A MODEL OF BASIC MENTAL STRUCTURES IN A GENERAL COGNITIVE ARCHITECTURE

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Abstract: *The development of cognitive modelling in artificial intelligence, as well as the aspiration toward more adequate architectural descriptions of human cognition, bring to the forefront the need for a clear understanding of the functioning and interaction of mental structures. In contemporary cognitive science, a large set of partially overlapping concepts is employed — schemas, scripts, heuristics, mental models, attention filters, and triggers — developed within the frameworks of different theoretical traditions and usually considered in isolation. This conceptual fragmentation hinders both the construction of consistent cognitive architectures and their systematic formalization and application in computational models.*

The present work proposes an integrative multilayered cognitive architecture, comprising an input, perceptual, transformational, and output layer, with a focus on the transformational core of cognition. Rather than introducing new mental constructs, the model systematizes an established set of structures by placing them within a unified architectural framework with clearly defined functional roles and interactions.

The transformational core is organized into three functionally distinguishable sublayers: (i) fundamental structures, considered as relatively specialized cognitive building blocks; (ii) integrative structures, responsible for combining and coordinating these elements into more complex configurations; and (iii) metacognitive structures, which carry out regulation, monitoring, and modification of processing within the layer. This organization is conceptualized as dynamic, with an emphasis on structured interactions and regulatory feedback, rather than on linear information processing.

The architecture treats mental structures as dynamic configurations, subject to development and reorganization over time. Compatibility with known mechanisms of neuroplasticity is taken as a functional constraint, without assuming direct neural realization. The indication of neural correlates serves to ground the model in available empirical data. The architecture includes a regulatory component, through which processes of volitional control, dependent on the subject, as well as affective and interoceptive modulators of cognitive dynamics, are modelled.

The main contribution of the work is an architecturally explicit and conceptually coherent framework, which allows different classes of cognitive structures to be described, compared, and related within a single transformational system. The model is conceived as a preparatory step toward future procedural descriptions and formalization, more specifically through the identification and specification of mental operations, through which structures are activated, combined, regulated, and transformed.

By uniting heterogeneous cognitive constructs within a common architectural perspective, the proposed framework provides a stable foundation for subsequent theoretical refinement and for the development of computational or mathematical models of cognitive processes.

Keywords: *Mental Structures, Cognitive Architecture, Hierarchical Organization, Adaptation and Control*

ITHEA Keywords*: A.1 Introductory, Survey, and Overview, I.2 Artificial Intelligence; I.2.4 Knowledge Representation Formalisms and Methods*

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1. INTRODUCTION

The development of cognitive modelling in artificial intelligence and the aspiration toward the construction of more adequate architectural descriptions of human cognition bring to the forefront the question of what mental structures participate in cognitive processing and in what manner they interact. Such a formulation requires systematic knowledge, critical analysis, and conceptual

relating of the accumulated knowledge in cognitive science, where different aspects of cognition are traditionally investigated in relative isolation.

1.1. Cognitive Science: Between Systemic Integration and Theoretical Fragmentation

Every aspect of human activity is the result of continuous coordination among multiple highly specialized cognitive functions. In their everyday experience, subjects rarely become aware of the exceptional flexibility and scope of their own functioning — from the instantaneous recognition of objects and automated navigation in a familiar environment to decision-making under uncertainty and the maintenance of continuity of personal identity. This broad spectrum of cognitive capacities is realized through the interaction of different functional subsystems: some are specialized in the processing of sensory patterns and information filtering, others, in the automation of sequences of actions, and others still, in the prognostic simulation of possible events and outcomes.

Although in subjective experience the cognitive process manifests as a unified whole, it is the product of an exceptionally complex and hierarchically organized system. The existence of such a multifunctional cognitive architecture is the subject of broad scientific consensus, formed over the last decades of intensive interdisciplinary research. Nevertheless, cognitive science, regarded as the totality of disciplines studying the mind, continues to be marked by significant theoretical fragmentation.

Over a century of purposeful research has revealed the existence of a broad spectrum of functional components of cognitive organization, which in the literature are frequently designated by the generalizing term mental structures. Each of them fulfils a specific role in the organization and stabilization of experience, such as:

- Schemas: structured patterns of knowledge, investigated from the pioneering work of Bartlett (1932) to contemporary neurobiological analyses of semantic organization (Binder et al., 2009).

- Scripts: procedural sequences of action, occupying a central place in research on social cognition and artificial intelligence following the contribution of Schank and Abelson (1977).
- Mental models: internal simulations of systems, key to research on logical reasoning (Johnson-Laird, 1983) and processes of conceptual change (Vosniadou, 1994; Carey, 2009).
- Heuristics: cognitive mechanisms for decision-making under uncertainty, extensively documented by Tversky and Kahneman (1974), as well as by Gigerenzer and Todd (1999).

Each of these research domains, alongside the fundamental processes of attention, memory, language, and affect, possesses its own established literature, methods, and terminology, which in their totality shape contemporary cognitive science, but rarely integrate into a unified architectural framework.

This theoretical diversity, however, gives rise to the serious challenge of disciplinary fragmentation. As early as the 1970s, Allen Newell (1973) expressed the concern that without unifying principles, cognitive science risks becoming a collection of isolated phenomena and particular experimental results. This argument brings to the forefront the need for comprehensive architectural models, capable of integrating different cognitive functions into coherent systems. Despite significant progress over the last decades, the construction of a unified theoretical framework that encompasses the full complexity of the cognitive process remains an open problem for contemporary cognitive science.

One of the main reasons for this is the focus of different research paradigms on limited aspects of cognition, which hinders interdisciplinary synthesis. For example:

- research on memory concentrates on the mechanisms of schematization and encoding (Bartlett, 1932; Rumelhart, 1980);
- theories of attention analyze filtering and selective processes (Broadbent, 1958; Posner & Snyder, 1975);
- models of decision-making emphasize heuristics and cognitive biases (Kahneman, 2011; Gigerenzer & Todd, 1999);

- research on cognitive development traces the dynamics of conceptual change (Carey, 2009; Vosniadou, 1994);
- neuroscience maps the network organization of the brain and the mechanisms of neuroplasticity (Sporns, 2011; Pascual-Leone et al., 2005).

Despite the contribution of each of these traditions, an integrative perspective that shows how the phenomena under consideration are articulated within a single cognitive architecture is rarely proposed.

1.2. The Need for an Integrative Architecture

Contemporary neuroscience regards the functioning of the human brain not as a collection of isolated modules, but as a highly integrated system of interconnected networks. This systemic principle is an established scientific fact, confirmed by large-scale empirical studies employing contemporary methods of functional imaging and electrophysiological analysis (fMRI, EEG, PET). The accumulated data indicate that the activity of any individual zone is in dynamic dependence on the global state of the network, which makes it problematic to regard cognitive processes as localized and autonomous events (Sporns, 2011; Varela et al., 1991).

Within this integrative perspective, cognitive schemas, mechanisms of selective attention, and hierarchically organized goals function as mutually bound components of a unified process. They do not operate sequentially or independently, but are coordinated through widely distributed neural networks, which maintain the current state of the cognitive system. The plasticity of these networks allows continuous reorganization under the influence of experience (Pascual-Leone et al., 2005), thereby ensuring the functional stability and continuity of conscious dynamics.

