AN INTEGRATIVE DEFINITION FOR THE NOTION OF DYNAMIC COGNITIVE SCHEMA

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Abstract. *The paper analyzes, in the first place, the traditional meaning of the concept of cognitive schema in the cognitive psychology. This analysis revealed that a symbolic computationalist paradigm is inappropriate in what respects the interpretation of the main attributes ascribed to that concept on empirical bases. Instead, a dynamic approach is considered to be more advantageous for the understanding of those properties. Therefore, in the second place, the new concept of dynamic cognitive schema is introduced and defined. The traditional properties of a cognitive schema are reinterpreted dynamically and new properties are identified as relevant for the proposed concept.*

Key words: *cognitive schema, schema activation, dynamic systems, dynamic approach, symbolic computationalism*.

There is a particular difficult task to define what the notion of cognitive schema traditionally means because it has been progressively extended in different areas of research and for different purposes. Presently, the notion seems to be almost confounded with the idea of a mental representation having a higher level of abstractedness than the considered stimuli. Still, it has to have some differentiating elements in order to justify its maintenance. Its distinguishing feature seems to be the fact that it is a type of abstract representation having two parts: a fixed one, and a variable one. That feature is conferring it special functions, especially processing ones (generating expectancies, organizing information based on ready made models).

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1. THE TRADITIONAL COGNITIVE SCHEMA NOTION IN THE COGNITIVE PSYCHOLOGY

The traditional idea of cognitive schema occurred out of the need to find a *format of representation between specific experiences and discrete, constant symbolic representations through which memories are organized and expectations are generated*[1] in a more flexible manner. It is linked with the hypothesis that recollection of a memory or the perception of a situation or object are reconstructive processes. In these processes there are involved not only the current stimulation or cues, but also an internal framework (resulted from meeting other similar experiences, by abstracting their invariant structure) that provides a partially ready made organization in order to guide the information recollection or the interpretation of the received stimuli. Therefore, the schema construct was meant to explain the way people generate expectancies in what respects the incoming stimuli and recollect false memories under the influences of such guiding representations. The variable part of a schema was provided[2] out of the need to explain the way the skeleton of a schema is fleshed out with the variable, specific elements of a situation in a particular context or to account for the effects of the unmet expectancies generated by a schema. More generally, it was a way to render understandable the existing obvious flexibility in the way information is represented and processed, without falling into the apparent unacceptable solution that only specific and concrete experiences are stored in the memory. At the same time, it is a point of insertion, of confluence between such a solution, and the other unacceptable solution, that there are only general static symbolic representations which are too rigid to be useful for the adjustment to an environment and to contexts in constant change.

The metaphor of a slot was used in order to express the variable part of a schema as a flexible memory structure. The schema construct was further extended when it was adopted in the action control, and planning research, as a *ready made available organization through which effectors are rapidly and efficiently organized and controlled*, allowing also local and contextual decisions. Here, the schema is *organized around a central element, the general goal of a class of actions*, schemas being differentiated by their goals[3]. It is this version of the schema notion that was taken into consideration in the pragmatic reasoning schemas theory[4].

[1] Bartlett, 1932, apud R. C. Schank, *Dynamic Memory Revisited*, Cambridge, Cambridge University Press, 1999.

[2] R. C. Schank, *Dynamic Memory Revisited*, Cambridge, Cambridge University Press, 1999.

[3] R. P. Cooper, T. Shallice, *Hierarchical Schemas and Goals in the Control of Sequential Behavior*, “Psychological Review”, 113, 2006, p. 887–916.

[4] P. W. Cheng, K. J. Holyoak, *Pragmatic Reasoning Schemas*, “Cognitive Psychology”, 17, 1985, p. 391–416.

