The Mind of a Visionary: The Morphology of Cognitive Anticipation as a Cardinal Symptom

Fabián Labra-Spröhnle

"Morphology is not only a study of material things and of the forms of material things but it has its dynamical aspect, under which we deal with the interpretation, in terms of force, of the operations of Energy."

D'Arcy Wentworth Thomson. *On Growth and Form, page 19*

Abstract The Soviet neuroscientist and clinician Alexander Romanovich Luria was a visionary. He was endowed with an superior capacity for synthesis, building bridges across divides thus advancing new paths. This paper is a stroll along some of those paths, with a twofold purpose, to present a summary of some of Luria's fundamental notions and to update them according to our clinical intentions. The concepts of "function", "functional systems", "functional units", "anticipation" and "symptom" are revisited. In particular, the concept of "executive function" is precised by a new theoretical definition, based on the original sources used by Luria to build his notion of "functional systems". This new definition of executive functions is summarized, operationalized and articulated with the notion of "symptom", also proposed by Luria. Finally it is suggested that the morphology of cognitive "anticipation", enacted by inferential processes, could be used as a cardinal sign to assess executive functions.

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1 Introduction

The Chilean writer Antonio Skármeta wrote in his play, “The Postman”, that “poetry belongs to those who use it, not to those who write it”. This paper is about a similar kind of appropriation, in which some of the notions of the Soviet neuroscientist and clinician Alexander Romanovich Luria (1902-1977) are glossed and used for our particular purposes.

Without exaggeration it can be said that, A.R. Luria was a visionary. His theoretical and clinical work anticipated a presently widespread concept, that he did not name, i.e., “executive functions” (EF) [14]. Moreover he identified some related neurodevelopmental disorders; for example: “cerebro-asthenic syndrome” [28] [23] [12], which in our present days is labelled as, “attention-deficit/hyperactive disorder” (ADHD) [16].

2 Function, Functional Systems and Executive Functions

Most contemporary clinicians and scholars looking at ADHD and EF turn back to Luria’s work when looking for the original sources of the concept of EF, [14][8]. Because of Luria’s dialectical and systemic thinking, his thoughts, have been difficult to grasp for most of those scholars who are trained under the all-embracing, reductionist and positivist paradigm. This situation has hindered for many years the inception of a parsimonious and operational definition of EF.

Russel Barkley, in a lucid review, pointed out several drawbacks of lacking a proper definition of EF. He has thoroughly described the major theoretical and practical disadvantages of this situation [8].

One of the main confusions in interpreting Luria’s concepts, is due to the way he uses the term “function” and “functional system”, which have yet not been fully understood up to this day; despite all the warnings already made by him regarding this point [26] [27].

2.1 Luria’s trilogy: the origin, the structure and the localization of Functional Systems

The particular meaning of the term “function”, that Luria wished to call the attention,

> denote a complex adaptive activity of a whole system and sometimes of a whole organism, establishing certain relationship with the external environment and producing some form of adaptive effect [25].

Luria gave some examples like, the “function” of respiration or digestion. Function in this sense is:

> the complex result of the work of an entire *functional systems*, the links of which may be interchanged and which employing different intermediate stages, preserves the constancy only of its final effects [25].

"Functional systems" in Luria's framework is the result of a complex, but very precise theoretical synthesis, that conflates three complementary and inextricable aspects: the first one, is related with the genesis and development of FS which is based in Vygotsky's notions about the sociohistorical and developmental origin of higher forms of psychic activity [24] that are built from external activities mediated by tools, specially, language [49]. The second aspect makes reference to the systemic organization and mechanics of FS, based on Anokhin and Bernshtein's "Theory of Functional Systems"(TFS) [6][9]. The third aspect deals with the localization of FS, based on Filimonov principle of "graded localization of functions". This principle conveys the idea that no "formation of the central nervous system is responsible for solely a single function" [27]. Luria explains that according to this view:

> a function is, in fact, a functional system (a concept introduced by Anokhin,) directed toward the performance of a particular biological task and consisting of a group of interconnected acts that produce the corresponding biological effect. The most significant feature of a functional system is that, as a rule, it is based on a complex dynamic "constellation" of connections, situated at different levels of the nervous system, that, in the performance of the adaptive task, may be changed with the task itself remaining unchanged.[27]