Achieving a comprehensive understanding of cognitive processes requires surpassing the analysis of isolated cognitive phenomena and transitioning toward an integrative conceptual framework. Such a framework should encompass the multiple functional subsystems, define their interrelationships and hierarchical organization, and connect psychological phenomenology with

its neurobiological substrate. Only in this way can the adaptive character of cognition be explained at the level of the system as a whole.

The development of such an integrative framework would have a fundamental contribution in several directions:

- In theoretical terms, it would allow the identification of common principles of organization of the cognitive system and would facilitate the transition from the description of individual phenomena to the analysis of their systemic interconnections and potential dependencies.
- In methodological respects, a unified conceptual basis would facilitate interdisciplinary dialogue through the introduction of shared terminology and directing the research focus toward the interaction between different cognitive structures.
- In applied terms, a systemic understanding of cognitive architecture would contribute to optimizing educational strategies (Bransford et al., 2000), increasing the precision of psychotherapeutic interventions (Beck, 1976; Hayes et al., 2012), the analysis of organizational cultures (Schein, 2010), and the design of interfaces that support human cognition (Norman, 1988).

1.3. Theoretical Architectures for Integration and Their Characteristics

The aspiration toward the construction of unified theories has a long history in cognitive science. In response to the need for systemic integration, Allen Newell developed SOAR — one of the first large-scale cognitive architectures, aimed at explaining the emergence of different cognitive functions from a single basic system (Newell, 1990; Laird, 2012). In parallel, John Anderson created ACT-R (Adaptive Control of Thought—Rational) — an influential architecture that integrates declarative, procedural, and working memory into a unified functional model (Anderson, 1993, 2007).

These architectures represent significant theoretical and computational achievements and continue to be primary tools in cognitive modelling and artificial intelligence. They provide powerful means for the simulation of human

behaviour, but encounter difficulties in fully reconciling psychological phenomenology with the dynamic plasticity of biological neural networks.

In the context of a comprehensive theory of the mind, several essential limitations become apparent. In the first place, these architectures are optimized primarily for the modelling of logical and goal-directed processes, which leaves in the background subjective experience and the phenomenological dimensions of cognition (James, 1890). In the second place, the dominant focus on information processing frequently excludes the meaning-generating aspects of cognition, related to the formation of personal identity, value structures, and individual worldview (Markus & Wurf, 1987; McAdams, 2001).

An additional challenge is represented by the integration of the subject as an active and self-aware system. The accumulated empirical data indicate that self-awareness and emotional states do not function as peripheral modules, but are deeply interwoven into all cognitive processes, including those traditionally defined as rational. Although this unity is widely acknowledged, its precise formal description remains one of the key open challenges for the systemic approach in cognitive science.

Alongside the SOAR and ACT-R architectures, other integrative approaches have been proposed in cognitive science, emanating from different theoretical perspectives:

- Embodied cognition emphasizes the inseparable bond between cognition and sensorimotor interactions with the environment (Varela et al., 1991; Clark, 1997).
- The theory of dynamical systems regards cognitive processes as self-organizing structures unfolding over time (Thelen & Smith, 1994).
- Predictive processing proposes a model according to which the brain functions as a prediction system, minimizing the error between expected and incoming signals (Friston, 2010; Clark, 2013).

These approaches illuminate key aspects of cognitive integration, but the question of the subjective continuity of the Self remains weakly explicated. Neurobiological research, for example, has shown that the brain generates endogenous rhythms, which function as internal temporal markers and become

interwoven with the processing of sensory information (Llinás, 2001). Such mechanisms are directly related to self-awareness and the subjective temporal organization of experience. Nevertheless, the temporal and frequency characteristics of these processes are rarely adequately integrated into existing formal models, primarily due to their high dynamic complexity.

1.4. The Proposed Integrative Architecture

The present work introduces a multilayered cognitive architecture — an integrative framework that synthesizes different research paradigms into a unified systemic organization. The architecture regards the cognitive system hierarchically, from signal transduction to the final manifestations of behaviour, and comprises four main layers:

- Layer 0 (Input Layer): the level of sensory-physiological input, in which signals from the external and internal environment enter the system.
- Layer 1 (Perceptual Layer): the level of automatic integration, at which raw sensory signals are organized into coherent perceptual representations.
- Layer 2 (Transformational Layer): the central level of processing, organized into three hierarchical sublayers and comprising ten types of functional structures (schemas, models, heuristics, etc.), which will be detailed in the following section.
- Layer 3 (Output Layer): the level of behavioural and mental manifestations, comprising thoughts, decisions, plans, actions, and consciously experienced emotional states.

Between the transformational and output layers, a system of executive functions is positioned, designated as *the cognitive supervisor*. This system realizes volitional control, goal-setting, monitoring, and regulation of cognitive activity (Miller & Cohen, 2001; Zelazo et al., 2003).

In the proposed approach, the cognitive supervisor models volitional action, possible in the presence of self-awareness (Self). It should be noted that the cognitive supervisor is not equated with the Self itself, but represents an architectural level through which processes of volitional control and regulation

are realized. It is intended to function in close dependence on the overall emotional and interoceptive state of the system. Although the formal modelling of this dynamic relationship remains an open challenge, within the framework of the present architecture it is explicitly marked as a critical component, connecting rational processes with the biological integrity of the subject.

The presented architecture aims to describe the dynamics of cognitive processes, proceeding from the principle that cognitive phenomena arise from interactions among multiple components at different levels of organization. The framework connects psychological phenomenology with neurobiological realization, as for each type of functional structure in Layer 2 the corresponding neural substrates and network organizations are identified (Sporns, 2011; Casey et al., 2005).

The approach distances itself from strict reductionism without rejecting it, placing the subject in the role of an integral organizational centre of the system. In this context, the cognitive supervisor is not regarded as an abstract algorithm for control, but as a functional level through which volitional and regulatory processes are realized, dependent on the overall emotional and interoceptive state of the system.

Through the explicit description of the hierarchical and temporal dependencies between the layers, the present work proposes an architectural framework that simultaneously takes into account the empirical data on neuroplasticity (Kolb & Whishaw, 2015) and prepares the ground for future formalization. In particular, the architecture is constructed in such a way as to allow the introduction of mathematical apparatus, including in terms of category theory, for the description of a comprehensive, adaptive cognitive system.

1.5. Aim and Structure of the Exposition

The main aim of the present work is to introduce the conceptual framework of *the Multilayered Cognitive Architecture* with a view to its subsequent mathematical and formal modelling. The focus is placed on the systemic integration of the functional structures from Layer 2, since it is precisely at this hierarchical level that the most intensive cognitive transformations occur and

the richest empirical basis for theoretical synthesis and formalization is available.

The architecture has been developed as an engineering description of the cognitive system, which aims to make explicit the structural components, their interactions, and hierarchical dependencies, so that at a subsequent stage the introduction of a rigorous mathematical apparatus and program realization may become possible.