Norman and Shallice[5] have suggested a model through which cognitive schemas as passive representational structures become functional in a cognitive process by making appeal to the idea of *schema activation*, without having in mind a particular implementation. In what is named an "activation trigger schema system"[6], each schema is endowed with an activation value, reflecting the total amount of received excitation. The resting activation of a schema is assumed to be zero. This value is increased by excitation, and decreased by inhibition. The activation of a schema is influenced by the activation of other schemas (upwards especially by the "parent" or "source" schema in a hypothetical hierarchy of schemas, and downwards by rival schema, with which it is in competition), and by the satisfaction of the so called "trigger conditions" (referring to the appropriate environmental circumstances for a schema activation). Selection of a schema is made when its activation surpasses a specified threshold. Although such a model includes some dynamicity by defining the schema activation as a dynamic variable (with continuous values that vary in time), and by allowing interactions between schemas through phenomena of cooperation and competition, it has drawbacks in several respects.

2. **LIMITS OF THE TRADITIONAL COGNITIVE SCHEMA NOTION IN THE COGNITIVE PSYCHOLOGY**

Shortly said, the traditional notion of schema is a hybrid version, trying to accommodate both the demands of a symbolic paradigm and the empirical findings. It was elaborated progressively, its properties being added in order to explain dynamic aspects of the empirical findings in various domains of investigations. It is not particularly linked with the symbolic paradigm of cognition, but merely a way of accounting for some empirical findings by grouping them under a unifying label. Miclea[7] emphasized this idea by stating that the existence of the cognitive schema is a postulate, for which only indirect pieces of evidence exist: its effects on the information selection and interpretation. But since the notions of activation, interaction or competition used in the schema theory are hardly compatible with symbolic processes, it is not coherent, remaining a rigid representational format, and, therefore, it has a limited explicative power.

Synthesizing, the main limits of the traditional schema notion in cognitive psychology are:

– It ignores the internal dynamism of a schema, the interactions between its elements;

[5] R. P. Cooper, T. Shallice, *op. cit.*

[6] D. E. Rumelhart, D. A. Norman, *Simulating a Skilled Typist: A Study of Skilled Cognitive-Motor Performance*, "Cognitive Science", 6, 1982, p. 1–36.

[7] M. Miclea, *Psihologie cognitivă*, Cluj-Napoca, Edit. Gloria, 1994.

– It does not specify if and how the activation thresholds are changed. It is reasonable to assume that those thresholds could be also dynamically defined, in dependence with the activation level of other activated schemas.

– There lacks a clear explanation in what respects: a) how default values are acquired and included in a schema; b) how and in what conditions they are substituted with the values provided by a current situation; c) if and how they could change their status, being included in the fixed part of a schema. In other words, the relationship between the variable part and the fixed one has been ignored, remaining still rigid and unfunctional. This problem was, for example, signaled by Shallice[8] who showed that because schemas are provided with a continuum of activation values, then there is no way to draw a clear line between the processes having automatic characteristics from those consciously controlled. Therefore, in his opinion, there is a continuum, not a dichotomy in what respects the automatic-controlled dimension of the cognitive processes. Also, Allport, Styles and Hsieh[9], based on their findings in six experiments in which they tried to explain the task set inertia (a concept equivalent with the cognitive schema notion) have questioned the idea of a fundamental distinction between a controlled system and a separate executive, controller system, with a limited capacity. They pleaded for the need of another metaphor in order to explain their results. Their proposal was the notion of a kind of priming as explicative for what they called to be a "task carry over effect".

– It inherits the general limits of the symbolic paradigm, especially the ones regarding: a) the necessary existence of an external agent who has to make decision regarding the way schemas are built, maintained, changed and operated upon (leading to the peril of an infinite regression); b) the implicit separation between an executive part and a representational part of the cognitive system.

The limits of the symbolic computationalism in given a solid basis for this construct, developed mainly on an empirical foundation were apparent in the effort made by Schank[10] to define a dynamic cognitive schema, generalizing the notion of dynamic script proposed by him. Discussing the scenario notion, Schank[11] has sustained that it implies three important characteristics. The first one is that it is not possible that the content of a scenario to be completely specified, as it is constantly actualized. The second, related with the first one, is that a scenario, as an organizing structure of the semantic memory is something that has a life of its own, being inseparably linked with episodic memories. He thinks that the structures of the episodic memories are identical with the processing structures. Therefore,

[8] T. Shallice, *Multiple Levels of Control Processe*, in *Attention and Performance XV: Conscious and Nonconscious Information Processing*, C. Umiltà, M. Moscovitch (eds.), Cambridge, MIT Press, 1994, p. 395–420.

