Examination of the Theoretical Stage of Wells and Matthews' Model of Emotional Self-Regulation: Methodological Aspects*

Análisis de la fase teórica del modelo de autorregulación emocional de Wells y Matthews: aspectos metodológicos

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Abstract

This research examines the theoretical stage of the self-regulatory executive function model of the emotional state of Wells and Matthews (1994) from the metascientific criteria proposed by Bunge (2000). Specifically, the investigation will confirm whether the model has internal consistency, external consistency, heuristic power, and coherence with the present scientific conception of the world. To these objectives, various analysis techniques have been proposed and assessed, one for each object of study. The following methods were used: the formalization of the model as a method of theoretical reconstruction, the observation of the theoretical correspondence between the model and the cognitive ontological sublevel of Bunge's theory of mind (2012), the explanation of theses about voluntary acts by Libet (1985) and Libet *et al.* (1983), and the observation of the theoretical and textual references of the model to the neurological and psychosocial ontological sublevels in Bunge's aforementioned theory of mind. Jointly, the results obtained show that the model presents an ideal state of theoretical maturity since it completely meets the aforementioned metascientific criterium—only partially the ontological consistency. This paper emphasizes the methodological aspects of the investigation because the method and analytical procedure used here can be useful for evaluating other various models and theories from any scientific field.

Keywords: theoretical stage - emotional self-regulation - Wells - Matthews - Bunge

Resumen

Esta investigación examina la fase teórica del modelo de función ejecutiva autorreguladora de la fase emocional de Wells y Matthews (1994) desde los criterios metacientíficos propuestos por Bunge (2000). Específicamente, la investigación confirmará si el modelo posee consistencia interna, consistencia externa, poder heurístico y coherencia con la concepción científica actual del mundo. Para estos objetivos, se han propuesto y evaluado diversas técnicas de análisis, una para cada objeto de estudio. Se utilizaron los siguientes métodos: la formalización del modelo como método de reconstrucción teórica, la observación de la correspondencia teórica entre el modelo y el subnivel ontológico cognitivo de la teoría de la mente de Bunge (2012), la explicación de las tesis sobre actos voluntarios de Libet (1985) y Libet *et al.* (1983), y la observación de las referencias teóricas y textuales del modelo a los subniveles ontológicos neurológico y psicosocial en la mencionada teoría de la mente de Bunge. En conjunto, los resultados obtenidos muestran que el modelo presenta un estado ideal de madurez teórica, ya que cumple completamente con los criterios metacientíficos mencionados —excepto parcialmente con la consistencia ontológica—. Este artículo enfatiza los aspectos metodológicos de la investigación, ya que el método y el procedimiento analítico utilizados aquí pueden ser útiles para evaluar otros modelos y teorías de cualquier campo científico.

Palabras clave: fase teórica - autorregulación emocional - Wells - Matthews - Bunge

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1. Introducción

This article outlines the methodological aspects of Duro's doctoral research (2023) program, represented in Figure 1. The research involves examining Wells and Matthews' (1994) model of self-regulatory executive function, referred to as the S-REF model, and analyzing it using Bunge's (2000) metascientific criteria for evaluating theoretical development stages. Two preliminary questions are considered: What is the value of such an examination? And how can it be conducted? According to Bunge (2000), adhering to these criteria is important for scientific progress as it helps assess the relative value of competing theories or models in the same field. This research primarily seeks to answer the second question. Although it examines a metacognitive model of emotional self-regulation, the research is methodological and falls within the philosophy of science domain.

As an introduction to this discourse, it is important to note that the evaluation of theories, being of a metascientific nature, does not have predetermined decision rules that can be applied automatically. According to Bunge (2000), not all proposed criteria need to be fully adhered to. Nevertheless, these criteria offer specific guidelines for identifying theoretical truth (Bunge 2000).

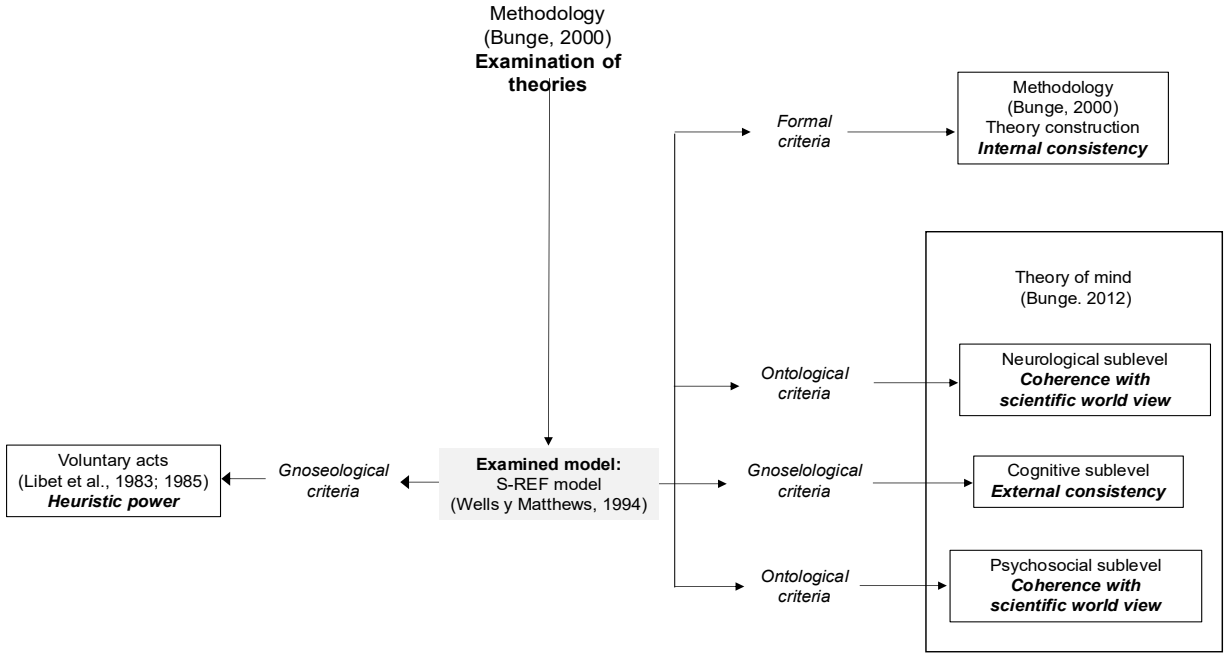

Figure 1: Thesis Program: Examination of the self-regulatory executive function model of Wells and Matthews (1994) from the methodology of Bunge (2000). In Duro (2023, Figure 1.1).

For this examination, due to their relevance, both the S-REF model and Bunge's methodology were chosen. The model has generated numerous research and scientific publications, and Bunge is an author with a renowned and extensive academic career with abundant work in the philosophy of science and psychology, among other disciplines (Ferrater 1994); furthermore, the opportunity was provided by the fact that no precedent was found for such an investigation. Its objects and methods are detailed in Tables 1 and 2. The research is based on and starts from the establishment of the following four working hypotheses, namely, whether or not the S-REF model meets (i) the formal criterion of internal consistency, (ii) the gnoseological criterion of external consistency, (iii) the gnoseological criterion of heuristic power, and (iv) the ontological criterion of coherence with the present scientific conception of the world. Specifically, whether (i) the model can be formalized as a deductive tree, (ii) the already

formalized model is compatible with the cognitive of Bunge's theory of mind (2012), (iii) the model can explain Libet and collaborators' theses about voluntary acts (Libet *et al* 1983, Libet 1985), and (iv) the model is consistent with the brain and the social neurological y psychosocial sublevels of Bunge's theory of mind. Therefore, first, a verification will be conducted relative to the *form* of the model, and then, three successive verifications will be conducted in relation to its *content*.