The exposition is structured as follows:

- Chapter 2 defines the hierarchical organization of the architecture, comprising the four functional layers and the cognitive supervisor. The mechanisms of feedback and multidirectional interactions among the components are described, presented through a graphical model of the system.
- The conclusion summarizes the theoretical implications of the proposed framework and outlines concrete directions for future development, aimed at systematic mathematical formalization and subsequent program realization.

Through the focus on functional interconnectedness in Layer 2, the present work represents a first step toward the construction of a coherent architectural model of cognition, the full formal characterization and extension of which toward the remaining layers will be the subject of subsequent research.

2. Structure of the Multilayered Cognitive Architecture

The consideration of cognition as a dynamic and integrated system requires the definition of a functional architecture that describes the hierarchical and dynamic dependencies between its components. As was substantiated in Chapter 1, the Multilayered Cognitive Architecture (MCA) proposes a model of interaction, in which sensory processing, cognitive transformation, and executive control unfold in real time as mutually modulating processes.

2.1. General Architectural Schema

The architecture of the structural model is presented in the schema of Figure 1. The processes are systematized at four functional levels and one coordinating system.

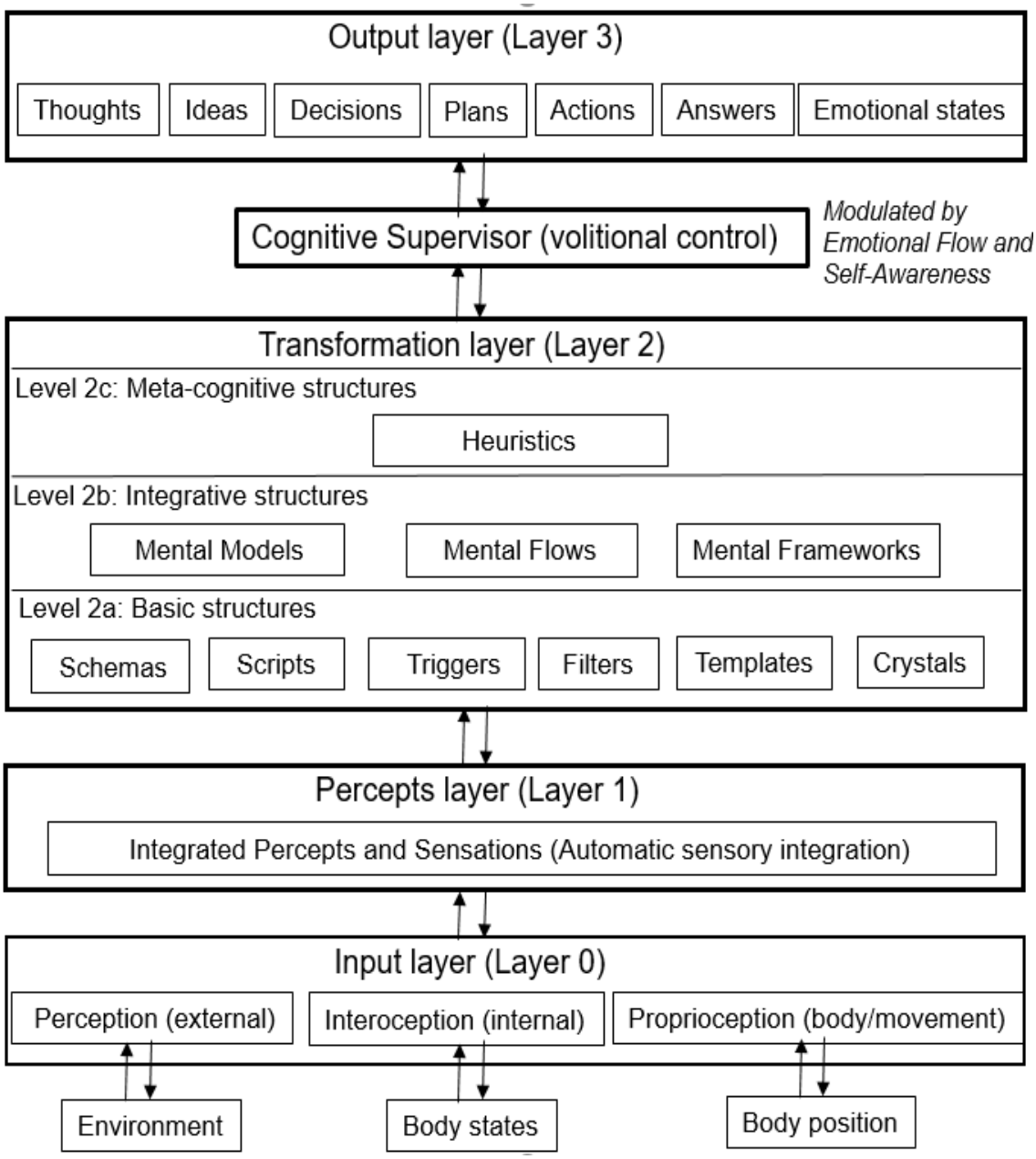


Figure 1. Architecture of the Proposed Model

It is important to emphasize that these levels do not represent isolated modules or ontologically distinguished domains, but designate dominant modes of processing, characterized by specific types of transformations and interactions:

- Layer 0 (Input Layer): encompasses the mechanisms of exteroception, interoception, and proprioception, through which the system receives signals about its external and internal state.
- Layer 1 (Perceptual Layer): carries out the automatic integration and preliminary organization of sensory signals into coherent percepts and sensations.
- Layer 2 (Transformational Layer): composed of three hierarchically organized sublayers, in which the essential conceptual, procedural, and meaning-generating processing is realized.
- Layer 3 (Output Layer): includes the final cognitive, behavioural, and consciously experienced mental manifestations of the system — thoughts, decisions, plans, actions, and emotional experiences.

It must be explicitly emphasized that this hierarchical organization does not presuppose strict linearity of the interactions between the levels. The layers of Figure 1 designate functional levels of dominant types of processing, rather than isolated modules. The interactions between the levels are bidirectional, nonlinear, and temporally dependent. The architecture includes feedback loops, horizontal interactions, and temporal cycles, which make it impossible to describe the cognitive process as a unidirectional flow or as a composition of simple functional dependencies.

A key element in the architecture is the Cognitive Supervisor, positioned between the transformational and the output layer. In accordance with the established scientific consensus (Miller & Cohen, 2001), it functions as a system of executive control, ensuring monitoring, hierarchical regulation, flexible goal-setting, and adaptation of behaviour with respect to the current context and the internal state of the system. In the present model, the supervisor is not regarded as a separate module or a central "controller", but as a dynamic regulatory structure, arising from the interaction among multiple cognitive and emotional processes.

A particularly important characteristic of the MCA is adaptive feedback — an iterative cycle, in which the outputs of the system are reintegrated as new incoming signals, ensuring the mechanisms of learning, self-regulation, and optimization (Carver & Scheier, 1998). These cycles are realized at different temporal scales and encompass both short-term corrections and long-term structural changes.

The system is characterized by nonlinear and bidirectional interactions between all functional levels. The cognitive process does not represent a unidirectional information flow, but a dynamic interaction between bottom-up processes, in which the lower levels set the constraints and possibilities of the environment, and top-down processes, in which the higher levels modulate perception, interpretation, and the choice of action (Varela et al., 1991).