[9] A. Allport, E. Styles, S. Hsieh, *Shifting Intentional Set: Exploring the Dynamic Control of Tasks*, in *Attention and performance XV: Conscious and Nonconscious Information Processing*, C. Umiltà, M. Moscovitch (eds.), Cambridge, MIT Press, 1994, p. 421–452.

[10] R. C. Schank, *op. cit.*

[11] *Ibidem*.

scripts are viewed to be as dynamic structures, active organizers of the memory. The third one is that a script is like any dynamic memory, defined by him to be a "flexible, open system". He shows that a dynamic memory is not like a library, having a fixed system of classification of the contained information. Such a structure needs an external intervention in order to change it. Therefore, Schank[12] argues that a dynamic memory has to have the property of changing itself, to be able to "self-organize" when new experiences demand changes. His conception of the scenario notion suggesting a dynamic stand is in line with his opinion regarding reasoning. In his view, a case-based reasoning theory of the reasoning is more appropriate since no system using symbolic rules could be functional in modeling mind, as such rules are considered to be inappropriate in characterizing mind processes. Schank[13] seems to have dynamic intuitions, but he lacks the more sophisticated conceptual tools of the present dynamic system approach in order to elaborate them.

The answers sought by Schank[14] are given by Eysenck and Keane[15]. They show that a connexionist approach (an implicitly, by extension, a dynamic systems approach, if we take into account a note made earlier) offers a solution to the main problems that the generic cognitive schema theory has encountered in a symbolic framework: underspecification, and an insufficient flexibility. In accordance with Eysenck and Keane[16], a schema is a general or generic knowledge structure that can be applied to or instantiatiated by many specific situations. It was conceived mainly in order to explain expectancies occurred when people are confronted with recurrent similar situations and their capacity to fill in some missing or missed parts in a perceived pattern. It is like a "prototypical, frame representation in memory"[17] of objects or events. Initially, the structure of a schemata was supposed to consist of various relations (of different sorts) and variables/slots (containing concepts or other sub-schemata), and values for these variables (specific values that fill in the slots). A specific filler of a slot is tested in order to see if it fits with the general type of that slot in what respects its meaning. The slots could be "open" (unfilled), or could be "associated with default concepts that are assumed if a slot is unfilled"[18]. But empirical data (for example, Bower et al., 1979)[19] have suggested that such a structure is too rigid. That is why, Schank[20] revised the schema theory, hoping to gain flexibility and dynamicity by stipulating that a schema has to have a

[12] *Ibidem*.
[13] *Ibidem*.
[14] *Ibidem*.
[15] M. W. Eysenck, M. T. Keane, *Cognitive Psychology: A Student's Handbook*, New York, Taylor & Francis Inc., 2000.
[16] *Ibidem*.
[17] M. W. Eysenck, M. T. Keane, *op. cit.*, p. 256.
[18] M. W. Eysenck, M. T. Keane, *op. cit.*, p. 254.
[19] M. W. Eysenck, M. T. Keane, *op. cit.*
[20] R. C. Schank, *op. cit.*