For this examination, the S-REF model and Bunge's methodology were selected due to their relevance. The S-REF model has generated numerous research articles and scientific publications, and Mario Bunge is a distinguished author with an extensive academic career, having made significant contributions to the philosophy of science and psychology, among other disciplines (Ferrater 1994). Furthermore, the investigation was timely as no prior studies on this topic were found. The objectives and methods are detailed in Tables 1 and 2.

The research is based on four working hypotheses to evaluate whether the S-REF model meets specific criteria: (i) the formal criterion of internal consistency, (ii) the epistemological criterion of external consistency, (iii) the epistemological criterion of heuristic power, and (iv) the ontological criterion of coherence with the current scientific conception of the world. Specifically, it examines whether (i) the model can be formalized as a deductive tree, (ii) the formalized model is compatible with Bunge's cognitive theory of mind (2012), (iii) the model can explain Libet and collaborators' theses about voluntary acts (Libet *et al* 1983, Libet 1985), and (iv) the model aligns with the brain and social neurological and psychosocial sublevels of Bunge's theory of mind (see Tables 1 and 2).

Therefore, the research will first verify the *form* of the model, followed by three successive verifications pertaining to its *content*.

Table 1

Objects of the Doctoral Thesis

Object	Theories exam: Type of criteria	Exam focuses	Theoretical foundation
Check the formal systematism of the S-REF model.	Formal	Internal consistency	Methodology (Bunge 2000).
Check compatibility of the S-REF model with Bunge`s theory of mind.	Gnoseological	External consistency	Bunge's theory of mind - included in his ontology- (Bunge 2012).
Explain voluntary acts according to Libet *et al*. from the S-REF model.	Gnoseological	Heuristic power	Cognitive and metacognitive approaches.
Check ontological systemism of the S-REF model.	Ontological	Coherence with scientific vision of the world.	Ontology (Bunge 2012).

Table 1: S-REF model: model of self-regulatory executive function (Wells and Matthews 1994). In Duro (2023, Cuadro 1.1).

The research is novel due to its organic approach, integrating diverse methods for one purpose, and the proposed analysis techniques which are detailed below. Our goal is to outline the method, analytical procedure, and results profile.

Table 2

Doctoral Thesis Method

Focus of the analysis	Method	Analysis technique
Internal consistency	Theoretical reconstruction	Formalization of the S-REF model as a deductive tree.
External consistency	Observation	Analysis of theoretical correspondences between the S-REF model and the cognitive ontological sublevel of Bunge's theory of mind (2012).
Heuristic power	Explanation	Account for the experiments of Libet *et al.* (1983) and Libet (1985) from the S-REF model.
Coherence with scientific vision of the world	Observation	Analysis of theoretical and textual references of the S-REF model to neurological and psychosocial ontological sublevels of Bunge's theory of mind (2012).

Table 2: S-REF model: model of self-regulatory executive function (Wells and Matthews 1994). In Duro (2023, Cuadro 1.2).

1.1. Bunge's Metascientific Criteria

Bunge (2000) classifies these criteria into five main categories: formal, semantic, gnoseological, methodological, and ontological.

Formal criteria: There are three essential formal criteria: (i) formal correctness, which ensures that formulations are not arbitrary and consist of well-formed formulas; in the case of interpreted theories, correctness pertains to the statements of their theoretical components; (ii) internal consistency, requiring that formulas or statements be compatible and coherent with one another, meaning the system must be free of contradictions; and (iii) validity, which stipulates that formulas or statements must be logically derived.

Semantic criteria: The three most significant criteria in this context are: (i) linguistic accuracy, which entails minimal ambiguity and vagueness; (ii) *conceptual unity*, characterized by a well-defined universe of discourse and semantically homogeneous predicates; and (iii) *empirical interpretability*, which requires that low-level theorems must be empirically translatable. Conceptual unity further encompasses (a) the formal unit, referring to the logic*al or se*mantic relationship among all formulas or statements within the theory—none should be isolated—and (b) the material unit, which involves reference to a single set of objects—the objectivity of an interpreted theory is grounded in its reference to external entities.

Gnoseological criteria: Two important gnoseological criteria are: (i) *external consistency*, meaning the theory aligns with established knowledge, and (ii) *scope*, indicating the theory effectively addresses many of the problems it was designed to solve. Additionally, *heuristic power* (iii) refers to the theory's ability to inspire or guide future research in its field or related areas.

Ontological criteria: The criteria are: (i) parsimony of levels, meaning the theory should reference its own level, and (ii) coherence with *the conception of the world*, ensuring consistency with the prevailing scientific view. Due to strong empirical support for the S-REF model (Wells 2000; 2009), the analysis here focuses on its *heuristic power* instead of *scope* and excludes methodological criteria. Semantic criteria analysis is omitted for brevity.

1.2. Model Examined: Model S-REF

The Self-Regulatory Executive Function (S-REF) model, developed by Wells and Matthews (1994, 1996), offers a metacognitive account of emotional self-regulation. It postulates that self-regulation is a dynamic

process aimed at reducing or eliminating discrepancies between an individual's current and desired emotional states. This is achieved through feedback-based updating of self-knowledge and the generation of new processing strategies. The model presents a multi-level cognitive system that interacts with internal and external stimuli, allowing for flexible, goal-directed regulation of thought and behavior (Wells 2000, Figure 2.0).

Structurally, the S-REF model is organized into a three-tiered functional architecture. At the lower level, automatic, stimulus-driven processing units operate outside of conscious awareness. These units require minimal cognitive resources and are responsible for transmitting environmental and interoceptive information to higher levels via automatic intrusions. Their activity is influenced by both situational inputs and pre-established cognitive schemas.

The central level is characterized by conscious, voluntary, and controlled processing. It is essential for emotional self-regulation, as it mediates between environmental input and internal cognitive responses. This level encompasses two main processes: (1) appraisal, or the evaluation of input from the lower level, and (2) action control, guided by beliefs stored at the higher level. Based on this integration, the central level can generate three types of output: feedback to lower-level systems, elaboration or reinforcement of higher-level beliefs, or the cessation of further processing when the emotional discrepancy is resolved (Wells & Matthews 1994).

At the higher level, the system stores declarative knowledge and metacognitive beliefs about thinking. This level houses self-knowledge and plans for processing that regulate emotional responses. Although it typically interacts with the central level, it can also influence lower-level systems directly under specific conditions. Accessing this level allows individuals to implement coping strategies and monitor their effectiveness (see Figure 2).

