Behavior and Philosophy, *50* 65-79 (2022). © 2022 Cambridge Center for Behavioral Studies

ON THE EVOLUTION OF CONSCIOUSNESS

Olavo de Faria Galvão[1]
Universidade Federal do Pará

ABSTRACT Natural selection precedes the first cellulae, beginning with the synthesis of large organic compounds, as organic complexity gradually evolved in natural history. Chemotropism of organic molecules, formation of larger molecules, and molecular groupings resulted in individuation, corresponding to the emergence of molecular layers, dividing internal and external environments, protocells, and multicellular assemblies. Reactions resulting in advances of the organic unit through a given gradient are selected. Eventually, sparse signals began triggering adaptive movements. Responding to signals is a core property of life, consisting of energy transformation chains. Consistently anticipating changes in the flow of events in the organism and its surroundings defines the continuity from early organic compound reactions to gradients, to the capacity of anticipation in cordata and symbolic consciousness. Cycles of synchronous afferent activity, initiated at sensors of the internal and external environment, are followed by efferent activity. Consciousness is the organism's capability to continuously adjust to internal and external environments, respond consistently to contacted events associated in space and time, and effectively prepare for contact with subsequent events. Consciousness predates and dispenses with symbolic capacity. Evolution of communication and symbolic behavior in hominids leads to the emergence of symbolic awareness, a behavioral adaptation to the symbolic environment.
Keywords: Beginnings of natural selection, anticipation, sensory-motor integration, symbolic environment, symbolic behavior.

It is comfortable to discuss consciousness after Bennet & Hacker (2003) made clear that the attribution of psychological properties to parts of the brain is a logical error. In this article, anticipation is taken as the class of adaptations begun more than 3 billion years ago, when organic molecules initiated interactive processes in the organic environment. Anticipation is a central property along evolution of life that eventually gave rise to human adaptation to the symbolic environment that we call "consciousness."

Radical behaviorism's proposal concerning human conscience and consciousness as behavior is focused on the analysis of the modern verbal environment (Skinner, 1945, 1953, 1968, 1974, 1979). Modern humans lived for a quarter of a million years using things, body movements, and acoustic events to communicate. Around 10 thousand years ago, the codification of language began to evolve with the dawn of commerce and complex social contracts. Studies on the evolution of communication, however, must encompass steps that have occurred long before the existence of modern humans.

Comparative studies of cultural development have brought important data for the interpretation of the coevolution of structure and function long before the appearance of the Homo sapiens one million years ago, and modern humans' spoken language. It is worth cautioning that emphasis on humans' uniqueness

---

[1] Author Note

Galvao, O. F. https://orcid.org/0000-0001-9912-3833, is Professor at the Neurosciences and Behavior Graduate Program, Behavior Theory and Research Center, Pará State Federal University. Support for writing this paper came from a CNPq Research Productivity Fellowship to Olavo Galvao (P309475/2018-0, P). The first version of this text was prepared for the Epistemology of Psychology course, in 2016. I thank Paulo Goulart for the precious discussion of several topics relevant to the development of the text, the indication of important readings, and Jorge Raymundo, for the extensive review that generated a previous version of the manuscript. Correspondence should be sent to the author at <ogalvao@ufpa.br>. The author declares that the manuscript has been written without any commercial or financial relationships that could be understood as a potential conflict of interest.

does not contribute to the understanding of human evolution (Deacon, 1997; Heyes, 2018; Laurenti, Lopes, & Abib, 2020).

Organic evolution and natural selection began 3.7 billion years ago when conditions for organic synthesis emerged on earth, constituted by a favorable environment in terms of chemical concentration, luminosity, temperature, and humidity for the formation of the first carbon structured molecules with chemically active radicals. Sarma et al. (2019) presented a schedule of the evolution from the Big Bang to the bacteria, defining evolution in three steps: chemical, molecular, and Darwinian evolution. According to Deacon (2012), however, "...even a molecular system as simple as an autogen can give rise to a form of natural selection (p. 430)." I propose though, with Deacon, that through the evolution of organic molecules, and before the emergence of organic cells, Darwinian evolution was already present. The principles of variability and selection were already active in the selection of molecular groups more efficiently reproducing themselves. Generalized entropy gives way to organized subsystems, with chemical barriers that delay undifferentiated dissolution in the medium and begin selective exchanges of radicals, carrying molecules in and out of subsystems (structured molecular groups).

Associative properties of organic chains turned out to be frequent in the conditions that emerged with the cooling of the earth's surface. Chemotropism became an organizing force, resulting in the formation of the first molecular clusters, organized molecular structures, surfaces with membrane properties, tubules, open, and fully closed sacs. The formation of amino acids, macromolecules, and coacervates gave place to the emergence of osmotic processes and sol-gel transition. Organic chemotropism became a fundamental process for the emergence of natural selection and the evolution of organic dynamics to life on earth (Aumiller et al., 2016; Loeb, 1921; see Wikipedia.org entries "Primordial soup," "Entropy and life").

In the assemblies of organic molecules, capable of movement triggered by chemical or quantum inputs, the signaling function emerged, associated with positive or negative tropism. Positive tropism consisting of movements in the direction of incoming energy is consistently associated with the presence of favorable conditions, such as substances capable of incorporation. Negative tropism consisting of movements in the opposite direction to the energy input is related consistently to adverse thermal and chemical concentration conditions.

Osmosis and tropisms were early themes investigated at the beginning of Natural History. Dutrochet, a French scholar, first coined the term "osmosis," applied to the phenomenon of the passage of electrolytes through permeable membranes, in a tendency to equalize concentrations (Pickstone, 1994). Describing Dutrochet's work, Pickstone notes that for him, organic bodies behaved differently from inorganic bodies — not because the laws of nature were different for them; the same laws applied in all cases, but because certain conditions "[...] most commonly found in organic systems [...] osmosis normally only occurred in organized systems. In that sense osmosis was a feature of life" (Pickstone, 1994, p. 81). Although the dynamic balance of electrolyte concentration between environments separated by membranes is present in mineral systems, it is a fundamental characteristic of any biological system.

Biological organisms evolved in a stable environment as dynamic subsystems that react to energy inputs with changing processes that were naturally selected, ultimately, for survival (Godfrey-Smith, 2016). From coacervates to archaea (Woese, 1987), and from bacteria to chordates, mechanisms have evolved within the limits of the possible life cycle in a given habitat.

Organisms adapted to their ecological niches, and their complexity increased, as structures and functions were maintained, and new ones emerged. The ability, already present in coacervates, to respond to gradients by changing dynamically to increase or decrease the input of substances or energy, remained, and became more complex in cellular organisms. In multicellular organisms, cells, specialized in receiving energy inputs from external and internal environments and transferring it to effector structures or other sensory cells eventually differentiated, modulating this transfer (Hawkins, 1984).