hierarchical organization on three levels: at the top there is a general goal, at the intermediate level there are sets of actions, and at base there are the actions themselves. But soon it became evident (Rumelhart and Ortony, 1977)[21] that the slot metaphor was insufficient in order to model the empirical findings. Schank[22] himself acknowledged that if variables represented by slots are not allowed to interact with each other, then schema notion has a limited explicative value, especially in what respects the kind of expectancies generated through a schema. The notion of interaction is intrinsically dynamic, even though it could be awkwardly simulated by symbolic processes, in a forced, inefficient, cumbersome and artificial manner. That is why, some prominent theorists (for example, Rumelhart, Smolensky, McClelland, & Hinton, 1986a)[23] "still consider that the intuitive flexibility of the schematic approach has not been realized in any of the present schemes"[24]. For example, Rumelhart and Ortony (1977)[25] showed, too, that what is missing is a specification of the "interdependencies among the possible slot fillers. That is, if one slot is filled with a particular value, that it should initiate changes in the default values of other slots in the schema"[26]. In the opinion of Eysenck and Keane[27], this useful and important characteristic of schemata was never realized in the classic schema theories, built in a symbolic computationalist theoretical framework. However, a solution for this problem was proposed by Rumelhart et al. (1986)[28] from a connectionist point of view, being able to encode schema type knowledge into a connectionist network (based on which many empirical findings were reproduced). The connectionist schema concept was summarized by Eysenck & Keane as it follows: "Schemata emerge at the moment they are needed from the **interaction** of large numbers of parallel processing elements all working in concert with one another. In this scheme, there is no explicitly represented schema, but only patterns of activation that produce the sorts of effects attributed to schemata in previous research. When inputs are received by a parallel network, certain coalitions of units in the network are activated and others are inhibited. In some cases, when coalitions of units tend to work together, the more conventional notion of schema is realized, but when the units are more loosely interconnected, the structures are more fluid and less schema-like"[29]. In that way, it is admitted[30] that not only the flexibility problem is solved, but also, the

[21] M. W. Eysenck, M. T. Keane, *op. cit*.
[22] R. C. Schank, *op. cit*.
[23] M. W. Eysenck, M. T. Keane, *op. cit*.
[24] M. W. Eysenck, M. T. Keane, *op. cit.*, p. 257.
[25] M. W. Eysenck, M. T. Keane, *op. cit.*
[26] *Ibidem*.
[27] *Ibidem*.
[28] *Ibidem*.
[29] M. W. Eysenck, M. T. Keane, *op. cit.*, p. 257.
[30] M. W. Eysenck, M. T. Keane, *op. cit*.

underspecification issue, given that Eysenck and Keane[31] believe that its solution lies in showing how schema structures are acquired by combining different selected experiences. Learning in connectionist networks seems to them to be a promising modality to specify the way schemata acquire their contents in a remarkable manner, without the need to specify those contents. Beyond the fact that recurrent neural networks are dynamic systems, since in a connectionist version of the schemata, slots are permitted to interact, being interdependent, the similarity with the idea of dynamic variables interacting in a dynamic system (that is variables whose evolution in time is reciprocally dependent on the evolution in time of other variables with which they are linked) is apparent. So, synthetically speaking, the most successful models in implementing the schema notion were the connectionist ones (Rumelhart, Smolensky, McClelland, & Hinton, 1986)[32], i.e. associative networks having an elementary dynamicity, as it was the case for the *prototype notion*. In fact, the schema and prototype notions share the same underlying idea and were defined for similar purposes. Only that the schema notion is bound more with the research tradition regarding memory, action control and planning, and prototype notion with the research regarding perception and categorization.

3. DYNAMIC COGNITIVE SCHEMAS AND THEIR PROPERTIES

3.1. DYNAMIC SCHEMA AS A DYNAMIC REPRESENTATION

In the first place, a dynamic schema has all the usual properties ascribed to a dynamic representation. The most important one is that *it corresponds to a state or a set of states from the state space of a dynamic system*[33] *defined by their stability, and having a representational function*[34] *by its dynamic coupling*[35] *with the*

[31] *Ibidem*.

[32] R. P. Cooper, T. Shallice, *op. cit.*

[33] A ***dynamic system*** is a system composed of one ore more *dynamic variables* (variables changing in time) that reciprocally interact in real time (the change in time of a variable's value is dependent on the change in time of the other variables' values) and the so called *control parameters*, values of some external variables who control the interactions between the dynamic variables. They are included as constant values in the system of (differential or difference) equations describing the way the dynamic variables interact (in which the dynamic variables appear as unknown variables).

[34] The stable state is said to represent in an abstract manner the external situations corresponding to all its neighboring unstable states within its attractive range, because the dynamic system clusters them in what seems to be like a category (because all those states are similar), by virtue of its intrinsic dynamics. In fact, the category is represented at the level of the entire attractive region of a stable state, usually having fluid borders, and the stable state itself is what was traditionally named to be the prototypical case or a well-formed gestalt.