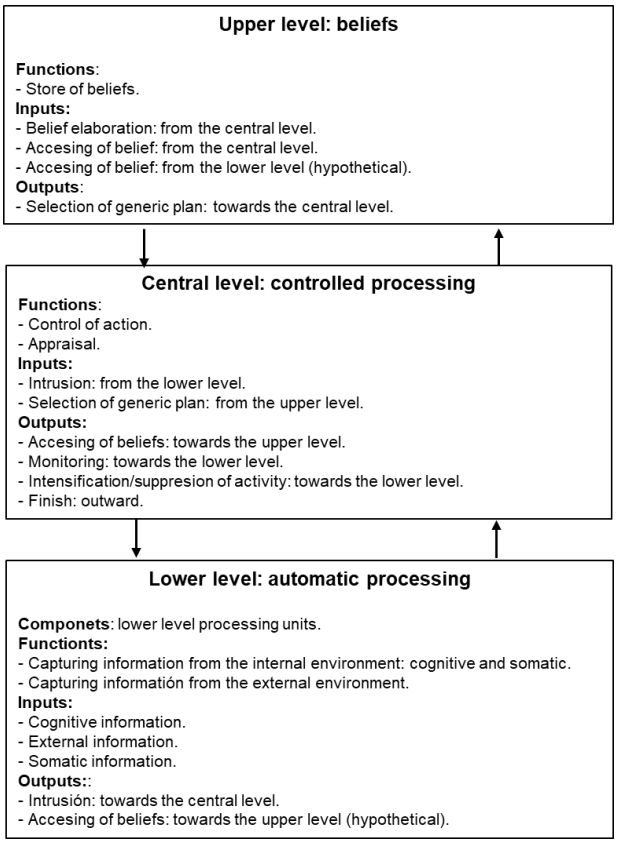

Figure 2: Model of self-regulatory executive function (Wells and Mathews 1994).

Activation of self-regulation occurs when emotionally charged stimuli or distressing thought patterns intrude into conscious awareness from the lower level, triggering a discrepancy signal. The central level then accesses relevant beliefs and selects coping responses. Conversely, deactivation of the system can occur through attentional disengagement, resolution of the perceived threat, or changes in metacognitive beliefs that eliminate the need for continued regulation (Wells 2000).

The model also distinguishes between two modes of processing: the object mode, in which thoughts are treated as accurate representations of reality, and the metacognitive mode, in which thoughts are experienced as cognitive events open to evaluation. While the object mode tends to reinforce dysfunctional beliefs, the metacognitive mode promotes cognitive flexibility and facilitates therapeutic change. Enhancing the latter is a central goal of metacognitive therapy (Wells 2000).

Self-regulation activates through invasive information from external or internal stimuli that threatens the emotional state or generate negative thoughts. Deactivating self-regulation involves (i) activating competing processes, (ii) diverting attention through distraction, and (iii) using coping strategies that reduce the threat or modify related beliefs. This aligns with the cybernetics of self-regulation and self-representation (Carver & Scheier 1981, Higgins 1990).

Although the S-REF model is detailed and explanatory, it has faced several criticisms. Its focus on metacognition is seen as too individualistic, missing social contexts in emotional regulation (Gross & Thompson 2007). The separation between cognition and metacognition has been deemed sometimes arbitrary or redundant (Matthews 2006). Experimentally, the model is hard to operationalize, especially in measuring metacognitive processes (Fernie *et al.* 2015). Lastly, it does not fully account for individual differences in emotion regulation styles, which limits its clinical use (Sugiura 2020).

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1.3. Bunge's Theory of Mind

This theory (Bunge 2012) has been selected to verify the external consistency of the S-REF model. It will serve as a benchmark for analyzing the model's theoretical compatibility. The theory includes fifty-seven definitions, six postulates, three theorems, and nine corollaries, organized numerically (see Table 3).

Table 3

Theoretical components of Bunge's theory of mind: Their ordinal number

Ontological sublevels	Sections	Definitions	Postulates	Theorems	Corollaries
Neurological	*Central nervous system*				
	- Initial definitions	1-8	-	-	-
	- Basic assumptions (axioms)	9	1-4	-	-
	Brain states				
	- Brain functions	10-12	5	-	-
	- Mental states and processes	13-15	-	-	1-5
	- Psychosomatic interactions	-	-	-	6-7
Cognitive	*Sensation and appraisal*				
	- Detection and perception	16-20	6	-	-
	- Body and environment mapping	21	7-8	-	-
	- Behavior	22-28	9-13	1-2	8-9
	Memories and knowledge				
	- Memory and learning Anticipation and purpose	29-31	14	-	-
	- Thought	32-34	-	-	-
	- Cognition and decision				
	- Creativity	35-36	15-17	-	-
		37-40	-	-	-
		41	18-19	-	-
Psychosocial	*Awareness, consciousness, will*	42-45	20-22	3	-
	Person and self	46-47	-	-	-
	Social behavior	48-50	23	-	-
	Social cohesion	51-54	24-25	-	-
	Communication	55-56	-	-	-
	Protoeconomics	57	26	-	-

Table 3: Bunge (2012). In Duro (2023, Cuadro 6.2).

It is important to underscore that the theoretical components constitute a *deductive tree*, interconnected and form a deductive framework. As evidence and illustration, Figure 3 demonstrates the relationships among the nine initial definitions and the four fundamental postulates pertaining to the central nervous system—definitions D1 to D9 and postulates P1 to P4.

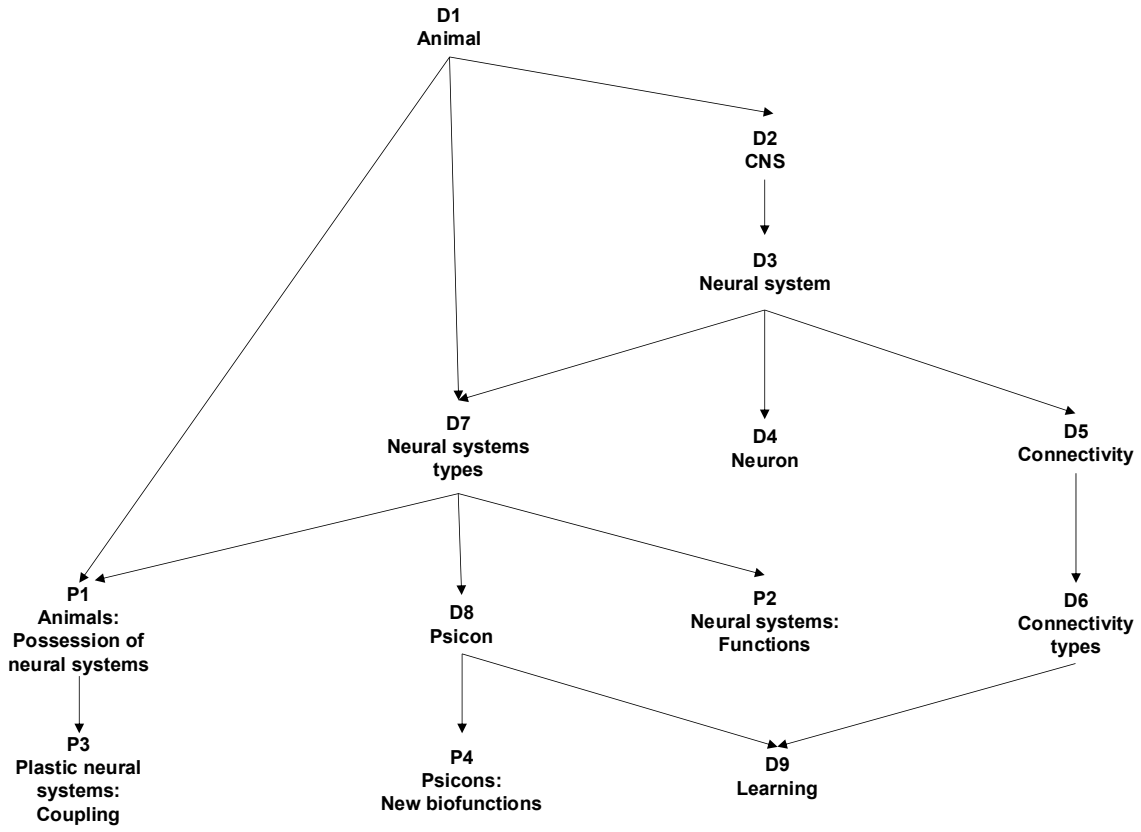

Figure 3: Bunge's theory of mind. Initial Definitions and Basic Assumptions of the CNS: Deduction Tree. D: definition, P: postulate. CNS: Central nervous system. Bunge's theory of mind (2012). In Duro (2023, Figure 6.1).

