehensive models (“circuit diagrams”) of the total nervous system and behavioral control could be described and verified in a center- and function-specific manner [3-5] modeling the formation of conditioned stimuli, the stabilization, i.e. the retention of memory contents. Thus, it was found that certain rules could be confirmed, such as those established by the physiologist and psychologist Hebb [6] - for example, that stimuli (nerve cell activations) are permanently linked if they occur repeatedly in close spatiotemporal proximity.

The activation by the conditioned stimulus alone just does not start at the postsynaptic but already at the presynaptic membrane or cell, and leads to the same overall effect. This is quite an interesting result. Alkon found that at the presynaptic cell, and in particular at the dendrites, where e.g. in the conditioned reflex the unconditioned and the conditioned stimulus arrive, something like a local interaction or feedback takes place, which just leads to the fact that the corresponding processes are triggered, which lead to the release of the neurotransmitter(s).

It turned out that many of these learning processes also occur in the same way in higher animals. Obviously, evolution has “worked out” and “preserved” all this quite early and stably. But it also turned out that in vertebrates, in higher mammals, not only a non-Hebbian synapse imprinting occurs, but also a quite narrowly Hebbian one, namely that the presynaptic and the postsynaptic cell must be activated simultaneously for an effect to occur.

So, there is also a Hebbian learning that plays a role especially in higher vertebrates and in mammals, where indeed via other receptors, e.g. so-called NMDA receptors and channels, calcium ions are ejected. Accordingly, in the corresponding cell then the flux of calcium ions to the outside is reduced so that the cell is activated. In this way an activation takes place which goes beyond the postsynaptic membrane and is in particular suitable to excite the excitatory postsynaptic potentials, whereby then in summation over many dendrites a new action impulse takes place in the cell. This is all relatively complicated and rather less studied in relation to higher cognition. But what we can learn from this in our context is that obviously memory contents and in particular, of course, general schematic contents may well be localized (or assigned in a network-like or distributed manner) on a neuronal basis, so that the “anchoring” in the neuronal is that the flow or responsiveness with respect to calcium and calcium ions and corresponding neurotransmitters is reduced or increased - and that in a relatively stabilized form. Thus, in each case, it is a matter of membranes and receptors at the presynaptic or/and postsynaptic junction (in the case of Hebbian conditioning at both). It is the connection between presynaptic and postsynaptic cells that is likely to be pertinent to the specification and changes in memory content changes. Primitive forms of learning, thus can be briefly stated, consists of synaptic receptor and flow changes that are relatively stabilized. It is not entirely clear whether in higher animals and in primates and humans both functions are involved. Thus., presynaptic activation, that is also sometimes called activity-dependent presynaptic gating, is involved. Actually, the very “Hebbian conditioning” or “Hebbian learning” is activated, when the presynaptic and postsynaptic cells are activated simultaneously or nearly simultaneously within a few fractions of a second. Presumably, both also play a crucial role in higher cognition of higher animals.

Back to the mentioned conditioning of the sea slug or “naked sea snail” Hermissenda crassicornis (also known as opalescent nudibranch or thick-horned nudibranch [3,5,7]. For this species its being flung around by waves etc. is the corresponding unpleasant stimulus, i.e. the unconditional stimulus, which is or will be now coupled with the conditioning stimulus “light”. For the slug, light is a signal for the direction of the water surface, where food can be reached. The coupling of the conditioning stimulus to the unconditioned stimulus causes the sea slug, after conditioning, to extend its “prehensile suction foot” to stick to the rock and protect itself from further being flung around. This is the unconditioned response or reaction to the unconditioned stimulus, which after conditioning could also be triggered by the conditioned stimulus, by light alone. In other words, the conditioned slugs now have much lower phototaxis (striving toward light) than they had before the conditioning by the presence of light stimuli. Phototaxis has been reduced by conditioning. This is "associative conditioning", a kind of learning that is now stored in memory. It is relatively stable and habit-forming - and has just a corresponding behavior structuring as a result. We have also here already a "pattern formation" in no longer totally fixed manner, but "semi-fixed", namely in conditioned form.

It is clear that the fixations[6] of complicated schema contents or abstract contents - of course do not only run over single cells, but over whole areas, functional centers, patterns etc. and that such dynamic stabilizations radiate to the corresponding other centers of the brain, i.e. also to the abilities to be localized in different centers of the brain, which can be linked to corresponding processing centers, such as motor or visual-receptor memory.