[35] Two *dynamic systems are* ***coupled*** when at least one dynamic variable of a system is control parameter for the other one.

external represented systems. *Stability* of a representation is a functional property, derived from the intrinsic dynamics of the underlying dynamic system. A state (or a set of states) is said to be maximally stable if it has an *attractive power*[36]. It is reasonable to think that a cognitive schema, as an abstract representation, could be put in relation with the stable states or sets (configurations) of stable sets of a dynamic system.

3.2. THE DYNAMIC INTERPRETATION OF THE PROPERTIES OF A COGNITIVE SCHEMA AND ITS NEW PROPERTIES

3.2.1. *The structure composed from a fixed part, and a variable part*

From one perspective, *the variable part of a schema* would correspond to the dynamic variables and to the unstable states from the attractive region surrounding the stable states[37]. *The traditional fixed part* would correspond to the dynamical law governing the interaction between the dynamical variables (including the control parameters), and the stable states themselves (to be noted, although, that in a dynamic interpretation that part is not actually fixed, but only stable)[38].

3.2.2. *Stability of a dynamic schema*

This property lacks in a symbolic account of the schema notion.

More precisely, on the one part, stability of a schema means:

– that the *actualization of a schema is differentially resistant to noise effects*: different intensities of noise (disturbing, unspecific stimuli or changes in the control parameters) are needed in order to move away a dynamic system from a stable state correspondent to a cognitive schema to neighboring states (states from the state space having a partial resemblance to the sate of the cognitive schemata). When a system is moved from the state of a schema to a neighboring one, phenomenally it may appear as if that schema is partially actualized, with only a few of its elements.

[36] ***Attractive power*** of set of states means that a system tends to autonomously evolve towards them when it is placed in another state or it tends to return spontaneously to them if it was displaced by external influences when they cease. The evolution of a system towards the nearest stable state is like an answer given by him to those external influences that placed him in an unstable state (which might be conceived to correspond to an unlearned, unknown stimulus or to a more particular stimulus).

[37] They correspond to configurations of values ascribed to the variables of a schema (named slots), but in this case those variables are allowed to interact dynamically.

[38] The values defining those stable states will be the ones that correspond to the *default values* of a schema. In that way, it is given an explanation both for the origin of the default values of a schema, and for the power of the expectations generated through them to replace the actually received stimuli, which lacks in the traditional symbolic paradigm. In this perspective, the schema is represented through a dynamics, not at the level of a dynamics.

– the *power of a schema to attract back the system into its region*, reflected in the: a) *speed of this return*[39] and b) in *the size of the region from the state space within which such an attractive power is exerted* (how dissimilar a distant state must be from which the system still tends to evolve toward the states of that schema). In traditional terms, it would mean the number of indices (cues, features) needed in order to actualize a schema, if those indices are interpreted as the common part between an initial state and the final schema state.

– when it represents a stable set of states (cyclic or chaotic attractors), *a more or less regular pattern of fluctuations in time of its states, resulting phenomenally in the occurrence or the disappearance, at more or less regular time intervals, of some of its elements*.

3.2.3. ***Generation of expectations***

The property of a traditionally defined schema to generate expectations and inferences[40] is dynamically ascribed for a dynamic schema:

– to the existing interactions between the variables included in its underlying dynamic system. In other words, *a dynamic schema is a way to decrease the number of freedom degrees defining the state of a system or through which its behavior could be controlled*. The fact that the value chosen for the first variables finally determines the unknown values for the remaining ones gives a way to *dynamically interpret the classical property of a schema to organize the interpretation of the incoming stimuli based on the ones already received*.

– to the idea of *emergent properties* in complex dynamic systems that have several levels of organization[41]. These properties are behaving in relation with the component systems as new control parameters, named *order parameters*. Through these order parameters, the behavior of the component systems could be controlled,

[39] Stability of a state is less clearly reflected in the *time needed to reach that state* because two factors are involved, with opposite effects in that respect. Those factors are the breadth and the depth of the region from the state space within which the respective stable state exerts an influence, i.e. it has an attractive power. Both are important in defining the speed with which a system will evolve toward the considered stable state, reflected in the slope of the trajectory followed by the system. Still, the time needed to reach a stable state from an initial state may serve as an index of the distance or the similarity between the two states. Especially its evolution is important as an index for the changes occurred in the dynamics of the underlying system under the influence of the control parameters. If through these changes, the stability of the stable state is increased (as in learning) even more, that time is shortened. If stability decreases (as in forgetting), that time is increased.