Response to gradient evolved into a broader property — anticipation, in which the complex molecular unit is modified by contact with events in its surroundings that systematically occur before others. Anticipation, evident in tropisms, even in human symbolic consciousness, cannot be confused with the belief in a future cause. Preparation for contact with still-missing events was selected by consequences. An example may clarify this apparent contradiction. The sight of a fruit triggers the approach, the touch confirms — or not — the continuation of the activity initiated by the vision. Taking the fruit to the mouth corroborates the continuation of the activity with chewing and swallowing. Symbolic capacity is not necessary for the development of the behavioral sequences "toward" and anticipating the future. A biobehavioral analysis is presented below.

From the most primitive, unicellular animals evolved to move in their environment along gradients of concentration of substances or energy. The movement of multicellular organisms, endowed with specialized structures, evolved from kinesis in gradients, which allows organisms to move away from harmful conditions and approach favorable conditions for feeding and reproduction.

Anticipating is responding to the set of present stimulations. It remains impossible to respond to the future, as Hume proposed. In practice, we perceive our action as "action to" even though we are responding to a present event based on our interactive history. Given the sequential characteristics of the environment-behavior dynamics, a stimulus at a given distance has been previously followed by success in reaching it after specific movements, keeping the object in the focus of vision as the visual angle occupied by the object on the retina increases. Even in the absence of a symbolic response, during its ontogeny, an animal has its spatio-temporal repertoire selected, which gives it, in practice, the character of "acting for," controlled by the objective to be achieved, even though the entire construction of the repertoire relies on successful experience under similar conditions.

Mechanisms of anticipation, though, were present since organic compounds began to evolve on Earth. Human symbolic awareness gives us the feeling of responding to the future, and to an absent condition. Animals are not symbolically competent; however, they learn to approach a visible object, and learn to search for an absent object. The insight here is the recognition of the symbolic environment as the source of symbolic competency. Chase (1999), citing Noble et al., (1996), recognized the importance of symbolism for social communication. The separation of cognition and communication is, however, an artificial division of a unitary phenomenon. The symbolic environment encompasses interpersonal symbolic communication and derived intrapersonal communication as well. But see Kotchoubey (2018) for another approach to anticipation as having a preponderant role in consciousness.

The Principle of Afference-Efference and the Symbolic Behavior (Or How Thought Is as Much Behavior as Scratching)

In early chordates, with the emergence of the notochord, a dorsal structure, a complete digestive system, and a nervous system that accompanies the notochord, the integrated reaction of the organism to stimuli becomes conspicuous. In more recent chordates, euchordates or vertebrates, including mammals, with the development of the central and peripheral nervous systems, a protracted ontogenetic development - longer period of growth and dependence, learning and individual history have become crucial features.

Euchordates are provided with a nervous system that has afferent structures — sensitive to specific energies, coming from the internal and external environment, and efferent, effector structures — linked to cells in all organs: smooth and striate muscles, glands, and ganglia. It is worth mentioning here the complexity of the functions of the nervous system, which goes beyond the electrical stimulation of muscle cells. An important part of neurons has specialized in providing substances with modulatory, excitatory, and inhibitory functions, reunited in subcortical structures. As an example of interneuronal interaction, afferent neurons of the visual system are organized in parallel, inhibiting their neighbors when they fire (Silveira et al., 2011). There is an expressive number of substances produced by neurons that act on synapses, and in addition to afferents and efferents, there are many other interneuron interactions, in addition to parallel inhibition, which will not be discussed in this work.

In the organism, each effector structure receives efferent innervation and has an afferent innervation. At each instant, the effector structures are activated and their action generates afferents initiated directly by the local afferent innervation, and indirectly, initiated by sensors affected by the activity. Each occurrence of stimulation delivered to individual effector structures by the efferent system may result from different origins in the nervous system.

It is worth remembering that the digestive system and the lung space are parts of the environment external to the body, and, therefore, the epithelial sensors of these organs detect substances and energy sources from external sources. In animals endowed with a nervous system, this system works at the limit of the speed of nervous impulses, from the firing of the receptor neuron to the execution of movements, whose simplest form is found in the reflex arc, described and studied in detail (see Kandel et al., 2013).

A continuous flow of afferent activities starts in the sensors of energy generated by changes in somatic areas and by external sources, while a continuous flow of efferences starts in peripheral and central cortices. Afferent flows progress through cortices and other structures. Efferent flows change the state of structures throughout the system: parts of the nervous system itself, striated muscles, smooth muscles in the glands, and organs of the circulatory and digestive systems.

Given all afferent activities initiated in a moment, some will generate complete efferent ways down to action. In cortices in general and the cerebral cortex in particular, it is through the synapses that have become more effective that the signals progress, most likely, toward efferent pathways. After completion, an afferent-efferent arc — from stimulus to response — may be followed by feedback. It was found that at the time of reinforcement the VTA (Ventral Tegmental Area) sends dopamine to the synapses of the premotor cortex, increasing the efficacy of active synapses (see Glasgow et al., 2019 for a review of synaptic plasticity linked to learning).

The speed of a nerve impulse is on the order of 100 meters per second, varying, however, according to the size of the neuron and the thickness of the axon (Hursh, 1939; Schmidt & Knösche, 2019). The larger the neuron, the greater the speed of electrical transmission. In general, in axon-dendrite synapses, after receiving stimulation and generating an impulse, there is a period of depletion, which also depends on many variables, until the same synapse can retransmit a new impulse. The effectiveness of a neuron-neuron input depends on the state of each receiving neuron.

Why am I weaving such considerations about the functioning of the nervous system? To contextualize the organism's interaction with its environment in a meaningful energy exchange and time scale. "Meaningful" here stands for the energy detection limits and response time intervals. The "parallel processing" metaphor was "right" for the wrong reason. Taken as a sensory-reactive system, a chordate organism can be considered an alternator. Continuously, the extremities of the peripheral nervous system initiate afferents. The afferents initiated at a given instant T_0 (Tzero) reach numerous cortices. Part proceeds as afferent, and part initiates efferents. At the same time, at T_0, efferences initiated at T_{-1} reach effectors throughout the organism.

That is, an organism is sensitive to its activity, to the afferences initiated by the input of energy from the external environment, internal sensors also initiate afferences. Thus, the efferents, which are already "responses" to previous afferents, produce movements that "are detected" and initiate, in turn, additional afferences, which correspond to the sensitivity of the changes in the body to each cycle of afferent-efferent alternation. The movement of organisms, for example, is typically an activity in which movements generate feedback (afferents), allowing the coordination of movements with the integration of external and internal stimulation. Each pore participates in this constant efferent afferent flow. The neural path that initiates any successful movement becomes more likely with each occurrence, even though there is not a perfect repetition of the path that generated the previous occurrence of the movement.