Luria applied this notion to cognitive processes, depicting them as complex functional systems:

> that they are not "localized" in narrow, circumscribed areas of the brain, but take place through the participation of groups of concertedly working brain structures, each of which makes its own particular contribution to the organization of this functional system *[26].*

With regards to the functional organisation of the brain, Luria distinguishes three principal *"functional units"*, whose participation is necessary for any type of mental activity, i.e.:

1. A unit for regulating tone or waking
2. A unit for obtaining and storing information arriving from the outside world
3. A unit for programming, regulating and verifying mental activity

The third unit is involved in what is presently called "executive functions".

The role of the third "functional unit" has been used by several scholars as a departure point for creating their definitions of EF. Notwithstanding, more than 30 different definitions of EF has been given to date. Nevertheless, the main drawback of these definitions is their ad-hoc, extensional nature, and poor or null operational character [30].

Acknowledging these problems, and with practical intentions, I have introduced a theoretical definition of EF based on Luria's notion of FS, by exploding the concept and exploiting its original sources. Here I would like to refer the reader to a previous paper, for a detailed account of that endeavor [1]. In summary it can be said that:

This definition of EF is re-linked to the original sources of the concept, paraphrasing Anokhin: executive functions are any of ***"those specific mechanisms of the functional system which provide for the universal physiological architecture of the behavioral act"*** [6].

The correct understanding of this definition requires the knowledge of "those specific mechanisms" and their interdependent operation as was depicted by Anokhin. The advantage of this "intensional" definition, is that it allows for the parsimonious linking of all of those mechanisms with a systemic organizational principle, within a theoretically sound framework. Additionally, this definition, that not only explains EF, could serve as practical methodological guidance for further exploration, becoming a heuristic tool.

In the same paper mentioned above, the heuristic power of the former definition has been shown by linking Anokhin's TFS with the inferences theory proposed by Peirce and Piaget [40][38]. These means allowed, conveniently, for this definition to be summarised and further operationalized, thus permitting the assessment of EF [2].

3 Cognitive Anticipation

Human cognitive anticipation is defined as, "future-oriented action, decision, or behaviour based on a (implicit or explicit) prediction" [33]. Luria was one of the first neuroscientist to fully acknowledge the radical importance of the anticipatory and proactive functioning of the human brain, or as he put it:

> It has become abundantly clear that human behaviour is active in character, that it is determined not only by past experience, but also by plans and designs formulating the *future*, and that the human brain is a remarkable apparatus which cannot only create these models of the future, but subordinate its behaviour to them. It has become evident at the same time that recognition of the decisive role played by such plans and designs, these schemes for the future and the programmes by which they are materialized, cannot be allowed to remain outside the sphere of scientific knowledge, and that the mechanisms on which they are based can and must be the subject of deterministic analysis and scientific explanation, like all other phenomena and association in the objective world. [26]

[1] Labra-Spröhnle, F.: *Human, All Too Human: Euclidean and Multifractal Analysis in an Experimental Diagrammatic Model of Thinking,* paper presented at the session: Anticipation in biological and physiological systems; to be published in the volume titled, "Anticipation Across Disciplines", M. Nadin (Ed.), Springer Verlag.

[2] Ibíd.

Luria's notion of anticipation (as an integral part of higher mental functions) entails all the three constitutive theoretical sources he used to build on his notion of FS. These sources account for the origin, development, structure and localisation of FS. Briefly:

1. Origin and development: All living beings are endowed with anticipatory capabilities [35] [2], that have an organic origin, but human cognitive anticipation is grounded in mediated mental activities of a sociohistorical origin. As Vygotsky put it:

> The first law of the development and structure of higher mental functions which are the basic nucleus of the personality being formed can be called the law of *the transition from direct, innate, natural forms and methods of behavior to mediated, artificial mental functions that develop in the process of cultural development*. This transition during ontogenesis corresponds to the process of the historical development of human behavior, a process, which, as we know, did not consist of acquiring new natural psychophysiological functions, but in a complex combination of elementary functions, in a perfecting of forms and methods of thinking, in the development of new methods of thinking based mainly on speech or on some other system of signs. [48]

Stressing this framework, elsewhere Vygotsky pointed to the importance of speech in forming anticipatory action plans.