Following Bunge's systematic approach, we distinguish three ontological sublevels for analyzing the theory of mind: (i) neurological: central nervous system and brain states; (ii) cognitive; sensation, evaluation, memories, knowledge; and (iii) psychosocial: self to society. This text will focus on awareness, consciousness and will, person and self, and social behavior. These sublevel names are provided for clarity. As per Bunge (2012, p. 40), "levels" here refer to conceptual precedence, not causality or hierarchy.

Given the scope of the theory, it is impractical to enumerate all its components individually in this context. However, we will provide a brief overview to illustrate its key characteristics. Below, we present an example from each level:

Neurological sublevel: DEFINITION 12 "P = A + E represents the *state function of a neural system v*. Then A(t) is the *spontaneous activity of v* at time t, while E(t) is the induced activity of v at t" (Bunge 2012, p. 189).

Cognitive sublevel: DEFINITION 16 "A system *detects* things or events if it reacts only to them" (Bunge 2012, p. 204).

Psychosocial sublevel: DEFINITION 48 "An animal performs *social behavior* if it acts on individuals of the same species, or they act on it" (Bunge 2012, p. 235).

1.4. Libet's Voluntary Acts

To calibrate the *heuristic power* of the S-REF model, the experiments on voluntary acts conducted by Libet *et al.* (1983) and Libet (1985) were selected to exam the gnoseological criterion. This selection is pertinent to our research due to its proximity to our field of study. The choice was deliberate since voluntary acts are associated with several domains related to the mind, including mental causation (Robb & Heil 2021), epiphenomenalism (Robinson 2019), consciousness (van Gulick 2021), will (Schlosser 2019), personal autonomy (Buss & Westlund 2018), free will (O'Connor & Franklin 2022), and the emergent properties of the brain (O'Connor 2021).

Libet and collaborators suggest that their results indicate that voluntary acts are initiated *automatically* in the subject's neural system before the subject is aware of them. In their study, they observed the finger movements made by experimental subjects and recorded their brain neural potentials. According to Brass and Haggard (2008), Bunge (2012), and Libet (1985), these movements occur before the subject has any conscious awareness or intention of performing them. After this automatic initiation, subjects can consciously decide whether to complete these acts. Thus, for these authors, a voluntary act is simply "a decision on a process initiated automatically" (Libet 1985, p. 536).

Despite being replicated several times (Braun *et al.*, 2021), Libet's findings have faced considerable criticism concerning their experimental design, data interpretation, and conceptual implications. Prominent scholars such as Kevin Mitchell (2020) and Daniel Dennett (2003, 2017) have challenged Libet's conclusion that preparatory brain activity precedes and overrides conscious intention. Mitchell asserts that the relationship between preparatory activity and voluntary action is more intricate than suggested by Libet's experiments. Dennett, on the other hand, contends that the concept of "conscious decision timing" may be misrepresented due to the introspective methods employed in those studies. These critiques underscore the necessity for a more refined interpretation of the data and emphasize the importance of models like S-REF, which integrate both automatic and controlled processes in emotional regulation.

1.5. Bunge's Ontology

Bunge's ontology (2012) offers a comprehensive framework grounded in emergentist systemism, conceiving reality as a stratified world composed of interrelated systems. These include physical, chemical, biological, psychological, and social systems, all of which are material, yet exhibit novel properties at higher levels of organization. He explicitly rejects both mind-body dualism and reductionist physicalism, arguing that although all real entities are material, not all are strictly physical (Bunge 2012).

In this framework, mental phenomena are conceived as emergent functions of the nervous system in complex animals. Bunge locates the mind within the broader class of biosystems, viewing it as composed of interdependent subsystems: neural structures, mental processes, and social dynamics. This materialist but non-reductionist stance—what Bunge calls psychoneural identity—insists that mental properties (such as qualia) are features of specific brain processes, not immaterial or detached entities (Bunge 2011, 2012). Consequently, psychological explanations must reference both biological underpinnings and social contexts.

Importantly, Bunge structures reality into ontological levels, where higher levels (e.g., psychosocial) emerge from but are not reducible to lower ones (e.g., neurological). Each level provides components and plays a role in assembling those above it. This stratification offers conceptual support for multilevel psychological models such as the S-REF, which operate across neurological, cognitive, and psychosocial dimensions. The coherence of the S-REF model is strengthened by Bunge's rejection of both ontological dualism and reductive explanation.

These distinctions also align with specialized fields of study: neuropsychology and cognitive neuropsychology (Denes *et al.* 2020, Stevens 1974) investigate the link between brain and cognition,

while social psychology explores the mutual influence of mental and social systems (Heinzen & Goodfriend 2021, Salazar *et al*. 1979). The integration of these perspectives reflects the systemist principle that all entities are either systems or components of systems.

Bunge's ontology further incorporates principles such as naturalism, pluralism, dynamism, and evolutionary emergence, reinforcing a vision of the mind as both biologically grounded and socially embedded. This multifaceted framework provides a philosophically robust foundation for evaluating complex psychological theories that traverse multiple levels of explanation.

2. Model Examination

2.1. Internal Consistency

This analysis assessed the S-REF model's *internal consistency* (Bunge 2000). Initially, the lack of formalization hindered our purpose. Thus, we adopted *theoretical reconstruction*, formalizing the model as a deductive tree, which is suitable for scientific theories (Bunge 2000). As the model is a semantic system, we ensured *semantic cohesion* among its components. We formalized the model based on two texts: the original by Wells and Matthews (1994) and a summary by Wells (2000).

2.2. Deductive Tree

This method of formalization was advantageous for our objectives, as the deductive tree serves as an intermediary between a precise mathematical formalization and a more flexible, theoretically indistinct one.

The S-REF model began with two preliminary definitions: D1, about the human mind functioning to improve interactions with the environment, and D2, concerning conscious mental contents. It continued with D3, defining a multilevel cognitive system, and further clarified levels, information, knowledge, and function in D4, D5, and D6. Finally, D7 defined the model and its explanatory scope.

Based on the definitions D4, D5, D6, and D7, the various postulates of the model were subsequently derived. The first postulate, P1, identifies the model as a multilevel cognitive system. From this basic postulate, the remaining postulates are derived, addressing distinct semantic contents: level structure (P2), cognitive processes (P3), processing and storage modes (P4), types and contents of information (P5), and self-regulatory function (P6). The remaining definitions, theorems, and corollaries that constitute the formalization were systematically derived from these components (see Figure 4).

The deductive tree of the model consists of 22 definitions, 6 postulates, 11 theorems, and 5 corollaries. It is divided into the following sections: (i) initial definitions, (ii) basic postulate, (iii) level components, (iv) process components, (v) components of processing modes, (vi) components for types and contents of information, and (vii) self-regulation components. This formalization aims to represent the fundamental aspects of the model.