The sensory integration necessary for successful acts demands efferents initiated in the brain cortices, an efferent activity with diverse origins and destination defined by previously selected paths, not by any "decision" in any brain "center," only by the flow of signals through effective synapses, in a milieu of modulating chemical environment triggered by hormonal, interneuronal activation (Barret, 2015). Donahoe & Palmer (1994) proposed that discoveries at the level of the nervous system functioning should corroborate discoveries at the level of environment-behavior relationships. The gradual behavioral complexity that evolves in ontogeny — the reinforcement at the organism-environment relation analysis — stems from the recursive action of reinforcement on neural pathways ultimately resulting in the enhancement of the efficacy of active synaptic connections at the time of reinforcement. Such analysis is consistent with the recognition of synapse plasticity as an ancient mechanism of behavioral adaptation (Pignatelli & Bonci, 2015).

The activity of all living organisms is integrated in time and space and is characterized by the continuous integration of contributions of both sets of simultaneous afferent and efferent activity, in consecutive times. Each set of external contributions at time T_0 is integrated to the re-afference of the effectuation at time T_{-1}, by its turn resulting from the afference at time T_{-2} (Figure 1). Cortices are relay structures where afferent activity is relayed to efferent and/or to intercortical activities. Effectuation is always the result of the efferent activity. Intercortical activities may occur in between afferences and efferences. Efferent activity may result from afference plus sincronic efferences of intercortical activity. A delayed efferent activity at time T_1 sum of efferences may result from afferences that occurred some cycles before and started intercortical travelling before finally being incorporated in efferences at time T_1 (Deacon, 1997).

	Afferences	Efferences
T_{-2}	Σ Afferences	
T_{-1}		Σ Efferences > effectuation
T_0	⊂ Afferent external inputs + ⊂ Afferences from effectuation at T_{-1}	
T_1		Σ Efferences > effectuation

Figure 1
Time scale of afferent-efferent integrative activity. The time scale is proportional to the speed and distance traveled by impulses.

We inherited the terms "mind" and "consciousness" from the ordinary language. They are older than modern science. In this article, however, the mind and consciousness are taken as anticipatory behavior and the human mind as anticipatory symbolic behavior. As we can consider a living organism to be a system in which matter and energy are continually interconverted, behavior, the human mind, and consciousness as well are no exception to this principle.

Many concepts dealt with by Psychology have their origin in "Folk Psychology." Folk Psychology borrows concepts and their uses from ordinary language concerning our behaviors and feelings in connection with diverse world views, creeds, and category systems, and integrates them into a psychological system fashion. I believe, following Wittgenstein (1953), that meanings' acceptability criteria are part of explicit or implicit rules of language games in a given community, and can be an object of scientific investigation and analysis. In Psychology, a heterogeneous community, metaphorical reasonings dressed as scientific discourse are common and thus have been a source of much confusion due to the acceptance of truth by definition, not by evidence. The attribution of causation of behavior to individual willingness, and the issue of first-person access to mental events led to formulations of a special nature for phenomena in this field, however, unnecessary and fanciful.

The psychologization of consciousness, encompassing "awareness" and "consciousness," was already criticized by Pavlov (1909/1972).

> The moment the physiologist reaches the highest limits of the central nervous system, the character of his activity changes abruptly. He ceases to focus his attention on the connection between external factors and the reaction they provoke in the animal: instead of researching concrete relationships, he begins to raise hypotheses about the interior state of animals, drawing inspiration from their subjective states. (Pavlov (1909/1972, p. 28, reverse translation from the author)

For Skinner (1974), all human cognitive behavior is verbal behavior, developed during ontogeny in the verbal environment. Overt and covert verbal behavior is learned along the individual's interaction with the environment, including other humans. It is Skinner's verbal behavior that I am treating in this manuscript as symbolic behavior, and the verbal environment is referred to as symbolic environment. The reason for this nomenclature comes from Wilkinson and McIlvane (2001), who argue that verbal operant stimulus relations treatment converges, and expands on Bates' (1979) largely accepted analysis of human linguistic communication. Besides being conventional, the symbolic environment is quite consistent. Meaning emerges from cultural interactions and stimulus association. Social groups provide an environment in which the actions of a member reaches smooth interplay with the actions of the others. Given the consistency of the environment, anticipation eventually develops, and situations are "meaningful."

Bodily feelings evolved because they brought value to environment-behavior interaction. Alarm calls are learned as part of dangerous situations. They are at the indexical level and already have a restricted meaning and syntax (Cheney & Seyfarth, 1988).

Most movements in our body occur without our attention — peristaltic movements for example. Other movements can be detected but cannot be directly produced at will, such as heartbeat. Some can be modified within limits, like breathing. And last, but not least, "...we do not experience the brain mechanisms of learning and memory, only their results" (Vandekerckhove et al., 2014, p.2).

Symbolic awareness exists in our symbolic environment. Symbols are used in human communication before being learned by individuals. It is the group that inherits and keeps the symbolic environment functioning. Every individual has a symbolic potential that may or may not develop into symbolic competence. Symbolic competence development clearly depends on a complete functional body along with inherited — although naive — neural processes, which will gradually form preferential afferent-efferent "highways" through synapses of high efficacy. The neural system contributes to the generation of complex competencies making more probable those behaviors — movements — that succeed in a given situation (Glasgow, et. al, 2019).

The following reasoning is correct:

> Cognition depends on, or, some would hold, even consists of, perception-action loops that bind organism and environment together in continuous reciprocal interaction. In embodied cognition, action and perceptual feedback become a necessary part of human problem solving and intelligence. There is no internal cognitive apparatus aside from the flow of the cognitive behavior" (Keijzer, 2005, p.124).

I would add: Every individual grows in a symbolic environment and gradually reaches a cognitive behavior competence whose origins are in the cultural environment. The "flow of cognitive behavior" is the expected flow of actions-reactions equal to the flow of the symbolic environment.

On the Implication of the Afference-Efference Principle for the Symbolic Behavior

One implication of the afference-efference principle for the symbolic behavior of humans concerns how the repertoire that involves symbolic relationships develops in ontogenesis. Such development takes place, first, as an interpersonal interactive activity and, gradually, as intrapersonal activity, based on feedback from activities that involve symbolic behaviors (Skinner, 1979; Uehara, et al., 2013; Vygotsky, 1984/2007). Intrapersonal "interactive" activities are present in most species. Insects show "cleaning" movements by rubbing their limbs. Scratching is popular among birds and mammals. Hearing one's own vocalizations, coordinated with appropriate movements is also important feedback in vocal interactions in many species.

The development of speech in our species is an example of how the afference-efference principle of movements participates in the selection of best-fit structures to deal with complex stimuli and responses. See Deacon (2000) for a detailed comparative analysis of the evolution of structures that enabled the operant control of vocalization.