> As speech becomes an intramental function, it begins to prepare in verbal form a preliminary solution of the problem which, in the course of our further experiments, is improved and, from the speech model that summarizes what has been completed, it is converted into preliminary verbal planning of future action.[50]

Last but not least, Vygotsky remarks that, the affective character of emotions make up a special system of anticipatory capabilities in living organisms:

> the emotions have to be considered as a system of anticipatory reactions that inform the organism as to the near future of his behaviour and organize the different form of this behaviour [47]

This anticipatory role played by emotions, as it was noted by Vygostky (that have a precise place in Anokhin theory of FS, as one of the major contributions to the stage of "afferent synthesis), has been commented by some contemporary scholars [17] [20] [21]. These comments are very much in line with some speculations about the goal-oriented nature of emotions in the "dynamic systems" approach to cognition [13].

Anokhin noticed the importance of emotions in providing the means for a fast and persistent evaluation of the quality of external influences. Emotions anticipates and selects the optimal conditions for the survival of the organism [3].

2. Structure: the structure of cognition and behavioural acts is based on Anokhin and Bernstein's theory of FS [5, 9]. According to Anokhin, the sequence of stages of operation of a FS can be summarised as follows:

1. Preparation for decision-making (afferent synthesis),
2. Decision making (selection of an action),
3. Prognosis of the action result (generation of acceptor of action result),
4. Generation of the action program (efferent synthesis),

5. Performance of an action,
6. Attainment of the result,
7. Backward afferentation (feedback) to the central nervous system about parameters of the result,
8. Comparison between the result of action and the prognosis [6].

Cognitive anticipation is a result of the integrative operation of all these stages of a FS. From a regulatory and control point of view, anticipations are always coordinated with guessing and evaluative operations.

3. Localisation: Luria pointed out the third "functional unit", i.e., the unit for programming, regulating and verifying mental activity, to be responsible for anticipatory operations. Furthermore he localised them, not exclusively, but mainly in prefrontal areas of the brain. This notion has mistaken some scholars, leading them to conflates EF with the operations of the prefrontal areas of the brain.

4 Luria's Concept of Symptom

When Luria was addressing the question of the brain localization of human mental activity, he did an insightful review about the concept of "symptom" [26]. From this review he concluded that:

> If mental activity is a complex functional system, involving the participation of a group of concertedly working areas of the cortex (and sometimes, widely distant areas of the brain), *a lesion of each of these zones or areas may lead to disintegration of the entire functional system, and in this way the symptom or "loss" of a particular function tells us nothing about its "localization"*. [26]

To overcome this situation, Luria suggested that once a symptom had been identified the next step was to perform a:

> *detailed psychological analysis of the structure of the disturbance and the elucidation of the immediate causes of collapse of the functional system* or, in other words, a *detailed qualification of the symptom observed.*[26]

This suggestion is meaningful, but at the same time has certain limitations imposed by the tools used to obtain such a *"detailed qualification of the symptom observed*". In a current clinical scenario this task is performed during the clinical examination by means of the direct observation of the patient's behavior and his or her verbal description and qualification. The feasibility of this task is not at risk when the sign or symptom can be properly described and qualified in verbal terms, but if the nature of the symptom is resistant to accurate verbal description, the task cannot be achieved. A common way to deal with this kind of situation is by using complementary clinical exams and psychological testing.

Nevertheless, it should be acknowledged that there exist certain disorders, which by the nature of their symptoms, are resistant to both, verbal descriptions and complementary exams qualifications. This is the case of some symptoms, that have a dynamic character, which are particularly difficult to deal with; good examples can be found in EF related disorders, like ADHD. In this clinical scenario the verbal descriptions of symptoms are very rough and imprecise, moreover all the actual complementary tests are of a very reductionist character, and which are mainly focused on performance [10] [41] [29].