[40] M. Miclea, *op. cit*.

[41] By being dynamically coupled, several dynamic systems form a new one, with superordinate stable states in a new multidimensional state space, having as coordinates all the coordinates of the component systems. The behavior of the resultant dynamic system has properties emergent from the properties of the dynamical behavior of the component systems, describing its state, but it is not possible to reduce them in any understandable way to those precursor properties. That is why they have an irreducible novelty in comparison with the existing, known properties.

"enslaved"[42]. In other words, order parameters of a supraordinate schema impose an organization onto subordinate schemas, and from such constraints, expectation are generated. It is a property recognized in the traditional cognitive psychology[43], but which is hard to be understood in a symbolic framework.

3.2.4. *The hierarchical organization of the schemas*

At their turn, the order parameters could be included as dynamic variables into another new dynamic system. Therefore, the system in which they emerged becomes through them dynamically coupled with the new one. This could go on in the same manner to new higher levels of organization.

3.2.5. *Schema priming*

A schema, also, could be dynamically thought to be primed or to prime other schemas, as it was traditionally suggested (especially in task switching experiments in which tasks or intentional sets are thought to be schemas).

The notion of priming is more naturally accountable in a fully dynamic approach as signifying *the fact that the previous stimulation brings a dynamic system in the proximity of the attractive region of a stable state corresponding to a schema*[44]. So, the chances that that stable state to be reached are increased, and the distance to be traveled in the state space toward it decreases (and, correspondingly, the evolution in time toward it).

It is understandable then why, generally, *a primed schema is more readily actualized, in a shorter period of time, and with a higher rate of success*. On the other hand, if a system is destabilized from a stable state corresponding to a schema, the chances to arrive to another stable state (i.e. the actualization of another schema) are increased if the other stable state is closer to it in the state space. *In that sense, the first schema could be considered to be a prime for the second one*.

3.2.6. *Schema activation vs. schema actualization*

To the notion of activation of a schema, the correspondent dynamic concept would be the notion of schema actualization. That change is justified by a change of perspective.

From a dynamically point of view, a schema, as a stable state, is always indirectly active, having the potential to influence the behavior of its underlying

[42] The behavior of a dynamic system is "enslaved" in the sense that it is driven away to other states from its state space than the ones toward which it would have had evolved if it were not coupled with other dynamic systems.

[43] M. Miclea, *op. cit.*

[44] R. Ferber, *Cognitive Dynamics – Dynamic Cognition?*, in *Iteration Theory, Proceedings of the European Conference*, Singapore, World Scientific, 1996, p. 65–76.

dynamic system by its attractive power. But it is not always *actualized, in the sense that the system is not always in a state from its attractive range of states*. In fact, *only the dynamical variables of a system are constantly active, and a stable state in its space is properly a virtual structure*. What traditionally means to increase the activation of a schema it would rather correspond to a change in its attractive power or to a reduction of the distance between the current state of the underlying dynamic system and the stable state of the schema. The so called activation threshold of a schema would correspond to the borders of the attractive range of its stable state, thus receiving a natural accounting of its occurrence and possible change. Moreover, in the traditional accounts of schema activation, the process is not clearly defined. It usually means that it has an additive nature, a schema being activated when the weighted sum of the activation values of its elements surpasses a given threshold (they are not allowed to be changed by an internal interaction between those elements). But the origin and the meaning (from an operational point of view) of that threshold have not been plainly stated. Some authors[45] believe that there is no such threshold, and that the activation of a schema is continuous, not an all-or-none process.