This systemic perspective corresponds to the contemporary scientific consensus regarding the brain as a highly integrated network, in which cognitive phenomena arise as a result of complex interactions among multiple components. The proposed model aims to formalize this dynamics through a hierarchical, but not strictly functionalist structure, which takes into account simultaneously the local specialization and the global connectedness of the cognitive system.

2.2. Layers in the Architectural Schema of the Model

In the following subsections, the four functional layers of the architecture, the role of the Cognitive Supervisor, the mechanisms of adaptive feedback, and the nature of the multidirectional interactions between the levels will be examined in detail. The exposition does not aim at an exhaustive description of all cognitive processes, but at a conceptual structuring of their functional dependencies and dynamic interrelationships.

The main aim of this section is to provide an analytical framework that allows the tracing of the manner in which different types of mental structures and processes are articulated in real time. In this sense, the architecture is not regarded as a mechanical aggregate of components, but as a self-organizing

system, in which cognitive phenomena arise from the interaction between multiple levels of processing.

Through this perspective it becomes possible to investigate how the integration of perceptual, conceptual, emotional, and executive processes maintains the continuity, adaptiveness, and meaning-generating character of subjective experience, which in the present framework we designate by the term consciousness, without presupposing its reduction to a separate structure or a localized mechanism.

2.2.1. Layer 0: Input Layer

At the foundation of the cognitive architecture is the Input Layer (Layer 0) — the functional level at which signals from the external environment and from the internal state of the body enter the cognitive system. This layer does not represent a passive "channel for nerve-coded signals", but a system for primary capture, transduction, and initial organization of the incoming signals, which sets the constraints and possibilities for all subsequent cognitive processes.

Layer 0 includes three main types of inputs, which function in parallel and in close interconnection:

2.2.1.1. Perception (exteroception / external perception)

External perception begins with the transduction of certain physicochemical signals from the surrounding environment into neural impulses through the peripheral sensory receptors: visual, auditory, tactile, thermo receptors, chemo-receptors for olfaction and taste, and others. Contrary to the intuitive notion of a passive reception of stimuli, this process represents an active encoding by the nervous system, through which objects, events, and changes in the environment are represented.

The primary processing and integration of sensory signals is carried out hierarchically — from the receptive fields toward the subcortical structures, including the nuclei of the brainstem and the thalamus (with the exception of the olfactory system), and reaches the primary and associative zones of the neocortex. These mechanisms of hierarchical encoding, filtering, and

subcortical integration are well documented in contemporary neuroscience and constitute a fundamental postulate for the understanding of the sensory systems.

It is important to note that even at this level the processing is context-sensitive and subject to modulation from higher levels, which underlines the nonlinear character of the input flow.

2.2.1.2. Interoception (interoception / internal perception)

Interoception represents a process of capture, encoding, and continuous monitoring of signals from the internal environment of the organism, critical for the maintenance of life and adaptive functioning — such as heart rate, breathing, blood pressure, hunger, thirst, visceral pain, and hormonal states.

This system does not serve solely for physiological regulation, but forms the basis of the emotional experience and bodily self-awareness. The interoceptive signals are processed by evolutionarily ancient brain structures, including the brainstem, the thalamus, the amygdala, and the insular cortex. Their integration in the associative cortical zones is a key to the formation of affective states, motivation, and the mechanisms of homeostasis and allostasis.

Within the framework of the architecture, interoception plays the role of a continuous modulator of cognitive processes, providing the connection between the biological integrity of the organism and the higher cognitive functions.

2.2.1.3. Proprioception (proprioception / bodily position and movement)

Proprioception is the process through which the system captures the position, movement, and tension of the body in space. It is realized through specialized receptors in the muscles, tendons, and joints, including muscle spindles and Golgi tendon organs, which encode and transmit nerve signals regarding the length and tension of the tissues.

The primary integration of these signals is carried out at the level of the spinal cord and the nuclei of the brainstem, where a dynamic body schema is formed. Further coordination is realized through the cerebellum and projections toward

the somatosensory cortex, ensuring precise motor control, coordination, and a sense of bodily orientation.

The proprioceptive input is critical not only for motor behaviour, but also for the formation of spatial cognition and the subject's sense of embodiment.

2.2.1.4. The dynamic cycle of interaction

The three sensory flows — exteroception, interoception, and proprioception — function within the framework of a continuous dynamic cycle of interaction between the organism and the environment. This cycle is not exhausted by conscious actions or volitional control, but includes a broad spectrum of automatic and partially unconscious regulatory processes.

Feedback is realized both through conscious motor control and through automatic integration and matching of signals from different modalities in subcortical and cortical neural networks. A significant part of these processes occurs outside the focus of conscious attention and is not accessible to direct introspection, despite exerting a substantial influence on the current cognitive and emotional state of the system.

The physical signals registered from the environment continuously modulate the bodily states, which in turn generate ascending encoded signals toward the cognitive system. This cyclic and bodily conditioned dynamics represents a fundamental neurobiological principle and lies at the basis of the contemporary understanding of embodied cognition, which over the last decades has established itself as a stable scientific consensus, supported by empirical data (Varela et al., 1991).

2.2.2. Layer 1: Perceptual Layer

The incoming signals from Layer 0 are processed in the Perceptual Layer (Layer 1) — the functional level at which the results of sensory transduction and primary bodily signalling are organized and integrated into coherent percepts and sensations. This process does not represent a mechanical transformation of "raw data", but an active, automatic, and context-sensitive form of processing, which occurs before access to conscious attention.

The sensory integration at this level is carried out involuntarily and pre-reflexively, that is, below the threshold of conscious control, which allows the cognitive system to construct a stable and continuous perceptual picture of the world before the engagement of the higher conceptual processes (Treisman, 1960). It is precisely at this level that the primary experience of "what we see, hear, or feel" arises, without it yet being conceptually interpreted or verbalized.

Within the framework of the Perceptual Layer, the brain performs complex operations, including noise filtering, enhancement of relevant features, detection of movement, contours, and spatial relations, as well as intramodal and intermodal integration of signals from different sensory systems (Neisser, 1967). These processes lead to the formation of relatively stable perceptual objects, which serve as input for further cognitive transformation.

A classic example of automatic multimodal integration at this level is the McGurk effect, in which visual information about the movement of the lips and auditory information about the produced sounds are combined into a unified perceptual experience, even when the two sources are in conflict. This phenomenon illustrates that perceptual organization is not a simple sum of modalities, but the result of a dynamic interaction between sensory flows.

From a neurobiological perspective, the Perceptual Layer corresponds to the primary and secondary sensory areas of the cerebral cortex, as well as the associated subcortical structures that participate in the early organization and synchronization of sensory information. These networks automatically construct the perceptual world, which subsequently becomes accessible to the higher cognitive processes in the transformational layer (Sporns, 2011).

It is important to emphasize that, although the processing in Layer 1 occurs without conscious control, it is not independent of the higher levels. Perceptual organization is subject to modulation by top-down processes, which can alter the sensitivity, selection, and interpretation of incoming signals depending on the context, goals, and prior experience of the system.