In general, then, we must assume a decentralized anchoring of functional modules in the brain for the various kinds of memory and processing.

However, this distribution of functions or the distribution of their anchoring is likely to apply much more generally. For example, connectivity and hemispheric partitioning can also be demonstrated for the "anchoring" of schemes in general - and not only for their memory storage. It is quite interesting that in some ways brain research nowadays comes closer to scheme-representation in cognitive psychology, especially also in the philosophical models of constructive processing via interpretations and by corresponding applications, e.g. by the formation and use of schemata. One may even define interpretation in general and the use of interpretive constructs as the formation, application, and activation of schemata with respect to individual cases [8-12]. Again, parallel to the results of basic brain science research, it can be assumed that processing is very modality-specific and just quasi-modular. According to the above-mentioned characteristics, this means that, first, processing is domain-specific, which can already be confirmed empirically on the basis of visual schema formation. Second, flexibility and plasticity are built in and present, as shown for example by the simple models of learning mentioned above. Third, fast pattern recognition and activation can indeed only be imagined by network connections, i.e. on the basis of the modern so-called connectionist neuron models [10,13,14]. Here, a possibility seems to be given that one can somehow imagine the working methods of "instantaneous" pattern recognition, of configurational representation, more plausibly than it was the case so far with traditional computer patterns and metaphors of the serially working type, which could process a program only successively and consequently rather slowly. These network models seem to offer possibilities how to functionally represent higher cognitions and to locate them in a rather distributed way. Obviously different layers of scheme-interpretation are involved, and as already emphasized, the activity or action-orientation of the apparently passive perceptual cognitions and already of the mere receptions, perceptions and in general of the cognitions in the brain are quite corroborated. That only underlines this picture. Again, cognition and thinking are essentially shown as acting on trial, if only virtually, which takes place in the form of activation of the corresponding premotor, supplementary motor and motor centers in the brain.

For example, it is particularly interesting that by radioactively labeled glucose turnover studies and by blood flow monitoring, one had been able to determine that when imagining motor actions - that is, for example, when I do not lift the arm, but only imagine that I am lifting the arm - shortly before, that is, before I consciously wanted to lift the arm, the corresponding motor centers in the frontal brain, which are causally effective for lifting the arm, are already being activated before. Obviously, then, thinking is very much designed for - and by! - action, for activation of the motor apparatus. It is true that, for example, a resting person who is subjected to appropriate blood

[6]And this is also the case with learning, especially with more complex dispositions.

flow tests has a much stronger blood flow to the anterior part of the brain, which is causally effective for the motor activities in question, than to the receptor centers of the posterior part of the brain. Apparently, as authors Lassen, Ingvar, and Skinhøj [15] conclude, at rest the brain is essentially engaged in imagining, planning actions, or the like. Thus, the motor centers are activated even during awake or rest. Of course, this is apparently not true during sleep, although we dream rather actively. In this respect, cognition and thinking - and even dreaming -are very strongly oriented towards and by, if virtual, motor action. That also corresponds to the application of motor schemata ("action scripts").

The overall picture is still somewhat confusing. Especially in view of higher cognitions, brain research has not yet progressed so far that one could now already draw direct epistemological and philosophical conclusions from it. One can at most make explanations plausible in the sense of "how is it possible?" insights, i.e. "explanations" in such a way as one can imagine that the brain or the human being is able to recognize, e.g. a pattern almost instantaneously visually, although a serial computer would need hours for it, if it is built up according to the traditional program form and has to scan everything to be processed. Thus, we can see that to a large extent a decentralized parallel processing first takes place area-specifically on different neural pathways and that only afterwards somewhere in higher centers a uniform representation is integrated, synthesized. The brain is, so to speak, a networking organ of integration, which, however, only integrates relatively late, quite late reunites the corresponding processed, already largely decentralized and analytically breaking up, decompositionally processed stimuli. How this happens now and where this really happens in detail, about this we still know quite little. The integration probably takes place via several stations and parallel pathway interconnections, that seem to start somewhere in the so-called sensorimotor cortical field and then radiate from there into the forebrain lobe of the neocortex and into the motor cortical field and the corresponding executive, again specified areas in front of it, which then set the corresponding muscles in motion. This, at least, has been recorded by activation studies.