In a traditional account, also, specifications in what respects the idea of partial activation are lacking. The activation being an additive process, it seems that no distinction could be made from an operational point of view between the case in which all the elements of a schema are equally poorly activated and the case in which some of its elements are intensely activated and others not at all activated. In a dynamical perspective, instead, it is predicted that no matter how increased is the activation level of an element, if it surpasses a certain threshold (given by the boundaries of the attractive domain of a schema), it would not lead to the actualization of the considered schema, even though the general threshold is met by summing all the activation values.

Also, for the assumed *interaction* or *competition* between the virtual, actualizable, schemas, there is no plausible mechanism through which they are symbolically rendered on a large scale[46]. From a dynamic point of view, when a schema is interpreted as a stable dynamic structure of a dynamic system, *the competition between schemas occurs when that dynamic system allows the simultaneous existence of several stable states in its state space*. Differently stated, it means that it is bi-[47] or *multistable*.

[45] T. Shallice, *op. cit*.

[46] If the interaction between schemas is realized not by a direct contact, in real time, but indirectly, by a symbolic transmission of information regarding the activation state of a schema to another one, there is bound to occur soon a computational explosion. That is why the schema notion was more successfully implemented in connectionist dynamic networks, by distributed representations.

[47] A well known case of such bistability is the case of an ambiguous figure where two interpretations (or schemas of organization for the given sensorial stimuli) are mutually competing.

In a dynamic interpretation, a *partially actualized* schema would correspond to a state from the neighboring region of the stable state corresponding to that schema. It may be a transitory, unstable state, from which the system will evolve toward a more stable one.

3.2.7. *Schema selection and change, schema inertia, schema biases*

In what respects the *transition from an actualized schema to another one*, it could be made in two ways:

– by *a change in the values of the dynamic variables* of the underlying dynamic system trough the internal dynamics or an external intervention.;
– by a *change in the values of one or more of the control parameters*.

In this last case, the *hysteresis phenomenon*[48] is possible to occur, explaining dynamically the known phenomenon of the *inertia of a schema*, manifested, for example, in the effects of a mental set. These effects are poorly accountable from a symbolical point of view[49].

The *selected schema* at a certain moment is the one that wins the competition with the others in a particular context (*defined* by the *initial state of the underlying system*, the *configuration of its control parameters,* and by the *recent actualization history* of the schema). Therefore, there is no imperious need of an external, executive instance in order to select an appropriate schema.

3.2.8. *The effects of learning on schema actualization*

A symbolic account of a cognitive schema also lacks a clear stipulation of the effects of an increased learning of a schema on its activation and operation[50]. At most, it could be said that the activation threshold is somehow decreased by learning. But that would lead to an increased vulnerability to noise, which is not what is expected to happen by learning.

Instead, in a dynamic account, by learning, in a first case, the *stability of a schema is increased*[51].

[48] *Hysteresis* occurs when, by changing control parameters, a stable state continues to be actualized because it has recently been actualized, even though for the new values of the control parameters other stable states should have been actualized if it were not for its recent actualization.

[49] As it was noticed before, the priming explanation is not in itself sufficient, and it is not ultimately symbolically accountable.

[50] P. Burgess, R. Cooper, *The Control of Thought and Action*, in *Cognitive Science: An Introduction*, D. W. Green and Others (eds.), Oxford, Blackwell Publishers, 1996, p. 340–368.

[51] The consequence is that *it becomes more easily actualized, and it is harder to be destabilized by a disturbing noise*. Dynamically interpreted, the more stable a schema is, and, implicitly, the more well-learned, the *fewer are the needed cues in order to be actualized* and *the less increased their intensity*. The argument is that a stable state of a well-learned schema has a broader attractive domain in the state space and an increased attractive power. Consequently, more dissimilar actualized states in comparison with the stable states of a schema will lead ultimately, trough the evolution in time of the underlying system, to the actualization of that schema.

In a second case, learning means *to dynamically couple or to increase the intensity of the dynamic coupling between the variable elements* of a schema[52].