2.2.3. Layer 2: Transformational Layer

The Transformational Layer represents the central functional level of the proposed cognitive architecture, in which perceptual structures undergo systematic processing, reorganization, and combination. It is precisely at this level that the greater part of the processes usually associated with "cognitive activity" is realized — the formation of meanings, procedures, goals, and internal models of the environment.

Within the framework of the architecture under consideration, the different types of mental structures do not function at a single homogeneous level, nor do they possess an equivalent functional status. Instead, they are organized into three interconnected hierarchical sublevels, which reflect different degrees of abstraction, integration, and regulation in cognitive processing.

2.2.3.1. Level 2a: Fundamental Structures (Basic Structures)

Level 2a of the transformational layer includes fundamental mental structures, which realize the primary level of cognitive organization over the perceptual representations arriving from the Perceptual Layer. These structures ensure local operations of recognition, association, selection, and stabilization, necessary for subsequent integration and control by the higher levels.

The fundamental structures at this sublevel are functionally specialized and relatively autonomous, but in actual cognitive functioning they operate in a coordinated configuration, with their interaction being modulated by the structures of the higher sublevels of the transformational layer.

Within the framework of the proposed model, the following main types of fundamental structures are distinguished:

- **Schemas** represent stabilized structures that organize representations of objects, situations, and concepts. They encode typical configurations of features and relations and allow rapid categorization and interpretation of new inputs through comparison with already available cognitive structures (Bartlett, 1932; Rumelhart, 1980). From a functional

perspective, schemas act as constraints on the interpretive space, reducing uncertainty in perceptual inputs.

- **Scripts** are procedural structures that organize sequences of actions or cognitive operations over time. They maintain automated execution of known activities and routine interactions, reducing the need for explicit planning of each individual step (Schank & Abelson, 1977). Scripts can be regarded as temporal operators over cognitive states.
- **Triggers** represent rapid associative mechanisms that link certain configurations of incoming signals with previously prepared cognitive, emotional, or behavioural responses. Their main function is the minimization of response latency in situations of high significance or risk (Bargh & Chartrand, 1999).
- **Filters** are structures for selective processing that modulate the permeability of the signal flow toward subsequent stages of cognitive processing. They determine which aspects of the current state will be enhanced, suppressed, or ignored, and in this way realize mechanisms of attention and preliminary interpretation (Broadbent, 1958; Posner & Snyder, 1975).
- **Templates** are generative structures that define admissible spaces of transformations and combinations among elements of cognitive content. They allow the construction of new configurations, while simultaneously maintaining structural coherence and constraints, which makes them key to the creative and productive aspects of cognition (Hofstadter, 2001).
- **Crystals** represent relatively stable structures that encode long-term value orientations, self-reference, and aspects of personal identity. They introduce temporal continuity and consistency into cognitive dynamics, exerting a modulating influence on the selection and interpretation of content (Rokeach, 1973; Markus & Wurf, 1987).

The fundamental structures of Level 2a do not function as isolated modules, but as interacting components within the framework of a dynamic cognitive system. Their coordination, activation, and combination are carried out by the integrative and metacognitive structures of the higher sublevels, which allow flexible and context-sensitive cognitive behaviour (Casey et al., 2005).

2.2.3.2. Level 2b: Integrative Structures

The integrative structures of Level 2b realize the coordination and composition of the fundamental mental structures from Level 2a, allowing the formation of more complex, stable, and functionally organized cognitive configurations. While the fundamental structures carry out locally specialized operations, the integrative structures determine the manner in which these operations are combined, synchronized, and applied in context.

The integration at this level should not be understood as a simple sum of components, but as a structured organization, in which the interaction between elements gives rise to new functional properties, inaccessible at the lower level.

Within the framework of the proposed model, the following main types of integrative structures are distinguished:

- **Mental Models** represent dynamic simulation structures that coordinate different types of fundamental structures — including schemas, scripts, and filters — into relatively stable representations of objects, situations, or systems. They allow forecasting, explanation, and planning through internal simulation of possible states and transitions (Johnson-Laird, 1983; Baddeley, 2012). From a functional perspective, mental models act as integrative operators over multiple cognitive elements.
- **Mental Flows** are structures that organize cognitive processes over time, determining the sequence, transitions, and duration of activated states. They ensure the temporal coherence of thought and perceptual dynamics, integrating activations of triggers, scripts, filters, and models into a continuous temporal organization (James, 1890; Csikszentmihalyi, 1990).
- **Mental Frameworks** represent higher-order structural contexts that define the admissible ways of constructing, interpreting, and applying cognitive structures. They act as systems of constraints and allowances, which modulate what types of models, flows, and fundamental structures can be activated and what relations among them are considered valid (Kuhn, 1962; Lakoff, 2002).

The interactions between integrative and fundamental structures are bidirectional. Integrative structures are realized through compositions of fundamental operations, while simultaneously determining the context and constraints within which fundamental structures can be activated and combined. It is precisely this level of organization that ensures the transition from local cognitive operations to globally organized and semantically coherent cognitive functioning (Sporns, 2011).

2.2.3.3. Level 2c: Metacognitive Structures

The highest sublevel of the Transformational Layer includes metacognitive structures — mechanisms that are not directed toward the processing of external stimuli or toward the construction of representations of the world, but toward the monitoring, regulation, and optimization of the cognitive processes themselves. They realize the system's ability to operate upon its own functioning, which in cognitive science is designated as cognition about cognition.

The metacognitive structures modify the manner in which the fundamental and integrative structures are activated, combined, and used, regulating the allocation of cognitive resources, the level of detail of processing, and the criteria for the termination or continuation of a given process.

Within the framework of the proposed model, a key representative of this sublevel is:

- **Heuristics —** generalized regulatory principles that govern cognitive processing through simplification, prioritization, and limiting of computational effort (Simon, 1956; Gigerenzer & Todd, 1999; Kahneman, 2011). Heuristics do not represent specific schemas, models, or procedures, but meta-rules that determine how and to what extent these structures are to be used in a given context.

Heuristics can modulate the functioning of all lower levels of the Transformational Layer. They influence the selection of active schemas, the degree of detail of mental models, the duration and direction of mental flows, as well as the relevance of the frameworks within which the situation is interpreted.

From this perspective, heuristics act as operators for the management of cognitive resources, rather than as content representations.

A characteristic feature of heuristics is that their action frequently occurs automatically and outside conscious control, although their effects can be recognized at a later stage. For example, the availability heuristic does not add new representations to memory, but determines which available representations will be preferred in decision-making. Similarly, the principle of satisficing does not describe a search procedure, but a criterion for the termination of cognitive search.

In this way, the metacognitive structures of Level 2c realize the adaptive control of cognitive complexity, allowing the system to function effectively under limited resources and in conditions of uncertainty. They ensure the flexibility of the cognitive process, not by introducing additional content, but through the modulation of the manner in which existing structures are used.

2.2.4. Interactions between the Sublevels of Layer 2

The sublevels of the Transformational Layer (Levels 2a–2c) form a hierarchically organized, but dynamic system, in which cognitive structures interact through composition, regulation, and contextual constraint. The hierarchy here should be understood as an organizational principle, rather than as a unidirectional chain of control.