Young *Homo sapiens* live in an environment intensely audio-visual, with frequent consistent audiovisual stimulus pairings and feedback for responses to these pairings. Learning to speak involves a history of the interaction of caretakers and the child. Adult-child and child-adult imitation and reinforcing feedback are important for both caretaker and child. Gradually, mouth movements and sounds take form and can be repeated freely or as a response to specific stimulation. The conspicuous property triggering feedback is the production of sounds, repeating the sound heard or emitting an expected follow-up sound. In general, this integration takes place in the presence of stimuli provided by adults, who respond by imitating babbling and emphatically repeating mouth movements and simple sounds that the child produces. Subsequently, they provide models and react to the child's performance. Gradually, the child's sound emissions are also added to the stimuli that determine the next responses as occurs with movements in space, such as walking. The first reinforced production of the sound "bah" in a baby-adult interaction will raise the probability of saying "bah" in similar situations, and may also generate the repetition of the sound, such that the baby will be reinforcing their own vocalization. Gradually, the complexity of stimulation and responses increases, and the child utters words that meet the interlocutor's requirement for reinforcement.

Competence in verbal communication does not initially have a direct relationship with what, much later, will become symbolic verbal thinking. Communication, an interactive interpersonal activity, is shaped by the consistent reactions in the social environment. Experienced individuals provide gestural and sound models and cater to the novice individuals' movements that resemble the models. Arbitrary but consistent sequences of interaction begin to form part of the infant's repertoire. A relatively complex oral response such as: “Mother, you are very selfish, see?” Said by a two-year-old in response to the mother's denial of the child's request to go play at her playmate's house, may surprise experienced listeners. The adults ask themselves: “How could the child respond using an apparently very abstract concept, in a correct and “adequate” way? To make a long story short, the child's experience was enough to produce this response, fitting the word "selfish" properly, a presymbolic relation even in the absence of the corresponding linguistic abstraction (see Peirce, 1955). The children's speech is initially mainly composed of echoing little sequences that will come up in similar situations for the rest of life. And countless ready-made dialogues accompany us through life. "Hey, how is it going?" “This is my friend X.” These responses are adapted to the circumstances without any additional complexity, they are as logical as any motor sequence, like raising a glass to the mouth, reinforced by immediate feedback.

As the child develops linguistic competence, using words properly in interactions with other people, speaking and attending to the words heard, a novelty emerges. The child, who hears the words they speak, begins to play both functions, of speaker and audience, when playing alone, eventually, learning to "talk" to oneself inaudibly (I am not going back to the first behaviorists' guess that thinking could be assessed by the amplification of subliminal talk). Words learned first in dialogue with other people come to be used in dialogue with oneself, initially expressed, and gradually not audibly uttered. The "dialogue" between self and oneself, inaudible to others, starts to accompany activities, and vestigial verbal responses — and their functions as stimuli — are added to the activities, eventually helping the child to manage imaginary situations (Vygotsky, 1984/2007).

Play is central, according to Vygotsky, to children's thought development. The concept of symbolic environment, as used here, is consistent with Vygotsky’s idea of "social formation of the mind." Play is a secure introduction to the gradual acquisition of abilities and competencies and thus augments the environmental scope of anticipation repertoire. These considerations are in complete disagreement with Kotchoubey's statement: "Play is the first important consequence of the ability to learn without reinforcement" (Kotchoubey, 2018, p.3). It is hard for me to understand such an interpretation of both concepts, play and reinforcement (Wertsch, 1985). Kotchoubey's attribution of "uselessness" to play, dismissing the constant feedback provided by actions during play is unsustainable.

The Symbolic Environment

The concept of environment entails the whole set of matter and energy in which every living being, animal, and plant, from unicellular to whales, are immersed. Regarding social animals, a considerable number of adaptations are related to interactions with conspecifics. Communication evolved from chemical recognition to complex display sequences are more or less stereotyped, spontaneous, or learned. Alarm calls are learned as part of dangerous situations; their function as indexes (Peirce, 1955) already have a restricted meaning and syntax. In long-lived animals, more variation in interactive behavior is found. Anticipation is always required for adequate interplay. Multi-channel communication is common, involving sound, movements, visual displays, contact. Only humans live in a symbolic environment; human environment is "significant." Bodily feelings evolved because they brought value to environment-behavior interaction.

Symbolic consciousness exists in our symbolic environment before it is learned by individuals. It is the group that inherits and keeps the symbolic environment functioning. Every individual has a symbolic potential that may or may not develop into symbolic competence. Development of symbolic competence clearly depends on a functional body along with inherited — although naïve — neural processes, which will gradually form preferential afferent-efferent "highways" through synapses of higher efficacy. The neural system contributes to the generation of complex competencies making more probable those behaviors — movements — that succeed in a given situation. The symbolic environment can be taken as equivalent to the verbal environment although during ontogenesis, effective verbal interactions precede symbolic competence.

The Ontological Status of the Mental Phenomena

We must agree with Araujo's (2013) statement that the precise characterization of mental phenomena, as an object of study in Psychology, is a fundamental issue. To make this characterization universally acceptable, however, it is necessary to consider some conditions.

First, it is necessary to describe empirically tested or testable functions. Inferences cannot serve as passages through the looking glass, in the manner of Lewis Carroll, to systems with laws arbitrated by the author's thought. Second, a natural, data-based approach must be taken to the question of the relationship between matter and energy in organisms that evolved in a stable environment.

The "content" of the mind, in the symbolic species, is cultural, and the process is biological. The concepts of memory and attention, for example, coming from "folk psychology," help to identify examples of organism-environment exchanges either in adult humans or in young children and animals. Those who have developed language and, therefore, the concepts of memory and attention in their repertoire, and those who have not developed such repertoire. The activities to which these concepts refer are vital to survival, important in sensory-afferent and operant-efferent integration, regardless of the individual's symbolic capacity.

The "content" of the mind of long-lived animals is constructed in ontogenesis. Memory is not the recording of a fact in the mind or the brain, it is the activity of imagining and categorizing the imagined event as a previously occurred event. Remembering is an adaptive re-view of interactive chunks that enact to the immediate new present pre-wired action modules; repeated parts sawed into new fitting actions.

Fuchs (2011) presents an example of the organism-environment interaction from an embodied cognition perspective — as far as we give the word "disposition" a functional status, not an internal psychological inferred mechanism — a clear understanding of the role of the nervous system in the development of repertoires during ontogenesis:

> …in the course of organism-environment interactions are extracted and ingrained in *microstructures* of the brain. This results in the formation of neural networks that serve as dispositions for meaningful reactions to similar situations in the future." (p. 197)

Simple examples of symbolic awareness may illustrate our interaction with the symbolic environment, "finding" a word that fits an argument and solves a problem, giving to the person satisfaction. Or the musician Hermeto Paschoal saying that a song is not made, it is found. According to this point of view, music can occur to the musician, just as a paragraph occurs to its writer. Here these examples may be of help in characterizing the mind as an activity, not as a thing. The text could be very different. The above sentences were rewritten a number of times before the actual text, evaluated as useful for the reader.