As an example, we reproduce the first component of each type below:

DEFINITION 1. *Functionality of the human mind*: The human mind operates through systems designed to fulfill objectives that optimize interaction with the environment.

POSTULATE 1. *Functional identity*: The S-REF model constitutes a multilevel cognitive system as it integrates all its distinctive features.

THEOREM 1. *Types of processing*: Information processing at various levels can be automatic or deliberate (controlled).

COROLLARY 1. *Psychopathology*: If the self-regulation objective of the system is not achieved, emotional balance will not be assured.

To detail the components of the deductive tree, the following rules were observed: (i) deduce subsequent components from the previously introduced elements in the tree; (ii) derive the consequent theorems from their corresponding postulate—for example, theorem T1 (types of processing) is derived from postulate P2 (specificity of levels); (iii) derive the corollaries of the consequent from its corresponding theorem—for example, corollary C2 (vulnerability) is derived from theorem T4 (object processing mode); and (iv) ensure each new deduced component and its principle share a common predicate—for example, both definition D5 (information and knowledge) and postulate P1 (functional identity) include "cognitive system" in their statements. This repetition of the same concept strengthens conceptual unity, which is an important semantic criterion (Bunge 2000).

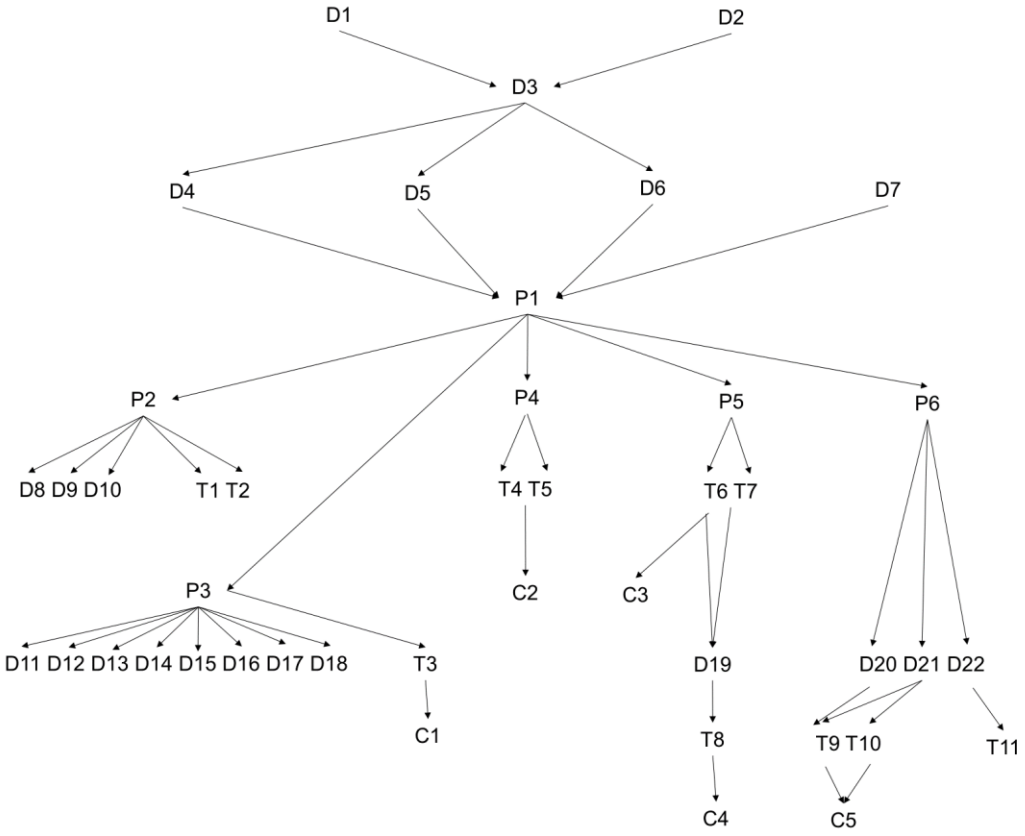

Figure 4: Formalized S-REF model: Deductive tree. S-REF model: Model of self-regulatory executive function (Wells and Matthews 1994). D: definition; P: postulate; T: theorem; C: corollary. D1: Mind functionality; D2: Consciousness; D3: Multilevel cognitive system; D4: Level structure; D5: Information and knowledge; D6: Function; D7: S-REF model; D8: Center level; D9: Lower level; D10: Upper level; D11: Intrusion process; D12: Belief access process; D13: Plan selection process; D14: Appraisal process; D15: Action control process; D16: Belief making process; D17: Intensification or suppression of activity processes; D18: Monitoring processes; D19: Self-knowledge; D20: Coping; D21: Threats; D22: Self-discrepancies; P1: Identity; P2: Specificity levels; P3: Cognitive processes; P4: Processing modes; P5: Types and content of information; P6: Self-regulation; T1: Processing types; T2: Storage types; T3: Dynamic dysfunction; T4: Object processing mode; T5: Metacognitive processing mode; T6: Declarative knowledge; T7: Procedural knowledge; T8: Origin and validity of beliefs; T9: Self-regulation activation/deactivation; T10: Barriers; T11: Emotions; C1: Psychopathology; C2: Vulnerability; C3: Signaling; C4: Beliefs invariability; C5: Self-regulation perseverance. In Duro (2023, Figure 8.1).

2.3. Predicate Logic

The S-REF model, as described by Wells (2000) and Wells and Matthews (1994), can be formalized using predicate logic. This analysis extends formal logic by analyzing a structure of statements (Deaño 1978). To formalize the model, first-order predicate logic with quantifiable variables would suffice (Deaño 1978). Although this formalization was initially excluded due to research limits, we will demonstrate its feasibility with examples, partially utilizing D7 of the formalized model.

-DEFINITION 7. S-REF Model: "A model designed to elucidate the self-regulation function within the human mind, predicated on the structure and interaction of various levels of information processing and storage" (Duro 2023, p. 89).

In schematic terms, according to predicate logic, we can express this as follows:

$$D7\ (partial) = \forall x\ (Sx \rightarrow Px)$$

where *x* denotes "system" as the variable, and S and P represent the properties ascribed to this variable, where S signifies "being a multilevel cognitive system" and P signifies "being a system that processes information." This formula exemplifies a first-order monadic predicate and aligns with the structure of an affirmative universal statement. The interpretation is: "For all *x*, if *x* is a multilevel cognitive system, then it is a system that processes information." Such representation is considered a formal correction model (Bunge 2000).

To analyze the internal consistency of the model from this logic, it is sufficient to demonstrate that there is no contradiction among its statements; in other words, that there are no propositions that, by opposing each other, invalidate one another. Continuing with the previous example, there should never be a logical relationship of contradiction (Sacristán 1973), such that:

$$[\forall \underline{x}\ (Sx \rightarrow Px)] \leftrightarrow [\exists x\ (Sx \rightarrow \neg Px)]$$

where the second term, denying exactly what the first term expresses, affirms that at least some multilevel cognitive system is not a system that processes information.

Similarly, the *formal validity* of the formalized model with predicate logic could be analyzed, requiring demonstration that new theoretical components introduced are derived from previous components—precisely the procedure followed for theoretical reconstruction (Duro 2023).