2.2.4.1. Composition: from Level 2a toward Level 2b

The fundamental structures of Level 2a (schemas, scripts, triggers, filters, templates, and crystals) function as basic cognitive operations and representations. The integrative structures of Level 2b arise through the composition and coordination of these elements. Mental models, flows, and frameworks do not represent a new type of content, but a higher level of organization, in which the fundamental structures are combined into stable functional configurations. In this way, Level 2b realizes the transition from local cognitive operations to systemically organized cognitive functioning.

2.2.4.2. Regulation: from Level 2c toward Levels 2a and 2b

The metacognitive structures of Level 2c do not participate directly in the composition of cognitive content, but carry out regulation of processing. Heuristics act as meta-operators that modulate the activation, duration, and detail of the processes in Levels 2a and 2b. They set criteria for prioritization, termination, and economy of cognitive resources, thereby ensuring adaptiveness under limited computational capacity.

2.2.4.3. Bidirectionality and Horizontal Interactions

The interactions between the sublevels are bidirectional. The accumulated structures and constraints of the lower levels determine the possible forms of integration and regulation of the higher ones, while the higher levels modulate the activity and combinations of the lower ones. In addition, at each sublevel horizontal interactions between structures of the same type are observed, which contribute to the contextual sensitivity and internal coherence of the cognitive dynamics.

2.2.4.4. Boundary of the Transformational Layer

It is important to emphasize that the internal dynamics between Levels 2a–2c does not exhaust the mechanisms of cognitive control in the architecture. Although the metacognitive structures regulate processing within the Transformational Layer, they do not realize volitional control, goal-setting, and global monitoring. These functions belong to the *Cognitive Supervisor*, which is positioned outside Layer 2 and carries out coordination between the transformational processes and the behavioural outputs of the system.

In this sense, Layer 2 realizes the internal organization and adaptiveness of cognitive processing, while the Supervisor ensures its global directing and integration with the acting subject.

2.2.5. Cognitive Supervisor

Between the Transformational Layer and the Output Layer is situated a key architectural component: *the Cognitive Supervisor*, which models the presence

of volitional control. In the proposed model it corresponds to the system of executive functions (the capacity for conscious, goal-directed directing and coordination of cognitive processes) and is associated primarily with the dorsolateral and medial prefrontal cortex (Miller & Cohen, 2001).

Unlike the metacognitive mechanisms of Level 2c, which regulate the processes within the Transformational Layer, the Cognitive Supervisor determines when, why, and with what goal these processes are activated, reconfigured, or terminated. It functions as a global control mechanism that coordinates the transformational processes with respect to current goals and behavioural requirements.

The main functions of the Cognitive Supervisor include:

- Goal-setting: determining and maintaining goals and priorities;
- Monitoring: observation of the current cognitive processes and their results (Zelazo et al., 2003);
- Strategy regulation: adapting the cognitive strategies employed on the basis of feedback;
- Inhibition: suppression of automatic but inadequate or counterproductive responses;
- Task switching: flexible redirection of attention and resources among competing tasks.

Neurobiologically, the Cognitive Supervisor corresponds to the functional organization of the prefrontal cortex — a system which is critical for planning, decision-making and volitional control (Casey et al., 2005). Architecturally, it represents an interface between the internal cognitive dynamics and external behaviour.

In this way, while the Transformational Layer ensures the internal organization, adaptiveness, and integration of cognitive content, the Cognitive Supervisor realizes its goal-directed utilization in the context of action, choice, and self-regulation.

2.2.6. Layer 3: Output Layer

The Output Layer represents the level, at which cognitive processes are actualized as conscious experience and/or external behaviour. It is not an autonomous computational module, but the point at which the results from the transformational layer — under the regulation of the cognitive supervisor — become phenomenally accessible to the subject or are realized in action.

Typical manifestations of the Output Layer include:

- *Conscious thoughts* — verbal or non-verbal mental contents, accessible to introspection;
- *Ideas and insights* — newly organized cognitive configurations, experienced as meaningful wholes;
- *Decisions* — conscious choices between alternatives, frequently accompanied by a sense of intention;
- *Plans* — temporally structured representations of future actions;
- *Actions* — realized motor behaviour in the external environment;
- *Responses* — verbal or behavioural reactions to questions and problems;
- *Consciously experienced emotional states* — subjectively experienced affective states and moods.

These manifestations represent the phenomenal and behavioural "summit" of the cognitive architecture. They do not exhaust the processes that are occurring, but are those aspects which reach conscious experience or become observable to the external world.

It is important to emphasize that the Output Layer is not a terminal point in a linear chain. The realized actions alter the environment and in this way generate new exteroceptive inputs. Conscious thoughts and decisions can activate new associations and cognitive structures. Consciously experienced emotional states are reflected in bodily regulation and return as interoceptive signals. In this way the architecture functions as a continuous closed cycle, rather than as a sequential processing line.

Emotions occupy a particular place in this dynamics. While consciously experienced emotional experiences can be regarded as outputs of Layer 3, affective processes as a whole are distributed throughout the entire architecture — from the perceptual inputs to the cognitive supervisor. The Supervisor exercises volitional control not in an emotional vacuum, but under continuous affective modulation, including from unconscious emotional signals.

2.3. Adaptive Regulation and Volitional Control

2.3.1. Bidirectional Interactions in the Cognitive Architecture

An essential characteristic of the presented architecture is the presence of bidirectional interactions between all of its layers. Cognitive processes do not represent a unidirectional flow from input to output, but an iterative dynamics, in which processing is modulated both by the higher and by the lower levels of organization (Varela et al., 1991).

In the top-down direction, the higher levels of the architecture modulate the processing of the lower ones. Conceptual frameworks and active models shape expectations and set the context for interpretation, thereby influencing the selection and organization of perceptual information (Neisser, 1967; Kuhn, 1962). In this process, the Cognitive Supervisor exercises control over attention and priorities, regulating the access of information to further processing (Posner & Snyder, 1975).

In the bottom-up direction, signals from the perceptual and bodily level can constrain or correct the higher cognitive structures. Discrepancies between expectations and actual perceptual signals can trigger the revision of active models (Johnson-Laird, 1983). Affective and bodily states can attract attention and influence evaluation and decision-making, including in situations in which volitional control is partially limited (Damasio, 1994; Bargh & Chartrand, 1999).

This bidirectional iterative dynamics ensures simultaneously the stability and adaptiveness of the cognitive system. It allows behaviour and experience to be directed by goals and internal organization, while at the same time remaining sensitive to changes in the environment and the bodily state (Sporns, 2011).

2.3.2. Adaptive Regulation and Control Mechanisms

An essential element of the multilayered cognitive architecture is the mechanism of adaptive regulation, which connects the Transformational Layer, the Cognitive Supervisor, and the Output Layer into a unified, self-referential control cycle (Figure 2).