The Mind-Body Problem

Uttal (2004) presents a careful review of the evolution of dualism since the prehistory of humanity. When faced with the task of defining mind and consciousness, he declares “I apologize for simply being unable to arrive at a useful definition of what I believe is an inaccessible and indivisible process occurring within the depths of the complex brain (p. 260).” As so many philosophers, psychologists, and others have done, this statement contains a contradictory confession of not knowing what the mind is while defining it as someone who knows exactly what it comes to be: "an inaccessible and indivisible process that takes place in the depths of the complex brain (p. 260)."

A conception of mind — the human mind — as a result of developmental processes is a satisfactory solution, proposed by Vygotsky (1984/2007). Analyzing research data on the use of concepts by children he showed that in the process of development, the young child solves practical problems without the resources of language, which, little by little, begins to become more important (see also Galvão, et al., 2007). Practical intelligence develops independently of speech development. Vygotsky proposed that human thought — symbolic thinking I would say — arises with the internalization of language (Wertsch, 1985).

Vygotsky's proposal for the formation of the mind is extremely relevant to understanding human consciousness. Initially, the child learns, with help, to respond in expected ways in situations in which words are spoken. The responses reinforced by the interlocutors may involve, among other actions, saying words. After becoming able to spell words in coordination with the immediate environment, the child begins to predict — saying to themself — the "correct" response to speeches. Also, the child learns to listen. They learn to reinforce, correct, and even answer the interlocutor in cases where they do not respond, as is the case with interactions with animals or toys. When playing, the concepts are applied in the creation of imaginary situations, with support from the learned concepts. Once the child can play both the roles of speaker and listener, they begin to do this without using voice. The new silent talk becomes the origin of thought. Vygotsky proposed that human thinking results from the convergence of practical intelligence and language in problem-solving (see Heyes, 2018, for a cognitivist interpretation of the role of social interaction in cognitive development).

Closely related to the question of consciousness is that of the mind-body relationship, insofar as consciousness is understood as a mental quality. Due to its relevance and the difficulty of accommodating these concepts in philosophical systems and empirical science, this issue remains on the agenda, as an epistemological problem pending solution.

Kuhn (1975) drew attention to the fact that the change in paradigms would be more in changing the questions than the answers. Considering that the activity of research is to look for answers, the question is fundamental. It was only after questioning the behavior of gases came up that chemistry and the law of conservation in reactions could emerge.

Over the centuries, thinkers have dedicated themselves to the exercise of defining the concept of consciousness. Etymologically, the term comes from the Latin conscientia, shared knowledge. Among other meanings, “an inner voice” appears in the dictionary. It can refer to the waking state, as in the expression “being conscious,” which is opposed to “being unconscious.” It also refers to the perception of complex events and the implications between events. Being aware can also refer to knowing that one knows. "Attention" and "purpose" are concepts related to consciousness.

A characteristic that is considered to be especially distinctive of the phenomenon of consciousness is that of private access, as the only form of access, while other natural events would share access in the third person. In this regard, Araujo (2013) comments:

> ...if all emerging physical properties can be observed in the third person, with the only exception of consciousness, which can only be accessed in the first person, what is the point of comparing it exactly with phenomena that depart from it? And if there is no other emergent physical property comparable to consciousness, then what is the reason for insisting that it is still a physical phenomenon? (p. 246)

Such an argument is based on the beliefs that: (1) unless proven otherwise, consciousness is not a physical phenomenon; and (2) human consciousness is the only phenomenon that can be accessed exclusively in the first person.

Contradictorily, the admission that consciousness is not a physical event — or may not be — appears in the arguments of authors who explicitly reject dualism. The inconsistency is eventually detected, but a satisfactory solution is not found. This has kept the consciousness literature in a whirlwind of inconsistencies. In the wake of the ignorance of what the origin, the stuffing, and the way of interacting of consciousness with other natural phenomena are, inconsistent proposals continue to appear, based on beliefs and not on evidence.

The difficulty in understanding consciousness and the body-mind relationship is rooted in the quality of the symbolic communication, which uses naming as a way of categorizing. In a human oral culture, before writing, a category comes from practical criteria. For example, the Mebêngôkre people, called Kaiapós by the invaders, who inhabit the banks of the Xingu River in the Occidental Amazonia, classify birds according to habitat: forest, forest edge, and countryside. In our culture, as elsewhere, practical concepts are the rule, not the exception. Fruit, for example, is a practical concept, which includes edible plant products. The pineapple, which scientifically, considering its genesis, structure, and function, is a modified bunch of flowers, by practical criteria is a fruit.

In psychology, the reification of concepts, the process of creating immaterial constructs and taking them as existing entities, including hypothetical relationships with observable events, is also the rule, not the exception (Galvão, 1978; Galvão, 1980; Politzer, 1930/1998). Modern science has added genesis as a criterion to resolve doubts arising from the similarities and differences between observations. Thus, the investigation of the genesis of symbolic behavior can solve the problem of consciousness and body-mind interaction. It may also clarify why beliefs are so important to the human mind (Uttal, 2004). To date, no scholar has solved the problem of consciousness, because they take it as a fully developed class of phenomena as if human consciousness had arisen ready-made, and as if individual consciousness were a gift. Hence human consciousness is regarded as something special and unique, impossible to be integrated into biological evolution. Understanding the evolution and development of the mind and consciousness is the key to overcoming the dualistic intuition, which reproduces, incessantly, a search to establish the relationship between two different essences, without considering the natural origins of these differences. Another origin for consciousness is searched in the nervous system evolution. The complexity of consciousness would be afforded by a corresponding complex neural structure and function that evolved for unknown reasons. And the old behaviorist denial — or negation of the possibility of scientific investigation — of events that are categorized as mental, consciousness included, does not resolve the misunderstanding of mistaken reification. A satisfactory solution emerges by taking the large class of behaviors and creating the subclass of cognitive behaviors, which allows the study of their evolution in nature, in animals — in primates, in their relationship with culture, and their development in the individual (Zilio, 2010; Chapman, & Huffman, 2018).

In the early days of symbolic communication, the confidence of the person receiving a report of events witnessed by the person who reports it was essential, as it still is. Correspondence and trust were essential in the selection of symbolic communication, but they brought with them fiction and reification.

The difficulty of accommodating the phenomenon of consciousness in nature has been such that its scientific study, together with that of all human cultural manifestations, is structured on its own foundations, with its own logic, apart from the paradigm of universal science. A second "nature," independent and apart from natural history, is created for consciousness and culture. Therefore, the use of the plural to designate the human sciences is not meaningless. Abib (2009), referring to psychology, but applicable to the human sciences, argues that, due to the lack of a universal paradigm, psychology is nothing more than a project, in fact, different projects, according to the inspiration of its author, lacking universal paradigm status. The concepts of mind and consciousness are articulated to others, in different ways in each proposed system, without a consistent relationship with the principles of natural selection and even explicitly contrary to them.