2.4. External Consistency

We will now examine whether the S-REF model meets the gnoseological criterion of *external consistency* (Bunge 2000). Specifically, we will determine if there is compatibility between the components of the formalized model and the components of the cognitive sublevel of Bunge's theory of mind (2012). The prior formalization of the model allows for this comparison. Unlike syncretism, an approach where different *theories* are *combined*, external consistency pertains to the feasibility o*f two or* more *separate* theories or models about the same phenomena that can coexist without any conceptual conflict.

Observation will analyze the theoretical *correspondences* between the formalized model and the theory, comparing their theoretical components. This method is akin to injective and/or surjective linear application in mathematics as it checks if the model's components have at least one *image* within the theory's cognitive sublevel. The analysis is divided into four content classes: (i) general theoretical aspects, (ii) processing levels, (iii) processed and stored information and knowledge, and (iv) self-regulation function.

2.5. Compatibility Rules

To ensure objective criteria, these rules were established to align the formalized model with the theory: (i) terminological identity between components, such as the term "process"; (ii) semantic field identity, like "storage types" and "memory" both concerning information processing; and (iii) implication of concepts, such as "awareness" and "consciousness".

2.6. Correspondence Planes

General Theoretical Aspects. The analysis includes correspondences, in relation to the theory of mind (Bunge 2012), of the following components of the model (Wells & Matthews 1994): D1: Mind functionality, D2: Consciousness, D3: Multilevel cognitive system, D4: Processing levels, D5: Knowledge and information, and D6: Function. For instance, the model component D2: Consciousness, aligns with the following theory of mind components: D20: Awareness of mental processes; D21: Perception of the environment; D42: Consciousness; D43: Awareness; and P20: Awareness of brain processes. An example is the external consistency between the definition of model D5, on knowledge and information, and the definition of theory D37, regarding knowledge of events (see Table 4).

Table 4

Correspondences between the S-REF model and Bunge's theory of mind: General theoretical aspects

Formalized S-REF model	Bunge's Theory of mind: Cognitive ontological sublevel
D1 Mind functionality	Theoretical assumption: mind as an emergent function of the brain C3 Function mental processes* C5 Functional process system* D16 Detection of things and events D17 Detector as a neurosensor D18 Sensory system as a subsystem of the SNC
D2 Consciousness	D20 Awareness of mental processes D21 Environment perception D42 Consciousness D43 Awareness P20 Awareness brain processes**
D3 Multilevel cognitive system	D2 Nervous system* P3 Coupled plastic neural systems*
D4 Processing levels	P3 Coupled plastic neural systems*
D5 Knowledge and information	D37 Events knowledge D39 Rational decision based on knowledge.
D6 Function	D16 Detection of things and events D20 Process and perceptual system
D7 S-REF model	-
P1 Functional identity	-

Table 4: D: definition, P: postulate, C: corollary. S-REF model: model of self-regulatory executive function (Wells and Matthews, 1994), * Neurological ontological sublevel components in Bunge's theory of mind (Bunge 2012) ** The psychosocial ontological sublevel in Bunge's theory of mind (Bunge 2012). In Duro (2023, Cuadro 9.1).

Processing Levels. The analysis focuses on the correspondence between the components of the model (Wells & Matthews 1994) and the theory of mind (Bunge 2012): P2: Specificity levels, T1: Types of processing, T2: Types of storage, D8-D9-D10: Levels of processing, P3: Processes, T3: Dysfunction dynamics, C1: Psychopathology, and D11...D18: Specific processes. For instance, the model component T1—types of processing—aligns with components of the theory of mind such as P9: Controlled behavior and T2: Repertoire of plastic behavior. Similarly, the postulate of model P2 concerning level specificity is consistent with the definition in theory D13 regarding process specificity. Further details can be found in Duro (2023, Table 9.2.).

Information and Knowledge. In this plane of correspondence, alignment with Bunge's theory of mind (2012) is observed in the following components of Wells and Matthews' model (1994): P4:

Processing modes; T4-T5: Objective and metacognitive modes; C2: Vulnerability; P5: Types of information; T6: Declarative knowledge; T7: Processual knowledge; D19: Self-knowledge; and T8: Origin of beliefs. For instance, model component P5: Types of information corresponds to these aspects of the theory of mind: D1: Orientation/avoidance toward stimuli, D30: External and internal stimuli that are detected, and P20: Awareness of stimuli (Duro 2023, Table 9.3).

Self-regulating function. The analysis includes the theory of mind correspondences (Bunge 2012) with these seven model components (Wells & Matthews 1994): P6: Self-regulation, D20: Coping, D21: Threats, T9: Activation/deactivation, T10: Barriers, C9: Perseverance, D22: Self-discrepancies, and T11: Emotions. For example, P6 self-regulation aligns with D26 discrepancy detection; D27 value system; P7 body and environment mapping; P8 environment mapping; P10 behavior with biovalue; and P12 drive and reducing behavior. Similarly, D21 threats align with D26 event detection (Duro 2023, Table 9.4).

Recent studies in cognitive neuroscience emphasize the role of automatic and unconscious processes in emotional regulation and decision-making (Gyurak, Gross & Etkin 2011, Pessoa 2017, Proulx *et al.* 2022). These contemporary paradigms expand on Libet's model by offering a more contextual and critical evaluation.

2.7. Heuristic Power

The method used to examine compliance with this criterion by the S-REF model (Wells & Matthews 1994) will involve *explanation*. The process will assess whether information from its theoretical structure can elucidate the experimental findings on voluntary acts conducted by Libet *et al.* (1983) and Libet (1985).

This topic is highly relevant because they address principles established in several academic disciplines, such as philosophy, jurisprudence, neuroscience, and psychology (Braun *et al.* 2021); and, because they pertain to essential and currently debated fields of study related to the theory of mind. These include mental causation (Robb & Heil 2021), epiphenomenalism (Robinson 2019), consciousness (van Gulick 2021), will (Schlosser 2019), personal autonomy (Buss & Westlund 2018), free will (O'Connor & Franklin 2022), and emergent properties (O'Connor 2021), which we will not delve into here for various reasons.

The model's heuristic power evaluation is based on these points: (i) self-regulation and voluntary acts are *behaviors*; (ii) behavior *responds* to situations within human conduct schemes; (iii) both have spe*cific ante*cedents; (iv) both aim f*or an obj*ective; (v) thus, the*y are fi*nalist behaviors emerging from certain antecedents; and (vi) both adapt to action plans guided *by a* task *scheme*.

This reasoning is necessary because the material focus of the model is emotional self-regulation rather than voluntary acts. Therefore, it is essential to adopt a broader perspective that includes the universal person-environment interaction, encompassing self-regulation and performance during the test.

2.8. Cognitive and Metacognitive Approaches

Both approaches form the foundation of the model, providing the necessary perspective. They argue that behavior results from a trigger, requiring an activating experience (Ellis & Grieger 1981), critical incident (Wells 2000), or antecedent (Wells 2009). All behavior is a response. Self-regulation and voluntary acts do not occur in isolation but *respond* to specific conditions. Even moving a finger voluntarily during a test fits this pattern.

Based on the methods discussed, it is clear that(i) The coping response in self-regulation follows a prior *rupture of homeostasis* or emotional balance, aiming to restore it. (ii) The finger movement in the lab is triggered by *experimental instructions*, aiming to comply. Both are examples of finalist behaviors.