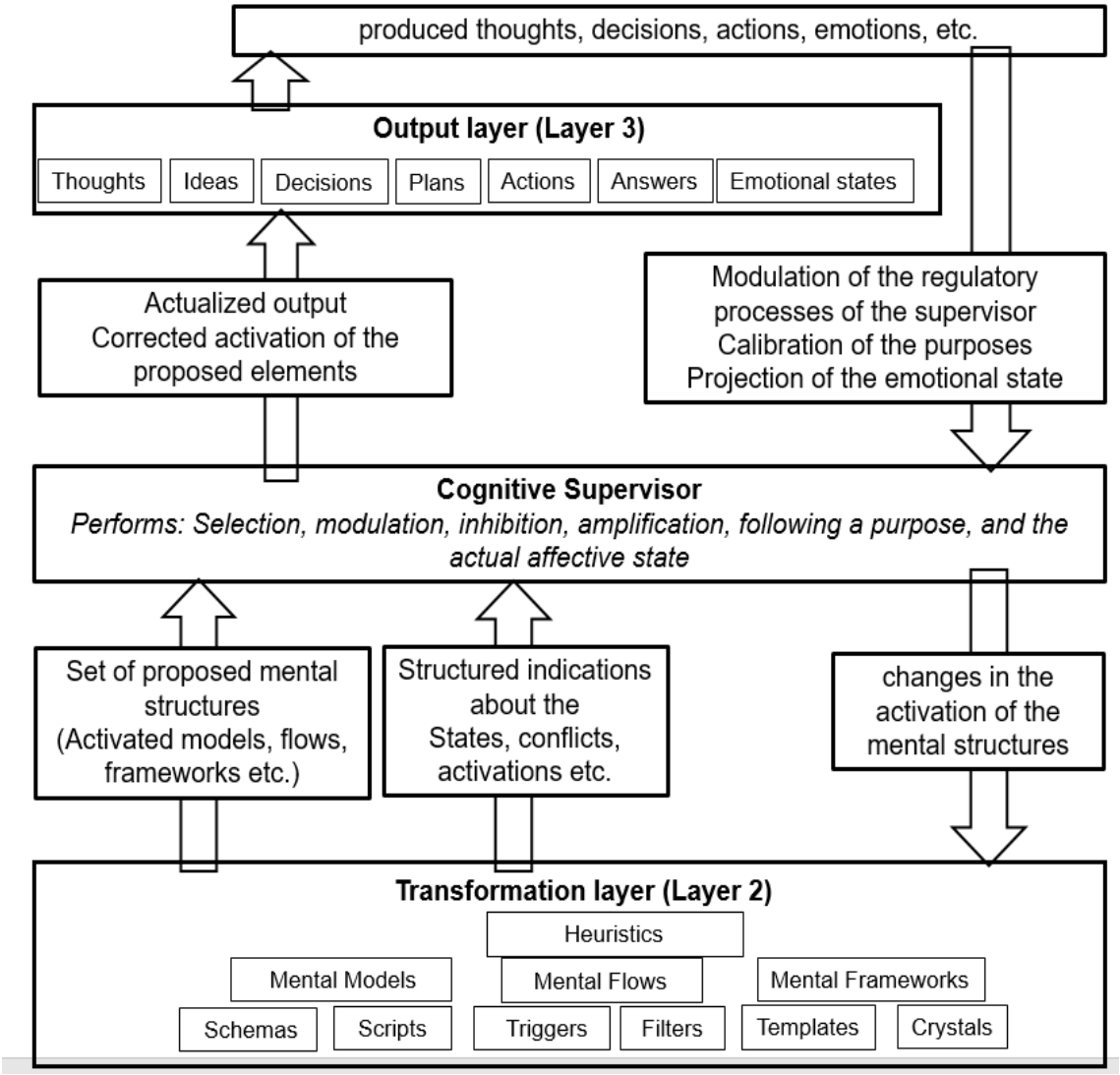


Figure 2. Closed Adaptive Control Cycle

This mechanism ensures the transition from internal cognitive organization to conscious content and behaviour, as well as their subsequent utilization for regulation and learning.

After the cognitive system actualizes a certain output — a conscious thought, decision, plan, action, or consciously experienced emotional state — the Cognitive Supervisor registers the consequences of this actualization and evaluates them with respect to the current goals and priorities. The goals in the system do not represent externally given parameters, but internally constructed and dynamically maintained referential states. They reflect the intentions, values, and contextual priorities of the subject and are subject to continuous modification under the influence of experience and affective regulation.

The feedback toward the Cognitive Supervisor represents evaluative and modulating signals. These include the perceptual consequences of the actions, bodily and interoceptive changes, affective reactions, as well as signals of discrepancy between the expected and the realized (Carver & Scheier, 1998). Through them the supervisor evaluates the adequacy of the current cognitive strategies and control decisions in the specific context.

Upon establishing a discrepancy, the supervisor can reconfigure the cognitive functioning through regulatory actions such as the redirection of attention, the alteration of active strategies or heuristics, the enhancement or suppression of automatic responses, as well as the updating of priorities and goals. These interventions modulate the selection and coordination of the cognitive structures in the Transformational Layer.

The cycle of evaluation and regulation represents the functional mechanism of adaptation and learning from experience. Repeated regulation over time leads to stable changes in the cognitive structures and control strategies, realized through neuroplasticity (Pascual-Leone et al., 2005), without learning being reduced to purely neural processes. In this sense, adaptive regulation connects volitional control, affective modulation, and long-term cognitive organization into a single dynamic process.

The interaction between the Transformational Layer, the Cognitive Supervisor, and the Output Layer (Figure 2) can be understood as a cycle of selection, realization, and regulation.

Layer 2 generates multiple parallel cognitive structures and possible interpretations, while the Cognitive Supervisor exercises control over their selection, prioritization, and temporal coordination.

The Output Layer represents the actualization of this control — the moment at which the selected configurations manifest as conscious content and behaviour.

It should be emphasized that Figure 2 presents schematically the architectural organization of the model and does not aim to reflect the full dynamic and multidimensional load of the envisaged processes, including the temporal evolution, affective modulation, and plastic changes of the underlying structures.

The realized outputs generate adaptive feedback toward the supervisor, through which future selection and regulation are reconfigured, leading to stable changes in cognitive organization.

2.4. Summary

The presented architecture conceptualizes human cognition not as a collection of isolated modules, but as an integrated, multilayered, and dynamic system, in which different levels of organization interact through iterative and bidirectional processes (Sporns, 2011). Each layer performs specific functions, but cognitive functioning arises from their coordination and mutual regulation.

The architecture describes a successive, but non-linear transition from perceptual and bodily processing toward transformational cognitive structures, volitional control, and conscious outputs in the form of thoughts, decisions, actions, and emotional experiences (James, 1890; Miller & Cohen, 2001). A key element in this organization is the Cognitive Supervisor, which carries out "volitional control" through the selection, prioritization, and coordination of cognitive structures in accordance with internally constructed goals and contextual priorities.

The goals in the system are not treated as external parameters, but as dynamic referential states, maintained and updated in the course of cognitive functioning. Through adaptive regulation, these goals exert influence over the entire architecture, modifying cognitive strategies and the manner in which the system responds to perceptual, bodily, and affective signals.

Affect occupies a structural place in the architecture, participating both in the modulation of perception and attention, and in the regulation of goals and "volitional control". In this way, emotional and bodily states are modelled as integral components of cognitive dynamics.

The adaptive feedback between the outputs of the system and the Cognitive Supervisor ensures the mechanism of learning and long-term reorganization through neuroplasticity (Pascual-Leone et al., 2005), without cognitive adaptation being reduced to purely neural changes. The bidirectional interactions between the layers guarantee simultaneously the stability and flexibility of the system.