Continuing with Luria's ideas, once again, he remarked that:

> The investigator's immediate task is to study the *structure of the observed defects and to qualify the symptoms*. Only then, by work leading to the *identification of the basic factor lying behind the observed symptom*, it is possible to draw conclusions regarding the localization of the focus lying at the basis of the defect.[26]

What Luria means by "factor" is in part related to the statistical procedure of "Factor Analysis" (developed by Spearman and Thurstone) [25]. Notwithstanding, Luria noted the limit of this kind of statistical procedure in unveiling the so-called factors. To surmount these limits, Luria advocated for a complementary analysis of the symptoms produced by local brain lesions, namely "syndrome analysis", i.e., the analysis of a set of "symptoms-complexes".

It is important to comment that, when the "basic factor" to be identified has a conspicuous, structural and static character, the task should not present major problems. But it could be the case that the "basic factor" is not dominated by a static and discrete structural character; let's say for example, that it has a main "conative character"[3] or "affective character" [15] (following Piaget, I will call them both, "energetic characters"[37]). In this situation the identification of the basic factor could become an elusive riddle. Luria was aware of these kind of situations and he elaborated on these problems in a couple of papers, one published in 1958 and the other in 1959 [22] [23], were addressing these energetic factors, he wrote that:

> In some cases it is the elementary nervous processes which constitute this defective link; the disorganization of the force, equilibrium and mobility of these nervous processes may from the very outset greatly impede the further development of the activity of the child. [22]

To further explain these "energetic factors", I will use a very simple example taken from car mechanics: Let's consider the following malfunction, where a car is not running smoothly, having excessive vibration and intermittent loss of power. From these symptoms, the mechanic's first thought is that the problem is related to some structure of the engine. He could explore this hypothesis by a quick visual inspection of the engine; moreover he may assume that the fault is due to an electric malfunction of a spark plug connector; as a result, he would clean the connectors and plug it in again. If after this maneuver the problem persists, and before engaging in more thorough inspections of the engine, he will explore some "conative or energetic" related causes. He will ask you, "what kind of petrol did you put in the tank?" and he will review the quality of it by taking a sample from the carburetor. Since, for example, it could be the case that the petrol became contaminated with water. Let's

[3] I use the word *conative* as it is used by J.M. Baldwin, meaning: those active dispositions or impulsive-appetitive and tendency processes of a vectorial nature (conatus in Spinoza's sense [42]); *"that furnish the context, the means of selection, the leading factor in the determination of the object"* of cognition [7].

say that this was the cause of the problem. This cause is what I would like to call an "energetic factor", that is not of a structural character.

Sometimes, "energetic factors" are not so easy to identify in brain functioning, as would be a mechanical failure of a car. I must warn the reader therefore, that, "energetic factors" in cognitive brain functioning should not be simply and solely equated to the fuel of a car, like in our example.

The "energetic factors" mentioned above, are related with the power that propels behavior and cognition in two isomorphic realms, as it is described under a psycho-physiological parallelism framework [34], i.e:

1. The causal energetic factor in physiological and behavioral terms as it was pointed by Luria above.

2. The energetic factor in cognitive processes as it is expressed in "meaning implications" of mental life as it was described by Piaget [34]. In this realm, energetic factors are related with:

- Conative: this aspect is related with the propulsion and driving role of intentions and dispositions on cognition and behavior.
- Affective: this aspect is related with the affective arousal produced by needs and feelings triggered by their satisfaction or dissatisfaction.

These factors are the "energetic" regulators of cognition and behavior [37] [31] [43] [44][4]. The main impact of theses factors is in the dynamics in which cognition and behavior unfold, rather than provoking a total collapse of cognitive operations. Generally and most of the time, they produce subtle dynamic qualitative symptoms that challenge verbal descriptions and hinder their adequate qualification.

In the section 6, these "dynamic factors" are illustrated, using an example taken from our past research that shows a possible way to perform a qualification of dynamic factors.