Task Scheme: Finalist behaviors are guided by mental representations called *task schemes*, which contain information about goals and plans (Schank & Abelson 1977). These schemas require both a description of the objective and a plan to achieve it (Pylyshyn 1986). The theory of action also supports this: it states that action begins with setting an objective and creating a plan (Frese & Zapf 1984). Task schemes are the mental foundation for executing purposeful actions.

Self-regulation: Based on the model, this function starts with the initial automatic processing, or preconsciousness, of information inputs that might disrupt emotional stability. These inputs involve (i) interaction with beliefs stored in memory and (ii) activation of a corresponding action plan to restore equilibrium; this plan eventually entails (iii) accessing consciousness for decision-making, which is now voluntary, through controlled processing. Summarized schematically:

"I have to do *x* when *y*"

where *x* represents "self-regulate" and *y* denotes "threat or loss of balance".

Self-regulation functions based on several key presuppositions: (i) The existence of a homeostasis criterion in the mind—a state of emotional equilibrium—that serves as a goal, and any threat or loss thereof activates the self-regulatory mechanism; (ii) Incoming threatening information must be linked to preexisting beliefs in memory related to maintaining or restoring emotional balance; (iii) These beliefs automatically trigger an action plan aimed at preserving or regaining such balance; and (iv) This plan reaches consciousness, allowing the individual to consciously decide the best course of action. In summary, self-regulation occurs when a preexisting and underlying task schema is activated.

Experimental Instructions: Before performing the test, the experimental subjects received initial instructions that we postulated to create in their minds a new representation that would be stored in their memory. This representation would obviously contain information about what the subject is expected to do during the experimental situation (performance expectations). Schematically, this representation would indicate:

"I have to do *x* when *y*"

where *x* = "voluntarily moving the finger" and *y* = "course of the test."

This representation is identified, as it was when self-regulation, with a task scheme that mechanically triggers an action program when certain antecedent conditions are met.

Reinterpretation: Considering the above, we can now propose an explanation, a reinterpretation, of the experimental results of Libet *et al.* (op. cit.) from the model and its principles. During the experimental situation, the following could have happened: When the experimental subjects "voluntarily" moved their finger, that movement was not a completely free or spontaneous voluntary act but rather a response to the situation where they were right in that precise moment (antecedent). Therefore, the movement of the finger would not have been an isolated behavior but rather one more link in a chain of successive events: a causal sequence of antecedents and responses.

Initially, the distal antecedent of the finger movement would have been the set of experimental instructions received by the subject before beginning the test, which would have generated a task scheme in his mind. From then on, the subject would have adjusted his future behavior during the course of the experiment to this scheme—using the cognitive processes of monitoring, instruction, action control, and the rest, collected by the model. Second, during the performance of the test, the course of the experimental time itself assumed the role of the proximal antecedent (input) of the finger movement. This input would activate the task scheme, already created and previously stored in memory, which, in accordance with its inherent objective, would mechanically put into operation its correlative action plan (automatic processing), which would end up accessing consciousness from where the person would decide deliberately (controlled processing) whether to execute the muscle movement required by the experimental rules.

In short, this analysis revealed that between self-regulation and the investigation of voluntary acts, there is complete parallelism in terms of distal antecedents, proximal antecedents, mental representations and consequences, which has allowed us to advance a tentative explanation of the experiments of Libet *et al*. from the model, according to our object in this study (see Table 5).

Table 5

Voluntary acts: Common dimensions in Libet et al. and in the S.REF model

Voluntary acts: Dimensions	Experiments by Libet *et al*.	S-REF model
Distal antecedent	Experimental instructions.	Homeostatic criterion (balanced emotional state).
Proximal antecedent	Experimental time course.	Information relevant to homeostasis.
Mental representation	Performance expectations.	Self-knowledge (beliefs).
Consequences	Finger movement.	Self-regulatory behavior.

Table 5: Libet *et al*. (1983) and Libet (1985). S-REF model: model of self-regulatory executive function (Wells & Matthews 1994). In Duro (2023, Cuadro 11.1).

2.9. Ontological Consistency

The method employed to assess whether the S-REF model satisfies the criterion of ontological consistency is *observation*. Specifically, we examine whether its description (Wells & Matthews 1994, Wells 2000) includes theoretical and/or textual references to the neurological and psychosocial components of Bunge's theory of mind (2012). Rather than conducting a syntactic analysis—such as word frequency counts (Real Academia Española 1979)—this study adopts a semantic approach, given that scientific treatises, and by extension theoretical models, are best understood as textual or argumentative superstructures (van Dijk 1978).

Given that ontological consistency aligns with the scientific worldview (Bunge2000), and that reality is conceived as a world of interconnected systems (Bunge 2012), the analysis seeks to determine whether the model under consideration alludes to higher-order and lower-order subsystems in relation to its own domain of mental processes. The analytical framework rests on three fundamental premises: (i) reality is structured as a world of systems; (ii) Bunge's theory of mind comprises three interrelated subsystems—neurological, cognitive, and psychosocial; and (iii) the S-REF model is situated within the cognitive ontological sublevel. Thus, the presence of references to the neurological and psychosocial subsystems within the model would be indicative of its ontological systemism. Bunge's ontological proposal (op. cit.) is adopted here as a *paradigmatic representation* of the scientific worldview, serving as the referential framework for comparison.

The references to the neurological and psychosocial ontological sublevels in Bunge's theory are analyzed separately. In each case, three distinct types of references are considered according to their level of explicitness: (i) theoretical references, wherein a theoretical construct in the model relates to corresponding constructs in the theory; (ii) explicit textual references, in which the model's texts directly mention terms or concepts associated with the theory; and (iii) implicit textual references, involving indirect or inferential allusions to theoretical elements.

2.10. References to the Neurological Sublevel in Bunge

Only those components of Bunge's theory of mind (2012) pertaining to brain states are considered, as these are most likely to bear conceptual relevance to the S-REF model. Full details are provided in Duro (2023).

Theoretical References. Several theoretical references to the neurological subsystem are identifiable in the model: (i) Although the model lacks explicit mention of the neural system, it presupposes the existence of low-level, automatic processing mechanisms, in accordance with definition D10 (Neural system: activation, intensity, and process); (ii) the model describes various temporally sequenced processes, consistent with definition D11 (Neural system processes: values within a temporal interval); and (iii) while induced activity is not directly referenced, it is implicitly presupposed in perceptual and response processes, aligning with definition D12 (Active neural system: states of induced or stimulated activity).

Explicit Textual References. The model's texts do not include terms such as "neuron," "nervous system," or "neural system." The term "brain" appears only once: "...emotions are controlled by subcortical brain structures..." (Wells 2000, p. 12). Other expressions such as "induced activity," "union of processes," "psychosomatic," "plastic system," or "coupling of processes" are likewise absent. However, terms such as "process" and "processing" are recurrent—albeit in a cognitive rather than neural context—and are therefore included here due to terminological overlap. Notable examples include: "...information processing..." (Wells 2000, p. 14); "...situationally activated processing routines..." (Wells 2000, p. 15); and the observation that processing activities may be "...open to varying degrees of conscious awareness" (Wells 2000, p. 16). The model also references "mental state" (Wells 2000, p. 108) and alludes to system plasticity in statements such as: "S-REF activity can modify the knowledge base (beliefs)..." (Wells 2000, p. 20). Although neural stimulation is not explicitly discussed, references to "stimuli" are frequent (e.g., Wells 2000, p. 16).