An important result of this conceptualization is that the architecture provides a clear basis for subsequent formalization. The distinguished layers, transformational mechanisms, and regulatory cycles define structural relations that are compatible with abstract mathematical descriptions. In particular, they allow interpretation within the framework of category theory, in which cognitive structures can be modelled as objects, the transformations between them as morphisms, and adaptive regulation — in terms of functors and compositions between categories. This perspective outlines a possibility for future formal description of cognitive dynamics, without the present work introducing a specific mathematical apparatus.

In this sense, the architecture is not only a descriptive model of cognition, but a metacognitive framework, which allows for the systematic analysis, modelling, and goal-directed intervention in different aspects of cognitive functioning. It serves as a map of cognitive organization, which allows the identification of the levels, mechanisms, and regulatory processes relevant to different theoretical, empirical, and formal research objectives.

3. Conclusion

In the present work, a model of a *Multilayered Cognitive Architecture* has been presented, with the analytical focus placed on the Transformational Layer (Layer 2) — the functional level at which the transformation of perceptual representations into meaningfully organized cognitive structures is carried out. Layer 2 has been conceptualized as a central link in the architecture, which ensures the connection between perceptual processing, regulatory mechanisms, and conscious cognitive and behavioural outputs.

The model proposes a manner in which ten main types of mental structures — schemas, scripts, triggers, filters, templates, crystals, mental models, mental flows, mental frameworks, and heuristics — can be organized into three hierarchically connected sublayers. This organization allows a systematic description of the interactions between different levels of cognitive processing and provides an integrated framework for the analysis of cognitive dynamics, without reducing it to separate mechanisms or localized functions.

3.1. Contributions

The present work contributes to cognitive modelling in artificial intelligence through conceptual analysis and systematization of cognitive processes and mental structures, developed up to this point predominantly within the frameworks of separate theoretical traditions. The main contributions can be summarized as follows:

1. *It formulates an integrated architectural framework for the description of the Transformational Layer (Layer 2) as a central level of cognitive processing.*

   Within this framework, different types of mental structures — schemas, scripts, triggers, filters, templates, crystals, mental models, mental flows, mental frameworks, and heuristics — have been conceptualized as functionally distinguished, but coordinated components of a unified transformational system. This allows their joint description and functional relating, without reduction to one specific theoretical paradigm (Newell, 1973).

2. *It proposes a conceptual distinction of three functionally different sublayers within Layer 2 — fundamental, integrative, and metacognitive structures.*

   This distinction ensures a systematic manner of describing different levels of cognitive organization within a single architecture: the fundamental structures as relatively specialized building blocks; the integrative structures as mechanisms for their combination into more complex configurations; and the metacognitive structures as means for the regulation and modification of processing. The hierarchical organization has been conceptualized as dynamic, rather than static, with the interactions between the sublayers maintaining the adaptiveness of the system (Simon, 1962; Sporns, 2011; Varela et al., 1991).

3. *It positions the proposed architecture with respect to contemporary data from cognitive neuroscience, without introducing a reductionist explanation.*

   For each type of mental structure from Layer 2, characteristic classes of neural correlates described in the literature have been indicated (e.g., Binder et al., 2009; Graybiel, 2008; LeDoux, 2000; Posner & Petersen, 1990; Baddeley, 2012; Baars, 1988; Buckner & Carroll, 2007). This relating has a clarifying and constraining function — it serves to clarify the functional scope of the model and to avoid interpretations in which the cognitive structures might be understood as purely abstract or detached from the empirical context.

4. *It integrates neuroplasticity as a structural principle in the description of the cognitive architecture.*

   The mental structures in Layer 2 are treated not as fixed units, but as dynamic configurations, subject to development, stabilization, and reorganization over time (Pascual-Leone et al., 2005; Kolb & Whishaw, 2015). Neuroplasticity has been included as a conceptual condition for the understanding of change, learning, and adaptation, without being regarded as the subject of independent empirical investigation.

5. *It introduces an architectural description of closed regulatory interactions within Layer 2.*

   Cognitive processes have been described as the result of structured feedback between different types of mental structures and sublayers, rather than as linear information processing. This allows adaptiveness, contextual sensitivity, and regulation to be regarded as internal properties of the architecture.

6. *It provides a conceptually clarified basis for subsequent formalization of cognitive processes.*

   The clear distinction of structural types, transformational mechanisms, and regulatory cycles creates preconditions for formal modelling of cognitive dynamics, including of adaptation and volitional control, without reduction to either purely symbolic or purely neural descriptions.

3.2. Future Research Directions

A natural continuation of the presented model is the systematic description of the mental operations through which the mental structures in the different layers of the cognitive architecture are activated, combined, modified, and transformed. Such a description is a necessary condition for the subsequent formalization of the architecture and for the precise modelling of cognitive dynamics.

Within the framework of future research, main classes of operations in the Transformational Layer should be identified and conceptually distinguished, as well as the manners in which they realize interactions between fundamental, integrative, and metacognitive structures. The analysis of these operations will allow the transition from a static description of structural types toward a procedural description of cognitive processing.

The present work includes Layer 0 (Input Layer), Layer 1 (Perceptual Layer), Layer 3 (Output Layer), and the Cognitive Supervisor as the context of the overall architecture. Their detailed examination remains the subject of future publications, directed toward:

- the mechanisms of sensory and bodily signalling;
- automatic perceptual integration;
- the nature of cognitive and behavioural outputs;
- executive control and volitional regulation;
- the integration of all components in real cognitive tasks.

The architectural perspective also outlines directions for future empirical research, directed toward the interactions between cognitive structures and toward their dynamics over time, as well as toward the relating of these interactions with distributed neural networks.

In this sense, the presented model should be regarded not as a completed theory, but as a conceptual foundation upon which both procedural descriptions and formal models of cognitive dynamics can be constructed.

3.3. Concluding Remarks

The present work presents an architectural description of the main mental structures in Layer 2, with the aim of systematization and functional distinction of key elements of cognitive transformation. The main contribution is not in the introduction of new psychological constructs, but in the integration of established structures into a unified framework with clearly defined roles, sublayers, and types of interactions.

The focus on Layer 2 reflects an engineering strategy: the identification and description of the transformational core of the cognitive architecture as a necessary precondition for subsequent proceduralization and formalization. In this sense, the model should be regarded as an architectural foundation, rather than as a completed theory of cognition.

Layers 0, 1, and 3, as well as the cognitive supervisor, have been included as contextual components of the overall architecture. Their detailed examination remains the subject of future research, directed toward the description of the input, perceptual, regulatory, and output processes and toward the manner in which they connect with the transformational layer.

A key characteristic of the proposed framework is the treatment of mental structures as dynamic and modifiable configurations, compatible with the known mechanisms of neuroplasticity. This allows the architecture to avoid static interpretations, without introducing additional assumptions about the mechanisms of change.

In conclusion, the present work aims to bring together heterogeneous conceptual elements, to arrange them within a unified architectural schema, and to outline the conditions under which a future formalization of cognitive processes would be possible. Any additional theoretical or empirical findings should be regarded as a potential, but not obligatory, result of this architectural perspective.

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