5 The Inferential Structure of Cognitive Anticipation

The Inferential processes that happen during inquiry cognitive processes, were depicted by Peirce and Piaget as composed by three different kind of inferences that work interdependently, namely [38][32]:

[4] It is very tempting to speculate that conative elements play a main role in abductive inferences and affective ones in inductive inferences. Some convergent speculative lines of thinking, regarding the conative nature of cognitive anticipation and the evaluative role of affects has been suggested, although without any reference to Peirce's inferences theory [11] [31]. Nevertheless, recent analysis of the role of guessing in abduction, as Peirce put forward in his last writings, seems to favor these conjectures [46]. Another source, that supports these speculations, comes from several experimental works. First Anokhin and later Sudakov, showed the main role of "dominant motivation" as an "energetic" factor at the "afferent synthesis" stage and during the generation of the "acceptor of action results" (prognosis of the action)[43] [44] .

- Abduction or hypothesis formation, this kind of inference has the form of a guess (with different gradations [45]) regarding the status and possible reactions from the environment.
- Deduction, is the inference that permits anticipating by predicting (following the logical consequences derived from the former guess or hypothetical configuration), the status and reactions from the environment.
- Induction, is the inference that evaluates the result of the actions carried out by the agent, by comparing the deductive prediction with the actual results.

As a remarkable coincidence, an isomorphic functional architecture was experimentally unveiled by Anokhin and Bernstein, in several physiologic processes and goal-directed behaviours, showing the ubiquitous character of these processes in living organisms TFS [4] [9].

To acknowledge the striking parallelism between Anokhin, Peirce and Piaget, it can be shown that the inferences depicted above, could be mapped directly onto the architecture of a FS as proposed by Anokhin:

Inferences	Stages of Operation of Functional System

$$\text{Abduction}\left\{\begin{matrix} Afferent\ synthesis \\ Decision\ \ making \end{matrix}\right\}\text{Guessing}$$

$$\text{Deduction}\left\{\begin{matrix} Action\quad acceptor \\ Efferent\ synthesis \end{matrix}\right\}\text{Anticipating}$$

$$\text{Induction}\left\{\begin{matrix} Backward\quad afferentation \\ Comparison\ results \end{matrix}\right\}\text{Evaluating}$$

The sequence of the stages of operation of a FS (within the brackets), are functionally equivalent to the three kinds of inferences as were described by Peirce and Piaget. Based on this mapping and in the proposed definition of EF, it can be postulated that inferences are in the core of EF, playing the elusive role of the “executive”; forming an integrative, distributed and hierarchical control with the cognitive functions at the top.

It is advanced that one way to assess EF is by assessing cognitive anticipation that is propelled by inferential processes. In the next section a display strategy and certain modelling procedures are outlined in order to achieve this aim.

6 The Form of Guessing and Cognitive Anticipation

Due to the everlasting influence of K. Popper’s ideas in philosophy of science [39] , logic and indirectly in psychology, some key operations involved in cognitive anticipation, like guessing or hypothesis formation, have been seen as random processes, lacking structure or form [45]. Hitherto, these views have discouraged the search for order or structure in these kind of operations.

In contrast with the views expressed above, it has been shown lately that hypothesis formation and their subsidiary anticipatory processes could be studied as a logical [46] and psychological processes and that they display a particular structure in human cognition [19, 18]. Notably this structure could be used for characterizing individual differences in cognitive anticipation.

Cognitive anticipatory processes can be rendered using a graphic representation of the inferential dynamics by means of a diagram. Further description of these diagrams can be accomplished using morphological descriptors, i.e., Euclidean and non-Euclidean geometric measures. The cognitive anticipation modeling is achieved by using a multivariate sets of geometrical measures and supervised machine learning techniques.

6.1 A Little Example

Following Anokhin's insights, our strategy to study cognitive anticipation (enacted by inferential processes) is by analyzing the dynamics of the continuum of the results in a thinking task [1].

Briefly, our problem task is analogous to one that was used by Piaget to study the children's dialectical thinking [36]. In our case the implemented task is an adaptation of a well-known board game called "Battleship" [18] [19].

Battleship is a popular worldwide guessing game for two players. The original objective of the game is to find and sink all of the other player's hidden ships before he or she sink all of your ships. This requires the players to devise their own battleship positions while guessing that of the opponent's position.

Our version of the game has been designed to be played only by one player at a time. In our case, the objective of the game is to find and sink four ships of different lengths (hidden in a board divided by a 10x10 grid) using the least possible shots, regardless of the time taken.