3.2.9. ***Types of schemas with different levels of complexity***

When a schema is *more complex*, surpassing the concept level, especially when it is meant to represent a class of events or actions, from a dynamical point of view, it should mean that it includes besides states more or less regular transitions:

– between states (i.e. trajectories between states) within a limited stable region of states (as it is the case with a cyclic, or chaotic attractor region), or;
– between one stable region to another one (as it is the case of chaotic itinerancy). It is a way to dynamically account for the schema notion when it signifies a rule or a set of rules, as it has been traditionally defined in some cases;
– between a dynamic structure characterizing a whole state space of the underlying dynamic system[53] to another one, through a change of one or more of its control parameters[54].

When a schema is put in relation with the dynamic structure of the whole state space of its underlying dynamic system, it could be said that it is a *schema of schemas* (the subordinate schemas being all the sets of stable states from that state space)[55]. At the same time, such a case shows that there are schemas that could be *actualized by changing only some values of their so called "constant" part (i.e. control parameters),* and that *their actualization would trigger the simultaneous actualization of a whole set of subordinate schemas*.

3.2.10. ***The effects of the recent past on schema actualization***

The most important change of perspective introduced by a dynamic perspective is the importance ascribed to the temporal context or to the recent past history in the evolution of the underlying dynamic system in determining the actualized schema in a certain moment of time. Recent history determines the future evolution of a dynamic system in several ways:

– if a system has been recently in a region closer to a stable state than to another one, the chances that finally the system will be stabilized in the first one are increased.

[52] Therefore, as they are more tightly related, it would be sufficient to know or to set the state or the value acquired by only a few of them in order that the others to be obtained by virtue of the constraints internally generated by their mutual interaction. Stated in more traditional terms, the more learned a schema is, the fewer are the needed triggering cues for the actualization of that schema.

[53] It comprises all the attractor regions together with their borders and position, i.e. the structure of attractors for a given configuration of the values of the control parameters.

[54] Such transitions could be catastrophic ones: sudden, unexpected, and leading to a qualitative change in the behavior of the underlying system.

[55] It is another way in which schemas could be envisioned to be hierarchically organized.

– when a schema is represented by a cyclic set of states, the determination of the value of one of its variables at a certain moment in time (when the values of the other ones are known for that moment) will also depend on the recent direction of evolution of the system within the set of stable states.

– the dynamic structure (or schema of schemas) in which a dynamic system will be stabilized when a control parameter is changed will depend on the recent values taken by that control parameter, i.e. on the direction and the continuity of the change of that control parameter.

Phenomenally, the effect of the recent past on a schema actualization leads to the expectation of *the occurrence of order effects* in what respects the previously actualized schemas or triggering cues for a schema.

3.3. A SYNTHETIC DEFINITION OF A DYNAMIC SCHEMA

Trying to give a synthetic and intuitive definition for the notion of dynamic schema, I will use the more familiar and concise term of pattern, since a pattern, as a configuration of values, is conceived to correspond to a point in a state space[56].

Taking into consideration the above mentioned note, the resultant definition is:

A dynamic cognitive schema is simultaneously a representational and processing structure that resides in a temporal pattern (configuration) of patterns, endowed with a degree of stability in time, placed at a higher level of abstractedness (a higher spatio-temporal scale, in which the degrees of freedom are decreased) and through which expectations are generated by dynamic processes of pattern completion involving the stabilization of a dynamic representational system into that pattern[57].

3.4. CONCLUSION

A dynamical point of view brings to the research focused on the cognitive schema notion a natural and coherent way to conceive its necessary and defining flexibility, or dynamism. It succeeds that by providing underlying processes of a dynamic type that does not restrict a schema dynamicity by forcing it into an unfit symbolic framework. Apart of an external dynamism (at the level of the interaction between schemas), which could be symbolically simulated in an awkward, cumbersome, manner, a dynamic approach endows a cognitive schema with an internal, essential, intrinsic dynamism that is lacking in its symbolic interpretation.

[56] P. Gärdenfors, *How Logic Emerges from the Dynamics of Information*, in *Logic and Information Flow*, J. van Eijck, A. Visser (eds.), Cambridge, MIT Press, 1994, p. 49–77.

[57] Stated differently, it means that a dynamic schema represents a set of states from a space of possibilities that is endowed with a temporal structure (i.e. temporal order) by virtue of an underlying dynamics defined on that space.