Deacon (1997), analyzing the evolution of the human species, which he calls the symbolic species, interprets research in which response delay, an executive function, is correlated with the activity of distant neurons, interconnected in cortical circuits. He argues that, from the adoption of the first symbols, the growth of the neocortex was favored, as more cortical neurons, with greater distance from each other, were more recruited. The increase in the complexity of stimuli demands delayed responses for the time necessary for several afferent stimulatory inputs to participate, together, in an efferent trigger.

It is no accident that the terms "short-term memory" and "working memory" are understood to be important for "conscious" behavior. The compositions to which the individual has to respond are not all presented simultaneously; they are composed gradually over time.

Our ancestors began to specialize in responses to complex stimulation, compromising reaction speed and increasing the number and extent of the origins of synchronous efferent firings. Very appropriately, Deacon (1997), criticizing the hypothetical construct of the Language Acquisition Device (LAD) (Hauser et al., 2002), points out why theories that disregard evolutionary processes constitute obstacles to the understanding of symbolic capacity when proposing hypothetical mechanisms not based on data.

Some principles of nervous system functioning in chordates are involved in the organism-environment exchange, including the symbolic behavior of humans[2]. There are no special neural principles necessary to understand symbolic behavior. The missing concept to understand symbolic behavior is the environment in which it develops: the symbolic environment.

Regardless of the specific content of each interaction, the organism-environment interaction is based on the functioning of the nervous system, in real-time. Relational functions of the organism emerge from the functioning of the nervous system within its environment. Afferent-efferent relationships are selected for their consequences, regardless of whether they come from external or internal stimulation to the organism. Such relationships are also independent of the specific effector triggered, which can be any muscle movement. An example of this could be the act of writing this text, reinforced by the opportunity to continue adding arguments. The nervous system does not know that I am writing, it does not "analyze" the stimuli; I do. Parallel processing is a reference to the fact that, at a given instant, at their apex, divergent afferents initiate convergent efferences. Basically, at a given T_0 moment, several substructures activate synchronously, efferently fire in a convergent way, activating, at moment T_1, a movement of an effector. Many synchronous, convergent neural efferent pathways initiated at T_{zero} activate an equal number of targets, the effectors. The same target can result from the most different efferent origins, from peripheral ganglia to synchronous firings coming from different sensory and interneuronal areas of the neocortex.

The breathing metaphor helps us understand the organism-environment interaction. Just as the lung breathes in and out, fulfilling its function of gas exchange at every moment, there is a particular assembly of afferents, re-afferents, and efferents in the function of consciousness as an anticipatory activity. At each moment, each effector is receiving efferent inputs and its response generates synchronous afferents, along with eventual stimulation derived from the movement itself or changes in the external environment. Besides the muscle movements, the efferents produce electrical and chemical-modulating interneuronal activations corresponding to the flow of thinking-feeling, for which the specific activation of the muscular and glandular effectors has been fading throughout the individual's experience, but can reappear at the level of communication, emotional expression, and other movements.

Nerve Cells Don't Talk to Each Other

In cognitive and behavioral neuroscience, there are many ways of accessing the functioning of the nervous system correlated to the execution of activities (Kandel et al. 2013). However, it is important to be alert to statements that are not related to the available data, which are the expression of the traditional use of metaphors.

[2] 1. Afferent divergence; 2. Cortical reciprocal innervation; 3. Electrical neuronal activity; 4. Modulation: Chemical neuronal activity; 5. Indeterminacy of the paths x prediction of the result; 6. Cortices: end of afference; 7. Efferent convergence; 8. Synchrony: parallel processing; 9. Efferent threshold; 10. Neuronal discharge.

It makes no sense to look at the mechanisms for the characteristics of the final behavior of a system. Sol-gel changes in a protozoan result in motility but cannot be confused with its result. Thus, at a given moment, one cannot look exclusively at the functioning of the nervous system for phenomena that result from the interaction of the organism with the environment. Consider, for example, spatial orientation, present in all animal species; it can be seen that the nervous system continuously receives stimulatory inputs and produces movements that are eventually selected (Donahoe & Palmer, 1994; Galvão, 1999).

When we say that people express ideas or communicate information, we elude the history of interactions with similar situations. Skinner (1974; 1979) was right to say that people behave in certain ways by the contingencies of reinforcement maintained by the verbal community. Ideas are part of a cultural universe, the analysis of which cannot be reduced to the contingencies that generate and maintain them as behaviors. What we call "Human" environment is the cultural and symbolic part of our world. Our interactions in the cultural and symbolic environment evolve in ontogeny inseparably from the evolution of direct interactions with intrinsic environmental properties.

Araujo (2013), criticizing Searle (2007), states that "Searle wants to explain what the mind, consciousness, beliefs, etc. are, which already presupposes, therefore, the acceptance of their existence" (p. 131- 153). Araujo hints at the possibility of denying the existence of the aforementioned phenomena, possibly due to the difficulty of framing them in a coherent conceptual universe. After all, mind and consciousness were categorized as immaterial, serving, together with the concepts of soul and spirit, to define Cartesian dualism, which modern science rejects, but without yet finding a satisfactory alternative. Lopes and Abib (2003) analyze the conceptual confusion that underlies the mind-body dualism and, based on Ryle (1949/1980), defend the consistency of the relational conception and reject the substantial conception of mind.

No one doubts the existence of the ability to observe, nor does restrict it to humans. Naturalists have shown, in social animals, the division of labor. For example, when an individual is vigilant while the others are dedicated to foraging, the differentiation of observation activity is linked to alarm by the appearance of predators.

Observing public events is no different from observing private events (Moore, 2017). The individual sees something external and sees that he sees. This is a way of saying that seeing is observable. Seeing that you see is categorized as "awareness" because seeing is an activity that takes place in your body. A diabetic can learn to discriminate a specific stimulation, which occurs in his body, to which he has private access, but which can also be accessed through biochemical indicators. One can observe objects and events including public and private ones (Malerbi & Matos, 2001). Pain is certainly a most ancient awareness capability, just to mention one.

A consequence of the principle that awareness includes observing private events is its participation in the ability to predict the future and act consistently. Intentionality is the individual's reaction to the observation of thinking about the future, which occurs here and now. Even a non-verbal individual can observe his reactions and act by integrating them in the production of his efferences. It is about stimulus control, a key repeatedly played by Skinner throughout his work.

Conclusion

In summary, the conception of human thought adopted in the present text corresponds to that of Skinner (1974), and Vygotsky (1934/1986), according to which speech is internalized — in other words, we learn to speak silently. This behavior is associated with problem-solving and human intelligence formation. Consciousness is material. At each instant, a set of afferent environmental events, including events in the individual's body, produces a set of efferents, and this environment-behavior relationship can be selected. Part of these efferents corresponds to the behavior of observing the temporal and spatial contiguous environmental and behavioral events (Schaal, 2005).