In our paradigm, it is assumed that the nature of the problem-solving behavior is connected intimately with the dynamic configuration of the continuum of results of the active thinking processes performed to solve the game.

To illustrate the above statement I will use some experimental results: Let's suppose that a child (Child-1) plays the Battleship game and we recorded all their moves to solve the problem, let' say that Child-1 made 48 shots, and that the following list of (x,y) coordinates were obtained:

(5,6-3,4-4,4-5,4-6,4-7,4-8,6-1,4-2,5-7,1-10,1-9,7-9,8-8,7-7,7-6,7-10,7-1,10-3,7-3,8-3,9-3,2-6,9-10,10-4,1-4,2-5,2-10,3-10,4-10,5-4,8-7,2-1,6-7,3-4,10-5,10-6,10-2,6-2,7-6,8-7,9-10,9-2,1-2,2-2,3-1,2-1,1-1,3).

Moreover consider this other set of shots made by Child-2, which is identical to the shots made by Child-1, but performed in a different order:

(5,2-10,10-2,2-2,6-2,7-7,2-4,10-10,1-3,2-7,4-1,1-9,8-3,9-3,4-4,4-7,7-5,6-10,3-8,7-3,8-2,3-6,8-4,1-4,8-6,9-2,5-1,2-6,4-4,2-7,9-3,7-6,7-10,9-10,5-9,7-10,7-2,1-5,10-7,1-6,10-1,6-5,4-8,6-10,4-7,3-1,4-1,3-1,10).

A diagram representing both games can be seen in Fig 1. These two sets of shots represent exactly the same performance in terms of “efficiency”, i.e., 48 shots to finish the game; but they are dynamically disparate because their sequential deployment is different. In other words, you can say that the “strategy” used was different but its final result was the same.

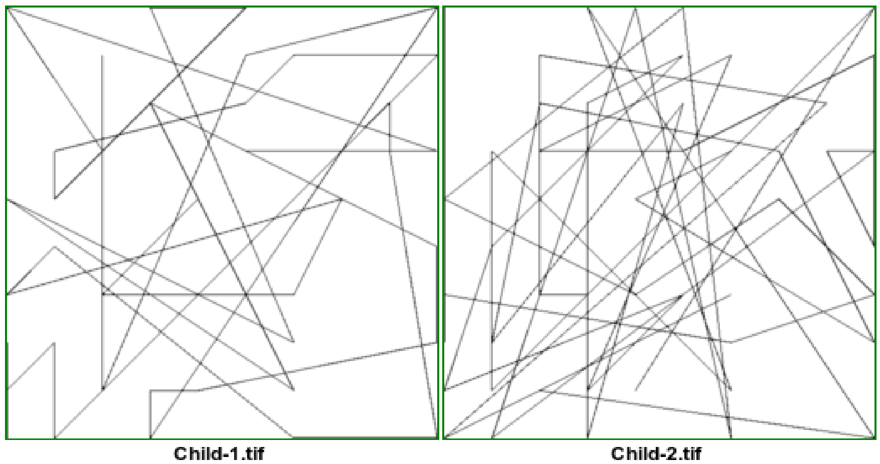

Fig. 1 Images/diagrams representing the inferential dynamics for two children from the example

It can be seen in this situation, that a verbal description of the game to qualify the problem-solving behavior will be imprecise and subjective. Moreover, all known complementary psychological tests which could be used in a problem-solving scenario, to properly qualify the behavior are performance based; informing us solely about the child’s efficiency in solving the task.

To overcome this situation, similar diagrams, as presented in the Fig 1, can be used as descriptors of cognitive anticipation operations, and certain geometric measures can be used to characterize its morphology. In our particular example, the fractal dimension was used, giving the following values: Child-1 = 1.7256 and Child-2 = 1.8036.

Using this strategy, it has been possible to obtain precise mathematical descriptions and statistical models of the inferential dynamics, that propel cognitive anticipation. It is proposed that by these means, the morphology of cognitive anticipation could be used as a cardinal symptom in those conditions, where its functioning is altered.

In conclusion, the beauty of the “functional systems” approach is that it permits the parsimonious integration of the three dimensions of human cognition; the cognitive, the conative and the affective [15]. Luria’s ideas still have a major role to play in orienting future research in cognitive anticipation. Our modest contribution, has shown how some of Luria’s notions have kept their heuristic power.