Implicit Textual References. The analysis reveals indirect references to concepts related to brain function, such as: (i) "storage capacity" and "processing capacity," which are widely associated with neural activity (Cowan 2011); and (ii) expressions referencing "attentional capacity" (Wells 2000, p. 27), "processing capacity" in restructuring maladaptive knowledge (p. 29), the "capacity-limited central engine" (p. 80), and the "limited capacity S-REF configuration" (p. 96).

2.11. References to the Psychosocial Sublevel in Bunge

This section assesses the extent to which the S-REF model refers to the psychosocial sublevel as outlined in Bunge's theory of mind (2012). It is important to clarify that "the social" in Bunge does not strictly denote society or social systems but refers to the psychosocial domain—namely, the interaction between individuals and their social environment, as studied in social psychology (Heinzen & Goodfriend 2021, Salazar *et al.* 1979). This analysis therefore partially overlaps with the assessment of external consistency, particularly with respect to the perception of the social environment. The focus here is on theoretical constructs closely aligned with the model, including those related to awareness, consciousness, volition, personhood, self-concept, and social behavior.

Theoretical References. Several correspondences are identified: (i) Controlled or deliberate processing in the model aligns with definition D42 (Awareness and consciousness); (ii) central-level processing, which integrates external information with internal knowledge, corresponds with definition D43 (Consciousness); (iii) the selection and implementation of responses to environmental stimuli aligns with definition D44 (Voluntary acts); and (iv) the overarching aim of self-regulation, as conceptualized in the model, presupposes definition D45 (Free will: voluntary acts and freely chosen goals).

Explicit Textual References. The integration of neurological and psychosocial subsystems in Bunge's theory implies a necessary person—environment interaction, alongside awareness of such interaction.

This is reflected in concepts such as "awareness," "consciousness," "voluntary and intentional acts," "freely chosen goals," "stimuli," "learning," "personality," "person," and "social behavior." Two core dimensions are emphasized:

(i) Person-environment interaction: Evident in the model's self-regulatory function, the nature of processed and stored information, its referential cognitive processes, and the model's executive function.

(ii) Self-awareness and voluntary action: Located at the central processing level, which is, by design, controlled processing. Voluntary acts and underlying personal objectives are expressed through the model's self-regulatory mechanism, aimed at maintaining or restoring emotional balance through deliberate action.

Examples of explicit textual references include: (i) "…anxiety is generated by threat to a self-preservation goal…" (Wells 2000, p. 12); (ii) "…S-REF activation can be moderated by abandoning the primary goal…" (Wells 2000, p. 18), or by "…the diversion of attention…" (Wells 2000, p. 24); and (iii) "A core objective of emotional processing is to strengthen plans for dealing with threat…" (Wells 2000, p. 66).

Implicit Textual References. Bunge (2012) uses the phrase "objects in the mind," which corresponds conceptually to the term "representations" in the S-REF model. This term appears consistently in statements such as: (i) "…reducing self-discrepancies between a representation of the current status of the self and a desired or 'normative' representation" (Wells 2000, p. 18); (ii) "…multiple levels of cognitive representation in disorder" (p. 75); (iii) "Self-knowledge consists of a representation of some 'normative' or desired state of the self" (p. 125); and (iv) "…knowledge guiding these behaviors contains a representation of a goal…" (p. 182).

3. Results and Conclusions

The results of the analysis of *internal consistency*—or formal systematism—of the S-REF model demonstrate that it satisfies this formal criterion, as it can be structured as a deductive tree. This configuration leaves open the possibility of further formalization according to predicate logic. Additionally, the same deductive structure supports its formal correctness and validity.

In accordance with the findings, the model fulfills the gnoseological criterion of *external consistency* or compatibility, as there are theoretical correspondences between its components and those of the cognitive sublevel of Bunge's theory of mind (2012). These correspondences span from general theoretical concepts to more specific elements (e.g., levels of processing, information and knowledge, and function). The model also satisfies the gnoseological criterion of *heuristic power*. The analysis demonstrates that, based on its theoretical assumptions, the model offers a plausible explanation of the voluntary acts described by Libet *et al.* (1983) and Libet (1985).

Regarding the *ontological criterion* of consistency with the scientific worldview—specifically, ontological systemism—the analysis reveals that the model implicitly incorporates both neurological and psychosocial dimensions, in line with Bunge's theory of mind (2012). In particular, the model's conception of the self-regulatory function *presupposes* neurological underpinnings and necessarily *entails* psychosocial involvement. Thus, the model is coherent—or at least not incompatible—with Bunge's ontological framework. Consequently, the model complies, albeit partially and through referential inclusion, with the criterion in question (see Table 5).

In summary, the evaluation yields a positive outcome: the S-REF model is in an advanced and satisfactory theoretical stage, as it adequately meets the metascientific criteria proposed by Bunge (2000) and assessed in this study. These findings help explain the growing scientific influence of the Self-Regulatory Executive Function model (Wells & Matthews 1994) and, simultaneously, suggest promising

avenues for future research. Particularly relevant are investigations aimed at strengthening theoretical connections between metacognitive, neurological, and psychosocial dimensions.

Regarding methodological aspects, the strategy employed served as an effective tool for the metascientific evaluation of a theoretical model. The method itself holds epistemological value and, as such, constitutes an object of knowledge, aligning with the domain of methodology (Ferrater 1994). Following McKeon (1951, as cited in Ferrater 1994, p. 2402), a general method of inquiry has been employed—one that comprises a plurality of approaches "whose purpose is to discover the solution of problems" and "to advance knowledge," each with its own set of rules. More specifically (Ferrater 1994), this study applies an axiomatic method in the theoretical reconstruction of the model as a deductive tree (internal consistency analysis); a demonstrative method in explaining Libet and collaborators' findings (heuristic power analysis); and a semiotic method—linguistic in nature—in identifying theoretical correspondences (external consistency) and theoretical or textual references (ontological consistency). The method, having proven suitable for the intended purpose, "is not only a path, but a path that can open others" (Ferrater 1994, p. 2400).

From our perspective, the main contributions of this study are as follows: (a) the integration of diverse issues—often treated in isolation—into a coherent whole that serves the overarching purpose of metascientific evaluation. The different analyses addressed a wide variety of topics, such as theory formalization, voluntary action, and ontological sublevel of the mind; (b) the proposal and application of distinct analytical techniques, each tailored to its respective object of study; and (c) the establishment of a procedure applicable to the evaluation of the theoretical maturity of other models or theories across various scientific domains.

Nonetheless, this study is not without limitations. First, nearly all the research was centered exclusively on the methodological and ontological positions of a single author (Bunge 2000, 2012), which introduces a certain unilaterality, as alternative epistemologies (e.g., Suárez 2019) and other scientific or ontological approaches to the mind were excluded a priori. Second, the analyses were macroscopic in nature: (i) the deductive tree used to formalize the model was relatively simple and derived solely from the authors' descriptive account, without employing propositional text representation (see Kintsch 1974, 1982); (ii) the identified correspondences and theoretical references remained relatively general; (iii) the explanation of voluntary acts rests on the assumption of functional equivalence; and (iv) both the model's external consistency and heuristic power were analyzed using a single point of comparison in each case.

Considering these limitations, we recommend that future studies adopt a more fine-grained analytical perspective and reexamine the model through alternative methodological and ontological lenses.

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