According to this perspective, the term consciousness can be used in the sense in which the expression "I am aware that" can be used. Consciousness translates, then, as the anticipation of the immediate future (Suddendorf & Redshaw, 2017). Observing someone's anticipation behavior, it can be inferred that the individual composes his response using stimulation derived from his experience, added to the present situation. Even individuals who cannot linguistically express "I am aware that..." can nevertheless be aware. Seen in this way, symbolic behavior goes beyond the capacity to be conscious.

Adopting such a perspective, dualisms, including psychophysical parallelism, and the most diverse causal constructs, including those that assume consciousness as a result of neural processes, become meaningless. Nervous activity along with the entire body organization allowed the environment-behavior relationship throughout evolution and allows it throughout ontogeny. As a baby in front of the mirror gradually adapts to specular reflections and differentiates responses to virtual images from responses to objects, in the iterative organism-environment interactive flow the anticipation of results — in fact, the effectiveness of afferent-efferent compositions — allows us to act in the present, whether as repetition or as change.

References

Abib, J. A. D. (2009). Epistemologia pluralizada e história da psicologia [Pluralized epistemology and history of Psychology]. *Scientiae Studia*, *7*, 195-268. https://doi.org/10.1590/S1678-31662009000200002

Araujo, S. F. (2013). *O novo mistério de Searle, ou, como não resolver o problema da consciência* [The new Searle's mystery, or how not to solve the consciousness problem] *In* S. F. Araujo (Ed.), Ecos do passado: estudos de história e filosofia da psicologia [Echoes from the Past: Studies on History and Philosophy of Psychology] (pp. 131 – 153). Juiz de Fora: Editora UFJF.

Aumiller, W. M., Cakmak, F. P., Davis, B. W., & Keating, C. D. (2016). RNA-based coacervates as a model for membraneless organelles: Formation, properties, and interfacial liposome assembly. *Langmuir*, *32*(39): 10042–10053. https://doi:10.1021/acs.langmuir.6b02499

Barrett, L. (2015). A better kind of continuity. *The Southern Journal of Philosophy*, *53*, 28-49. https://doi.org/10.1111/sjp.12123

Bates, E. (1979). *The emergence of symbols: Cognition and communication in infancy*. New York: Academic Press.

Bennett, M. R. & Hacker, P. M. S. (2003). *Philosophical foundations of neuroscience*. Malden, MA: Blackwell Publishing.

Chapman, C. A. & Huffman, M. A. (2018). Why do we want to think humans are different? *Animal Sentience*, *23*(1). https://doi.org/10.51291/2377-7478.1358 https://www.wellbeingintlstudiesrepository.org/cgi/viewcontent.cgi?article=1358&context=animsent

Chase, P. (1999). Symbolism as reference and symbolism as culture. In R. Dunbar, C. Knight, & C. Power (Eds.) *The Evolution of Culture* Chapter 3, (pp. 34-49). Edinburgh: Edinburgh University Press. https://doi.org/10.1515/9781474467889-005

Cheney, D. L., & Seyfarth, R. M. (1988). Assessment of meaning and the detection of unreliable signals by vervet monkeys. *Animal Behaviour*, *36*(2), 477-486. https://doi.org/10.1016/S0003-3472(88)80018-6

Deacon, T. W. (1997). *The Symbolic Species: The Co-Evolution of Language and the Brain*. New York, NY: W.W. Norton.

Deacon, T. W. (2000). Evolutionary perspectives on language and brain plasticity. *Journal of Communication Disorders*, *33*(4), 273-90. https://doi.org/10.1016/s0021-9924(00)00025-3

Deacon, T. W. (2012). *Incomplete Nature: How Mind Emerged from Matter*. New York/London: Norton.

Donahoe, J. W. & Palmer, D. C. (1994). *Learning and Complex Behavior*. Boston/ London: Allyn and Bacon.

Fuchs, T. (2011). The brain: a mediating organ. *Journal of Consciousness Studies*, *18*, No. 7‑8, 196‑221

Galvão, O. F. (1978). O comportamento do rato branco em situações de reforçamento dependente e independente da resposta [The behavior of the white rat in situations of reinforcement dependent and independent of the response]. *Psicologia*, *4*(1), 77-116.

Galvão, O. F. (1980). Invenção e Descoberta em Psicologia [Invention and Discovery in Psychology]. *Psicologia*, *6*(3), 13-19.

Galvão, O. F. (1999). O reforçamento na biologia evolucionária atual [Reinforcement in current evolutionary biology]. *Revista Brasileira de Terapia Comportamental e Cognitiva*, *1*(1), 49–56. https://doi.org/10.31505/rbtcc.v1i1.270

Galvão, O. F., Carmo, J. S., Nelson, T., Silva, L. S., & Oliveira, M. P. (2007). The role of naming in abstract conditional discrimination. *Ciências & Cognição*, *10*, 65-83. https://www.cienciasecognicao.org/revista/index.php/cec/article/view/623

Glasgow, S. D., McPhedrain, R., Madranges, J. F., Kennedy, T. E., & Ruthazer, E. S. (2019). Approaches and limitations in the investigation of synaptic transmission and plasticity. *Frontiers in synaptic neuroscience*, 20. https://doi.org/10.3389/fnsyn.2019.00020. PMID: 31396073; PMCID: PMC6667546

Hauser, M.D., Chomsky, N. & Fitch, W. T. (2002). The faculty of language: what is it, who has it, and how it evolved. *Science*, *298*, 1569-1579. https://doi.org/DOI: 10.1126/science.298.5598.1569

Hawkins, R. D. (1984). A cellular mechanism of classical conditioning in Aplysia. *Journal of Experimental Biology*, *112*(1), 113-128. https://doi.org/10.1242/jeb.112.1.113

Heyes, C. (2018). *Cognitive gadgets: The cultural evolution of thinking*. Harvard University Press. https://doi.org/10.4159/9780674985155

Hursh, J. B. (1939). Conduction velocity and diameter of nerve fibers. *American Journal of Physiology*, *127*(1), 131-139. https://doi.org/10.1152/ajplegacy.1939.127.1.131

Kandel, E. R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S.A., & Hudspeth, A. J. (2013). *Principles of Neural Science*. 5th ed. McGraw Hill, New York.

Keijzer, F. (2005). Theoretical behaviorism meets embodied cognition: two theoretical analyses of behavior. *Philosophical Psychology*, *18*(1), 123 -143. https://doi.org/10.1080/09515080500085460

Kotchoubey, B. (2018). Human consciousness: where is it from and what is it for. *Frontiers in Psychology*, *9*, 567. https://doi.org/10.3389/fpsyg.2018.00567

Kuhn, T. S. (1975). *A estrutura das revoluções científicas* [The structure of scientific revolutions]. Perspectiva: São Paulo.

Laurenti, C., & Lopes, C. E. & Abib, J. A. D. (2020). On usefulness of the useless: Philosophy as the consciousness of scientific knowledge. *Behavior and Philosophy*. *48*, 91-108.