References

1. Anojin, P.K.: Cuestiones de principio de la teoria general de los sistemas funcionales. In: Psicología y la filosofía de la ciencia: Metodología del sistema funcional, pp. 48–104. Trillas, Mexico (1987)
2. Anojin, P.K.: El reflejo anticipatorio de la realidad. In: Psicologia y la filosofia de la ciencia: Metodologia del sistema funcional, pp. 9–26. Trillas (1987)
3. Anojin, P.K.: Las emociones. In: Psicologia y la filosofia de la ciencia: Metodologia del sistema funcional, pp. 305–328. Trillas (1987)
4. Anojin, P.K.: Psicologia y La Filosofia De La Ciencia. Metodologia Del Sistema Funcional. Trillas, Mexico (1987)
5. Anokhin, P.K.: Biology and neurophysiology of the conditioned reflex and its role in adaptive behavior. Pergamon Press New York (1974)
6. Anokhin, P.K.: The Functional System as a Basis of the Physiological Architecture of the Behavioral Act. In: Biology and Neurophysiology of the Conditioned Reflex and its Role in Adaptive Behavior, Volume 3 in International Series of Monographs in Cerebrovisceral and Behavioral Physiology and Conditioned Reflexes, pp. 190–254. Elsevier Inc. (1974)
7. Baldwin, J.M.: Thought and Things. Swan Sonnenschein & CO., Lim, London (1906)
8. Barkley, R.A.: Executive functions: what they are, how they work, and why they evolved. Guilford Press, New York (2012)
9. Bernshtein, N.A.: The co-ordination and regulation of movements. Pergamon Press (1967)
10. Chan, R.C., Shum, D., Toulopoulou, T., Chen, E.Y.: Assessment of executive functions: Review of instruments and identification of critical issues. Archives of Clinical Neuropsychology **23**(2), 201–216 (2008)
11. Dai, D.Y., Sternberg, R.J.: Beyond cognitivism: Toward an integrated understanding of intellectual functioning and development. Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development pp. 3–38 (2004)
12. Dykman, R.A.: Historical aspects of attention deficit hyperactivity disorder. In: Attention Deficit Hyperactivity Disorder, pp. 1–40. Springer (2005)
13. Freeman, W.J.: Emotion is essential to all intentional behaviors. Emotion, development, and self-organization: Dynamic systems approaches to emotional development pp. 209–235 (2000)
14. Goldstein, S., Naglieri, J.A.: Handbook of Executive Functioning. Springer (2013)
15. Hilgard, E.R.: The trilogy of mind: Cognition, affection, and conation. Journal of the History of the Behavioral Sciences **16**(2), 107–117 (1980)
16. Holmes, J., Gathercole, S.E.: The Diagnostic Utility of Executive Function Assessments in the Identification of ADHD in Children. Child and adolescent mental health **15**(1), 37–43 (2010)
17. Jantzen, W: Alexander R. Luria and the Theory of Functional Systems. In: Simulating the Mind: A Technical Neuropsychoanalytical Approach, pp. 381–393. Springer-Verlag/Wien (2009)
18. Labra, F., Canals, M., Santibanez, I.: Descripciones fractales de procesos inferenciales en ninos durante la creacion de hipotesis tendientes a la solucion de problemas. Revista de Psicologia de la Universidad de Chile **6**, 123–38 (1997)
19. Labra, F., Quezada, A., Canete, O., Basaure, M., Mora, P.: Analisis geometrico de la dinamica inferencial: de la infancia a la adolescencia . Revista de Psicologia de la Universidad de Chile **9**, 45–60 (2000)
20. Levykh, M.G.: The affective establishment and maintenance of Vygotsky's zone of proximal development. Educational Theory **58**(1), 83–101 (2008)
21. Levykh, M.G: Personality, emotions, and behavioural mastery in the thought of Lev Vygotsky. Phd thesis, Faculty of Education - Simon Fraser University (2008). URL `http://summit.sfu.ca/item/9176`
22. Luria, A.R.: Dynamic approach to the mental development of the abnormal child. Journal of Intellectual Disability Research **2**(2), 37–52 (1958)