The whole development of schema research, be it in psychology, be it in brain research under the name of "brain constructs", as Singer [16] assumes, naturally aims at what one could call an epistemology of construct and scheme formations and (re)activations. Humans as a cognizing and as acting beings are keen to bring his world under certain schematic simplifying patterns. However, these are now represented: as patterns of perception or action-shaped "structurings". Humans are, so to speak, mainly scheme-forming and schema-applying beings. Other animals of course also activate schemata (at least of the primary, but probably also of the similarity-forming and sign-recognizing as well as on a sign-bound quasi rudimentary linguistic level). But humans perform and differentiate all this much more comprehensively, to a considerable extent consciously and in greater plasticity. They can vary the schemata flexibly and adapt their usage to the situation - and above all also: independent of the just present situation! - and can make thereby changes permanently!. They use notoriously and predominantly symbolic (conventional) signs, especially depending on education, culture, language forms etc., which are nothing else than certain rules for the formation of "interpretation constructs" [8,12] and their rule-governed use, controlled by rules which are themselves also interpretation constructs on a higher level.

All of this has led me to believe that my philosophy and epistemology as well as methodology of interpretive constructs, which has been in development for decades, is quite accurately paralleled here and basically confirmed by the recent development in brain research on the one hand and by developments in schema research in cognitive psychology on the other [12,17].

The "graspings" [18] the results of our cognitions are predominantly (scheme-)interpretation-dependent, they are structured by the application of partly innate, partly interactively and culturally developed, partly flexible schemata of interpretation. Thus, we have something like a principle of the interpretation-dependency of all cognition (and action!). That characteristic approach, however, at first essentially gives itself methodologically, but then possibly also refers to the conditions of the possibility of all cognition, thus, speaking with Kant, maybe called "transcendental" - though in a more pure methodological understanding. It is the principle of the fundamental (schema)-interpretation-boundedness or -shaping of all cognition and action. All cognitions and actions are interpretation-dependent, schematized, can only be grasped and understood as such. This refers to all our "graspings", active as well as passive ones. We cannot step out of the firmament of our interpretations. We are not able not to schematize - as we are not able not to interpret ([18], 350). We have no direct access to the (for good reasons hypostatized) external world independently of our interpretations and processes of interpretation and the corresponding constructs or schemata we (have to) work with.

Perhaps one can summarize like this: Our brain is not only our best organ of perception, as the perception and neuropsychologists sometimes exaggeratedly and one-sidedly think, but our brain is also an organ of action - and essentially an organ of integration and interpretation. Our brain is the essential organ with which we deal with the world via interpretation and schematization.

We recognize the world indeed (in double sense!) only insofar as it is our respectively the world version grasped and structured by our brain, just in this sense constructively[7] and actively interpreted. But this is not merely the world, but the world as it is reflected in our "captures" or "graspimgs" [18] constituted and represented by us, thus our constructed and always reconstructed version of the world. The world itself is not given to us directly, but only in the forms and functions of our "graspings" in the form of actions, interactions and interpretations [22-58].

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[7]Even brain researchers say today that the brain is "constructively" active; it is constantly "interpreting," it "interprets" (e.g. according to Singer 1989 [19], Roth 1992 [20], 120 f.) the world - or, rather, a "world version" as an interpretative construct. But is this "directistic" terminology referring directly to "the world" not a deviant use of language anyhow? First of all, it is originally the person, the subject, who interprets. Do we, so to speak, now refer this activity of interpreting merely to the brain? Is the brain - or a homunculus-like part of it - now the agent? Or is this expression "interpreting" then used in a decentralizing, just modular, sense, where one no longer has to immediately assume a central final agent behind it? The latter seems to me right. In any case, these interpretation processes and activities still have to be analyzed in more detail. It is clear that they can only refer to our "apprehensions" and that this has nothing to do with a quasi-idealistic constitution or production of "the world per se", even if brain researchers like Roth ([21], 289) speak, in my opinion somewhat misleadingly, states that "reality . . . is produced in reality by the real brain". Roth, of course, distinguishes between reality (per se) and reality, which could better be called a "version of reality".

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Volume 15 Issue 7 July 2023