Lopes, C. E. & Abib, J. A. D. (2003). O Behaviorismo Radical como Filosofia da Mente [Radical Behaviorism as Philosophy of Mind]. *Psicologia: Reflexão e Crítica*, *16*(1), 85-94. https://doi.org/10.1590/S0102-79722003000100009

Malerbi, F. E. K., & Matos, M. A. (2001). Blood glucose discrimination training: the role of internal and external cues. Journal of Health Psychology, 6(2), 229-240.

Moore, J. (2017). Private behavioral events. *Revista Brasileira de Análise do Comportamento/Brazilian Journal of Behavior Analysis*, *13*(2), 57-61. http://dx.doi.org/10.18542/rebac.v13i2.5906

Noble, W., Davidson, I., & Hobbs, D. (1996). Human evolution, language and mind: A psychological and archaeological inquiry. Cambridge University Press.

Pavlov, I. P. (1909/1972). As ciências naturais e o cérebro [The natural sciences and the brain]. *In* I. P. Pavlov, *Reflexos condicionados e inibições* [Conditioned reflexes and inhibitions]. Portuguese version: Dalcy Fontanive, Rio: Zahar.

Peirce, C. S. (1955). *Logic as semiotic: the theory of signs*. In: BUCHLER, J. (ed.) The Philosophical Writings of Peirce. Dover, New York.

Pickstone, J. V. (1994). Discovering the movement of life: osmosis and microstructure in 1826. *International Journal of Microcirculation*, *14*, 77-82. https://doi.org:10.1159/000178212. PMID: 7960449.

Pignatelli, M. & Bonci, A. (2015). Role of dopamine neurons in reward and aversion: A synaptic plasticity perspective, *Neuron*, *86*(5), 1145-1157, https://doi.org/10.1016/j.neuron.2015.04.015

Politzer, G. (1930/1998). *Crítica aos Fundamentos da Psicologia: a Psicologia e a Psicanálise* [Critic of the Foundations of Psychology: Psychology and Psychoanalysis]. Translation: Marcos Marcionilo & Yvone M. T. da Silva. Piracicaba, SP: UNIMEP.

Ryle, G. (1949/1980). *The concept of mind*. New York: Penguin Books.
Sarma, H., Pradhan, S., Kaushik, S., Mattaparthi, S. K. V. (2019). Phylogenetic Analysis: Early Evolution of Life. *In* Shoba Ranganathan, Michael Gribskov, Kenta Nakai, Christian Schönbach (Editors) *Encyclopedia of Bioinformatics and Computational Biology*, Academic Press, Pages 938-952, ISBN 9780128114322, https://doi.org/10.1016/B978-0-12-809633-8.20171-4. (http://www.sciencedirect.com/science/article/pii/B9780128096338201714)
Schaal, D. W. (2005). Naming our concerns about neuroscience: a review of Bennett and Hacker's philosophical foundations of neuroscience. *Journal of the Experimental Analysis of Behavavior*. *84*(3):683-92. https://doi: 10.1901/jeab.2005.83-05. PMID: 16596986; PMCID: PMC1389787.
Schmidt, H., & Knösche, T. R. (2019). Action potential propagation and synchronization in myelinated axons. *PLoS Computational Biology*, *15*(10): e1007004. https://doi.org/10.1371/journal.pcbi.1007004
Searle, J. R. (2007). *Mente, cérebro e ciência* [Mind, brain, and science]. Lisboa: Edições 70.
Silveira, L. C. L., da Silva Filho, M., do Nascimento, J. L. M. (2013). Neurociência, a ciência do sistema nervoso: da descoberta do impulso nervoso ao estudo da consciência e a uma nova revolução tecnológica [Neuroscience, the science of the nervous system: from the discover of the nervous impulse to the study of consciousness and a new technological revolution]. *Neurociências* (Rio de Janeiro), *9*(3), 80-112. ISSN 1807-1058
Skinner, B. F. (1945). The operational analysis of psychological terms. *Psychological Review*, *52*, 270-277.
Skinner, B. F. (1953). Science and human behavior. New York: Macmillan.
Skinner, B. F. (1968). The technology of teaching. Meredith Corporation.
Skinner, B. F. (1974). *About behaviorism*. New York: Alfred A. Knopf.
Skinner, B. F. (1979). *The shaping of a behaviorist: Part two of an autobiography*. New York: Alfred A. Knopf.
Suddendorf, T., & Redshaw, J. (2017). Anticipation of Future Events. *In* Vonk J., Shackelford T. (eds), *Encyclopedia of Animal Cognition and Behavior*. Springer, Cham. https://doi.org/10.1007/978-3-319-47829-6
Uehara, E., Charchat-Fichman, H., & Landeira-Fernandez, J. (2013). Funções executivas: Um retrato integrativo dos principais modelos e teorias desse conceito [Executive functions: An integrative portrait of the main models and theories of this concept]. *Revista Neuropsicologia Latinoamericana*, *5*, 25-37.
Uttal, W. R. (2004). *Dualism: the original sin of cognitivism*. Mahwah, New Jersey: Lawrence Erlbaum Associates.
Vandekerckhove, M.; Bulnes L. C.; Panksepp, J. (2014). The Emergence of Primary Anoetic Consciousness in Episodic Memory. *Frontiers in Behavioral Neuroscience*, *7*, 210, DOI=10.3389/fnbeh.2013.00210
Vygotsky, L. S. (1934/1986). *Thought and language*. Trad. Alex Kozulin. Cambridge: The MIT Press.
Vygotsky, L. S. (1984/2007). *A formação social da mente: O desenvolvimento dos processos psicológicos superiores* [Mind in Society: The Development of Higher Psychological Processes]. Michel Cole & Sylvia Scribner (Orgs.), (7th. Edition), Translated by José Cipolla Neto, Luís Silveira Mena Barreto, Solange Castro Afeche. São Paulo: Martins Fontes.
Wertsch, J. V. (1985). *Vygotsky and the social formation of mind*. Harvard University Press. ISBN 0-674-94351-I.
Wilkinson, K. M., & McIlvane, W. J. (2001). Methods for studying symbolic behavior and category formation: Contributions of stimulus equivalence research. *Developmental Review*, *21*(3), 355–374. https://doi.org/10.1006/drev.2000.0526
Wittgenstein, L. (1953). Philosophical investigations. New York: MacMillan.
Woese, C. R. (1987). Bacterial evolution. *Microbiological Reviews*, *51*(2), 221-271. https://doi: 10.1128/mr.51.2.221-271.1987
Zilio, D. (2010). *A natureza comportamental da mente: behaviorismo radical e filosofia da mente* [The behavioral nature of mind: Radical behaviorism and philosophy of mind]. São Paulo: Editora UNESP; São Paulo: Cultura Acadêmica. <http://books.scielo.org>