23. Luria, A.R.: Experimental study of the higher nervous activity of the abnormal child. Journal of Intellectual Disability Research **3**(1), 1–22 (1959)
24. Luria, A.R.: LS Vygotsky and the problem of localization of functions. Neuropsychologia **3**(4), 387–392 (1965)
25. Luria, A.R.: Human Brain and Psychological Processes, first edition edn. Harper & Row (1966)
26. Luria, A.R.: The Working brain: an introduction to neuropsychology. Basic Books, New York (1973)
27. Luria, A.R.: Higher cortical functions in man. Basic Books : Consultants Bureau, New York (1980)
28. Luria, A.R., Tizard, J.: The role of speech in the regulation of normal and abnormal behavior. Liveright New York (1961)
29. McCloskey, G., Perkins, L.A.: Essentials of executive function assessment. John Wiley & Sons, Hoboken, N.J. (2013)
30. Packwood, S., Hodgetts, H.M., Tremblay, S.: A multiperspective approach to the conceptualization of executive functions. Journal of clinical and experimental neuropsychology **33**(4), 456–470 (2011)
31. Pascual-Leone, J., Johnson, J.: Affect, self-motivation, and cognitive development: A dialectical constructivist view. Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development pp. 197–236 (2004)
32. Peirce, C.S.: A Neglected Argument for the Reality of God. Hibbert Journal **7**, 90–112 (1908)
33. Pezzulo, G., Butz, M.V., Castelfranchi, C.: The anticipatory approach: definitions and taxonomies. In: The Challenge of Anticipation, pp. 23–43. Springer (2008)
34. Piaget, J.: Explanation in psychology and psychophysiological parallelism. In: Experimental Psychology: Its Scope and Method. Paul Fraisse, and Jean Piaget, eds. London: Routledge and Kegan Paul (1968)
35. Piaget, J.: Biology and knowledge: an essay on the relations between organic regulations and cognitive processes. University of Chicago Press (1974)
36. Piaget, J.: Les formes Elementaires de la dialectique. Gallimard (1980)
37. Piaget, J.: Intelligence and Affectivity: Their Relationship During Child Development. Annual Reviews, Palo Alto, Calif (1981)
38. Piaget, J., Garcia, R., Banks, L., Davidson, P.M., Easley, J.A.: Toward a logic of meanings. Lawrence Erlbaum (1991)
39. Popper, K.: Conjectures and Refutations: The Growth of Scientific Knowledge, 2nd edition edn. Routledge, London ; New York (2002)
40. Santaella, L.: Abduction: The logic of guessing. Semiotica **2005**(153-1/4), 175–198 (2005)
41. Schwarte, A.R.: Evaluating the diagnostic utility of attention-deficit/hyperactivity measures using discriminant function analysis (2004)
42. Spinoza, B.d.: Ethics. Penguin Books, London; New York (1996)
43. Sudakov, K.V.: The pacemaker of dominant motivation. Neuroscience and behavioral physiology **24**(3), 260–266 (1994)
44. Sudakov, K.V.: The development of the scientific ideas of IP pavlov on the goal reflex in studies of the mechanisms of biological motivation. Neuroscience and behavioral physiology **31**(1), 87–94 (2001)
45. Tschaepe, M.: Gradations of Guessing: Preliminary Sketches and Suggestions. Contemporary Pragmatism. Volume 10, Number 2, December 2013 **10**(2), 135–154 (2013)
46. Tschaepe, M.: Guessing and Abduction. Transactions of the Charles S. Peirce Society: A Quarterly Journal in American Philosophy **50**(1), 115–138 (2014)
47. Vygotsky, L.S.: Educational Psychology. CRC Press (1997)
48. Vygotsky, L.S.: The Collected Works of L. S. Vygotsky: Child Psychology, vol. 5. Springer Science & Business Media (1998)
49. Vygotsky, L.S., Luria, A.: Tool and symbol in child development. The vygotsky reader pp. 99–174 (1994)
50. Vygotsky, L.S., Rieber, R.W., Hall, M.J.: The Collected Works of L. S. Vygotsky: Scientific Legacy. Plenum Press (1999)